INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED11
15 - 18 AUGUST 2011, TECHNICAL UNIVERSITY OF DENMARK

REPRESENTATION AND ANALYSIS OF BUSINESS ECOSYSTEMS CO-SPECIALIZING PRODUCTS AND SERVICES

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ABSTRACT
Recent dramatic changes in a mobile industry, initiated by smart phones, are drawing enormous attention to business ecosystems. A perspective to view firms as members of cross-industry ecosystem was first suggested by Moore [1] for describing co-evolution behavior in high-technology business areas. Although an ecosystem has been pervasive in any industry at any time, today's eco-systems are getting more horizontal and complex. This study develops a representation model of such complex ecosystems and a framework for analyzing interrelated productivity of ecosystem members. The proposed model especially emphasizes interdependency between product and service offerings that ecosystem members cooperatively deliver. This interdependency determines the interrelation between members' productivity, and finally sustainability of a whole ecosystem. This study describes a general procedure for representing and analyzing an ecosystem and discusses the difference between the traditional and smart phone mobile ecosystems based on the result of the analysis.

Keywords: Business ecosystem, requirement interdependency, productivity interrelation

1. INTRODUCTION
Recent dramatic changes in a mobile industry, initiated by smart phones, are drawing enormous attention to business ecosystems. Mobile contents business, which had stagnated for a decade in spite of desperate effort of network operators, burst open after the introduction of smart phones. In this business, contents providers, network operators and device vendors form an ecosystem for producing and delivering mobile contents to customers. Whereas competition in a traditional mobile industry had been device-to-device or service-to-service, the smart phones are competing with their own ecosystems in which various and interesting contents are continuously supplied by independent providers and developers. Device vendors and network operators now spend a lot of money on supporting third-party contents developers in order to promote their own ecosystems.
While anyone may intuitively understand a concept of the business ecosystem by the familiarity to its biological origin, a perspective to view firms as members of cross-industry ecosystem was first suggested by Moore [1] for describing co-evolution behavior in high-technology business areas. He stated that ecosystem members co-evolve their capabilities to support new products and satisfy customer needs around a new innovation. They also invest towards a shared future instead of each member's own because it is valued by the rest of the community [2]. Those behaviors are exactly same in smartphone ecosystems. All the members of iPhone and Android ecosystems try hard to expand their ecosystems in customer and developer communities as well as the leaders like Apple and Google.
Although an ecosystem has been pervasive in any industry at any time, today's ecosystems are getting more horizontal and complex. A common and traditional form of the ecosystem has been a supplier network in which individual firms are vertically linked with a seller-buyer relationship. Recently emerging innovation modes and business models, however, enforce to organize horizontal relationships between ecosystem members. A representative one is open innovation. It is a strategy to find sources of innovation from outside innovators as well as in-house capability [3]. Since outside innovators are prone to be loosely coupled with the firm, a firm needs to manage them like customers. Besides, advertisement sponsored business models [4] and integration of products and service drive horizontal cooperation between independent firms.
It is more complicated to build a healthy ecosystem with such horizontal and complex relationships. As Iansiti and Levien [2] advocated, the first condition of a healthy ecosystem is high productivity.

The productivity includes individual members' profit as well as the system's gross profit. In a horizontal relationship, if a member does not have proper profit from an ecosystem, she easily leaves and finds others like customers. Then, quality of the ecosystem offering quickly drops because it should have been complemented by the left member. Such an ecosystem cannot be healthy. Because profits of ecosystem member are prone to be interrelated each other, one who wants to build a healthy ecosystem needs to understand their relationships.

This study develops a representation model and a framework for analyzing interrelated productivity of ecosystem members based on this model. In literature, an ecosystem often has been represented as a network of value exchange between ecosystem members. However, it is a result of interdependencies between product and service offerings that all ecosystem participants cooperatively deliver. As shown in many studies [2, 5-8], their interdependencies determines positions of their providers in an ecosystem and share of profit they can have. Jacobides *et al.* [7] defined these interdependencies as requirement architecture. Therefore, the proposed representation model augments requirement architecture to value network model. The interrelated productivity of ecosystem members can be systematically analyzed by the proposed framework based on this representation.

2. LITERATURE REVIEW

An economic community of cooperating firms has been common from the beginning of industrialization, even before Moore [1] defined it as an ecosystem. The most well-known form of such a community is a supply chain, which is also referred as an ecosystem in Moore's work [1]. An ecosystem is, however, a more extended organization of firms and individuals beyond a vertical hierarchy of supplier-buyer relationships [9]. It also includes horizontal relationships with stakeholders who are not direct suppliers or customers, but suppliers of complementary products or services, firms outsourcing our business functions, financial supporters, technology providers, and even competitors [10]. As Iansiti and Levien [10] noted, defining boundaries of a firm's ecosystem is impossible, and they should be identified by examining which organizations are most closely intertwined with the firm.

The reason why a firm has to consider its ecosystem health as well as its own competitiveness is that it shares a fate with other ecosystem members [2]. In this sense, Adner [5] stated that a firm needs to concern risks involved in coordinating and integrating complementary innovators when formulating its innovation strategy. The most important one in determining the fate of an ecosystem is a *keystone* player. Following Iansiti and Levien's [2] definition, they provide 'a stable and predictable platform on which other members create niches depending, regulate connections among them, and work to increase diversity and productivity.' Because they provide a platform, they are also called as a *platform leader* in literature. Due to the importance of the role of keystones or platform leaders, most of the ecosystem strategies have been studied and proposed with their perspectives.

As the most comprehensive literature on ecosystem strategies, Iansiti and Levien [2] provided three measures of the ecosystem health, which are productivity, robustness, and niche creation, and described foundations for competing with other ecosystems. Gawer and Cusumano [6] presented what strategic levers platform leaders in industry like Intel, Microsoft, and Cisco use to maintain their leading position, and in their succeeding research [11], they defined two strategies to become a platform leader as coring and tipping through investigation on various practices. The coring strategy is to solve a common problem to create many niches and provide the solution as a platform, and the tipping strategy is to win competition with other platforms and ecosystems. Eisenmann [12] presented challenges in managing platforms when they are proprietary or shared, and Eisenmann *et al.* [13] extended this study by providing strategic elements that should be considered when opening a platform at sponsor, provider, and user levels. In a perspective of managing relationships with other members, Boudreau and Lakhani [14] addressed a decision whether a platform provider should organize outside innovators as a collaborative community or a competitive market according to their motivation and platform's business model, in an open-innovation ecosystem.

Meanwhile, the aim of this study is to analyze architecture of relationships between members and investigate its implications to ecosystem health. Iansiti and Levien [2] also chose architecture as the first foundation for competition. In this approach, several studies represent firm-by-firm relationships in an ecosystem and find implications of the network structure. Iyer *et al.* [15] analyzed network of famous software firms like IBM, Microsoft, SAP and found managerial implications in constructing ecosystem structure. Similarly, Basole [16] visualized inter-firm relationships in a mobile ecosystem and measured its structural properties. Whereas this representation and analysis intuitively shows positions of firms in a network, their roles and characteristics of relationships are ambiguous to analyze ecosystem health.

The more informative representation involves roles of members. Basole [16] also showed consolidation of firms in terms of their roles for abstracting the complex inter-firm network. Basole and Rouse [17] constructed a network consists of relationships between roles in a service delivery process. By analyzing networks of various industries, they asserted low complexity to consumers as a condition for a healthy ecosystem. Allee's [18] value network analysis and Donaldson *et al.*'s [19] customer value chain analysis more comprehensively represents an ecosystem by noting what values are transferred between players having a certain role. The proposed representation model augments the requirement architecture to such a value network between members playing a certain role.

The analysis of interrelated productivity of ecosystem members is still in infancy. While Allee [20] mentioned that each member's decisions on revenue and cost influence other members' productivity and system dynamics approach is applicable to analyze these relationships, no concrete model has been proposed in her work. On the other hand, Tian *et al.* [21] proposed a framework for analyzing these relationships based on game theory models and multi-agent simulation. More concrete analysis was conducted for special relationships. Parker and Van Alstyne [22] and Rochet and Tirole [23] analyzed pricing decisions on a platform that is independently sold to both customers and complementary product or service providers, considering their network effects. In a traditional supply chain, Cachon and Lariviere [24] proposed revenue sharing between sellers and suppliers and analyzed its impact on their profits. This study develops a generic analysis framework that can be applied to other types of ecosystems, and this framework investigates interrelation between more than two members' productivity considering their requirement architecture.

3. REQUIREMENT ARCHITECTURE AUGMENTED REPRESENTATION MODEL FOR BUSINESS ECOSYSTEMS

As Jacobides *et al.* [7] asserted and Tee and Gawer [8] assured by i-mode service example, complementarity and mobility between co-specializing assets plays an important role in benefiting from innovation. It is a fundamental reason for constructing an ecosystem beyond a dyadic relationship between sellers and buyers. Because more than one product and service complement each other and co-specialize a system, their producers cooperate each other as ecosystem members. What and how much profits they achieve may change according to the architecture, and it affects ecosystem health. Therefore, the requirement architecture must be considered in analyzing and improving an ecosystem. Nevertheless, existing ecosystem representation models lack this part and only show value exchange network between players.

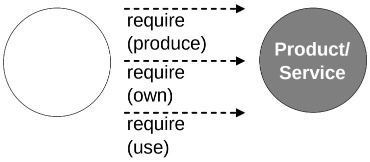
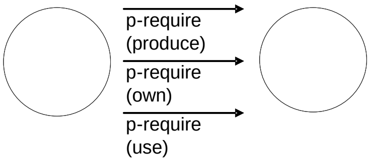
This study develops an ecosystem model that comprehensively represents requirement architecture as well as roles of players and their value network altogether, and ecosystem analysis and improvement framework based on this model. As Simon [25] said, "every problem solving effort must begin with creating a representation for the problem," the requirement architecture needs to be first represented in order to analyze its impact on ecosystem health. The procedure of representation starts from defining requirement architecture, specifies roles of players by engaging them to product and service components, and finishes by identifying value exchange between players. This section explains how an ecosystem is represented by the proposed model in this sequence, and illustrates an example of mobile ecosystem.

3.1 Definition of requirement architecture

The requirement architecture is defined by product and service components and their requirement relationships. As denoted in Table 1, entities of a network are product and service components which are cooperatively delivered by an entire ecosystem. For examples, a mobile ecosystem has cell phone devices, platforms, network service, and mobile contents as its product and service components, and a business solution ecosystem has operating systems, databases, server computers, business solutions, and add-on modules.

Their relationships are defined by requirement (*require*) and proprietary requirement (*p-require*) relationships. These two relationships implements Jacobides *et al.*'s [7] two aspects of asset dependence, which are complementarity and mobility. If a product or service component complements another component, this relationship is represented by a directional requirement relationship from the complementing component to the complemented component. For example, mobile contents complement

Table 1 Definition of requirement architecture

Entity	Description
Product (Service) component	
	A product or service component that is delivered by an ecosystem
Relationship	**Description**
require	
	A product/service *requires* a product/service *to produce* itself A product/service *requires* a product/service *to own* itself A product/service *requires* a product/service *to use* itself
p-require	
	A product/service *requires* a product/service *to produce* itself A product/service *requires* a product/service *to own* itself A product/service *requires* a product/service *to use* itself

mobile devices, and this relationship is interpreted as 'mobile contents require mobile devices for its usage.' The *require* relationship is notated by a dashed line as illustrated in Table 1. This model also distinguishes reasons of requirement. If a component is required for producing another component, it is notated by a *produce* tag in parentheses.

The proprietary requirement implements low mobility of assets. Low mobility means dedication to a specially offered product or service component that cannot be replaced with other ones. For example, Intel's CPUs (central processing units) are immobile to peripherals because other CPUs are not compatible and no one can substitute Intel's reputation. In an opposite way, peripherals are highly mobile to Intel because there are a number of providers of compatible and standard-quality peripherals. In this case, such an immobile asset like an Intel's CPU is denoted by 'proprietarily required by other components.' Hence, *p-require* relationships are a subset of *require* relationships. The *p-require* relationship is notated by a solid line as illustrated in Table 1.

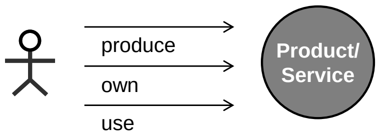
3.2 Definition of roles of players

Each member of an ecosystem plays one or more roles in producing or consuming interrelated product and service components. This model concentrates their roles instead of their individual distinctiveness as other representation models [17-19]. Therefore, all the members who play the same role are abstracted as a player entity whether it is a single firm or an open community of individuals. Following Moore's [1] definition on the ecosystem, "economic community produces goods and services of value to customers, who are themselves members of the ecosystem," the players are restricted to direct stakeholders who produce, own, or use product and service components. Other stakeholders such as auxiliary enablers in Basole and Rouse's [17] model are excluded from the scope of the proposed representation and analysis. The player entity is denoted by a graphical icon as illustrated in Table 2.

The role of a player is denoted by how it is engaged with product and service components. There are three types of engagement relationships: producing (*produce*), owning (*own*), and using (*use*) a product or service component. If a player has a role of producing a product, a directed arrow marked by *produce* notation is drawn from the player to the product. Likewise, owning and using relationships are denoted by arrows between player entities and product and service components as illustrated in Table 2. One caution is that the owning relationships are applicable to only products. One of the characteristics of service is inseparability between production and consumption [26]. Therefore, no one can have ownership of the service. For products, however, one can own a product and borrow it to actual users like a car leasing company.

The roles are interlinked with the requirement architecture. As defined earlier, product and service components have requirement relationships by which a producer, owner, or user of a component has to

Table 2 Definition of roles of players

Entity	Description
Player 	A single or group of ecosystem members who play a certain role of producing, owning, or using product and service components
Product (Service) component 	A product or service component that is delivered by an ecosystem
Relationship	**Description**
Produce/own/use 	A player *produces* a product/service A player *owns* a product A player *uses* a product/service

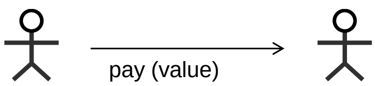
use another component. These relationships partially determine roles of players. For example, a mobile device user should be a user of mobile network service since the device requires the network service to use itself. As another example, a doctor who is a producer of medical service is also a user of medical devices which are required to produce the service. Therefore, roles are defined after identifying the requirement architecture.

This notation of the roles is flexible and convenient to represent multiple roles of one player and evolution of the roles. In a mobile ecosystem, while a network service operator or a device manufacturer also plays a role of providing content market service like Apple's Appstore, it is hard to figure out who plays this role in other representation models in which roles are defined only by the names. The proposed model does not have this problem since it can be represented by linking the corresponding player and content market service with a *produce* relationship. Moreover, when roles of a player evolve, it can be conveniently represented by rearranging the linkage between players and product and service components.

3.3 Definition of value exchange between players

The players of an ecosystem gain profit from exchange of values between themselves. The value exchange has been most comprehensively represented by the existing models. In existing models like Allee's [18] value network and Donaldson *et al.*'s [19] customer value chain, a relationship between a producer and a user is represented by exchange of a product or service and payment for it. The proposed model, however, represents this relationship by specifying their roles and defining a payment relationship according to the roles. In addition, only values that directly contribute to player's profit are modeled because the goal of the representation is to analyze productivity of an ecosystem. Latent values like user's complaints are out of the scope of this model.

Table 3 Definition of value exchange between players

Entity	Description
Player 	A single or group of ecosystem members who play a certain role of producing, owning, or using product and service components
Relationship	**Description**
pay 	A player *pays* a certain *value* that directly contributes to profit to another player

The relationship of value exchange is payment (*pay*). As illustrated in Table 3, the payment relationship is denoted by an arrow marked by *pay* notation. It also notes what value is paid in parentheses. Although the most common value is monetary price of a product or service, other intangible values can be paid if it contributes to player's profit. For example, advertisement is a kind of service produced by an advertiser, and a consumer who watches the advertisement pays his attention to the advertiser. From a player's perspective, in-bound and out-bound payment arrows indicate his revenue and cost, respectively. This notation enables to conveniently identify revenue and cost of participating in an ecosystem and analyze its productivity.

A special type of the payment relationship is paying subsidy to a third-party player. Where other payment relationships exist between a producer and an owner or a user, subsidy is paid for owning or using other player's product or service. The subsidy payment is a common way to attract more participants into an ecosystem [11]. It is usual that a network service operator pays subsidy for buying a mobile phone to network subscribers. Because the subsidy payment is not directly linked with roles of the players, it should be defined according to player's ecosystem strategies. As Eisenmann *et al.* [27] explained, who will subsidize and be subsidized changes according to market and other environmental situations.

Summarizing the above steps of ecosystem modeling, Figure 1 illustrates a smart phone ecosystem represented by the proposed model. The ecosystem delivers a smart phone device, network service, and mobile contents to customers. This example assumes a device includes its platform like Apple's iPhone and iOS. The mobile contents for smart phones are dedicated to a device instead of network service unlike traditional mobile contents. Therefore, a specific device is proprietarily required for producing or using mobile contents. Network service is also required for owning and using the contents, but is not proprietary. The device and network service are mutually required for using each other.

4. A FRAMEWORK FOR ANALYSIS OF INTERRELATED PRODUCTIVITY BETWEEN ECOSYSTEM MEMBERS

Success of an ecosystem does not depend only on excellence of its offerings. It largely depends on

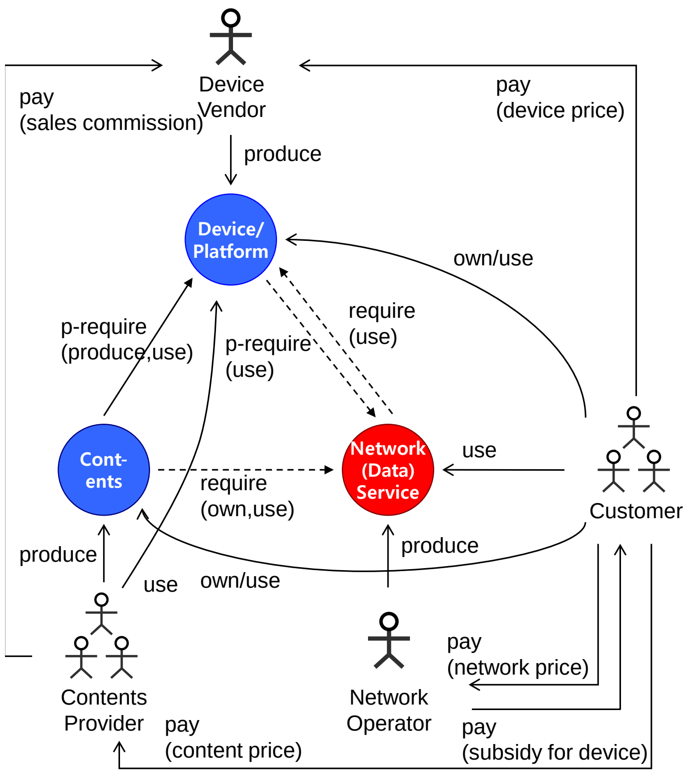


Figure 1. Illustration of modeling procedure: a smart phone ecosystem

how many and competitive members participate in the ecosystem. To be precise, the excellence of the offerings is determined by who are its participants. This phenomena is also called two-sided network effect [22]. The HDTV example is an extreme case in which it could not be diffused in the market over ten years because its content ecosystem was not ready [5]. As Iansiti and Levien [2] pointed out, a healthy ecosystem is nothing but an ecosystem that attracts more members than competing ones.
Iansiti and Levien [2] presented three aspects of the ecosystem health: productivity, robustness, and niche creation. In other words, more firms and individuals want to participate a highly productive, robust, and variety creating ecosystem. This study aims to analyze the ecosystem health in a perspective of productivity among them. It is because the productivity is a prerequisite for other aspects, and the robustness and niche creation can be interpreted as ability to maintain high productivity in an evolving ecosystem.

4.1 Measurement of productivity of players

The first step of the analysis is to identify benefit and cost elements that affect productivity of each player and measure their values. While productivity can be defined in various ways, the most widespread measure is ratio between the benefit and cost, in other words, return on invested capital. More benefit and less cost increases productivity and attracts more members to join an ecosystem. Necessary benefit and cost elements are identified from the proposed ecosystem representation.
First, roles of a player like producing, owning, or using product and service components induce their corresponding benefit and cost. The cost elements are more obvious. Producing a product or service requires material, labor, and other miscellaneous costs, owning it charges maintenance and depreciation costs, and using it also needs time and effort of users. The cost elements of owning and using a product or service beyond its purchasing price have been well studied in total cost of ownership (TCO) literature, which is first introduced by Ellram [28].
The benefit elements are more implicit and unobservable. The benefit of usage is often referred as a concept of utility. As a product or service provides more functions, higher performance, and better quality, its user receives more utility. However, the benefit of producing and owning is usually indirectly observable. Whereas production experience may accumulate learning know-how and ownership may give reputation to owners, they are usually insignificant to take into account in the analysis.
Second, the value exchange between players reveals clearly observable benefit and cost elements. When a player pays a certain value to the other player, the value is a cost element of the payer and a benefit element of the receiver. Accordingly, price of a product or service is benefit of a producer and cost of an owner or user. It should be noted that the benefit and cost elements incurred by the value exchange and the roles of each player are not distinguished in the following analysis. The two step procedure is merely for not overlooking possible elements.

4.2 Influence analysis between benefit and cost elements

In the next step, the identified benefit and cost elements and their possible values are analyzed in a perspective that how they are interrelated. Obviously, benefit and cost elements have positive and negative influence to productivity, respectively. The benefit and cost elements also have interrelation between themselves. A higher price increases producer’s benefit while increasing user’s cost. In a complex ecosystem, such impact is propagated in a more complicated manner.
In order to represent these relationships, we adopt a causal loop diagram which is commonly used for analyzing system dynamics. A diagram denotes the benefit and cost elements as nodes and their positive and negative influence relationships as links between them. In addition, productivity of each player and some important system variables that affect benefit and cost are also denoted as nodes. It depends on an objective of the analysis which system variables are taken into account. It could be severity of government regulation or social consciousness if an ecosystem delivers environmental product and service components. The causal loop representation for business structure is also found in Casadesus-Masanell and Ricart’s work [29]. They modeled a business model of a single firm as a causal loop of business choices and their consequences.
The influence links between nodes can be determined by many different factors. First of all, business models of individual players determine positive and negative influence of benefit and cost elements, respectively. Casadesus-Masanell and Ricart [29] defines those influence links as a business model itself. In ordinary business models, price and cost elements have clear influence links. A product or service price increases seller’s productivity while decreasing buyer’s productivity. Cost for producing

such a product or service usually improves its utility, which increases buyer's productivity. Influence of other elements such as subsidy and commission should be identified according to business models of individual players.

The requirement architecture also determines a structure of influence links. The requirement architecture augmented ecosystem representation model is also required for this analysis. As described in the previous section, the requirement architecture is defined by requirement and proprietary-requirement relationships between complementing product and service components. If a product or service component *A* requires another component *B*, *A*'s utility positively influences to *B*'s utility. Requirement is a kind of the means-end relationship. As an end (requiring component) is more valuable, its mean (required component) deserves more value. In an airline industry, airline companies often advertise overseas travel despite no earnings from it, since pleasure of the travel increases utility of the airline service. Also in a smart phone industry, quality and variety of applications determines preference to smart phones which are required for using them.

Finally, influence of internal and external system variables to benefit and cost elements could be found. The most significant system variable is volume of members joining an ecosystem, and the most representative influence is network externality. Network externality is simply defined by effect of the number of users of a product or service on its utility [30]. Direct network externality accelerates growth of volume of users because increased utility attracts more users. It is also defined for two-sided markets as two-sided network externality [22]. If there are two groups of suppliers and users, increase of supplier volume attracts users by expectation for better offerings, and increase of user volume attracts suppliers by expectation for expanded market.

A mobile ecosystem including contents business is a good example to illustrate influence links induced by all these factors. Productivity of all four players, who are a customer, a device vendor, a network operator, and a contents provider, and volume of customers and contents providers are identified as underlined system variables as illustrated in Figure 2. Because productivity and volume can be considered as identical state variables, only volume variables are left in Figure 2. Influence links of price, utility, and cost elements of ecosystem offerings, which are a smart phone device, network service, and other elements identified by business models, which are subsidy for device and contents sales commission, to system variables are also defined. Those can be considered as a set of business

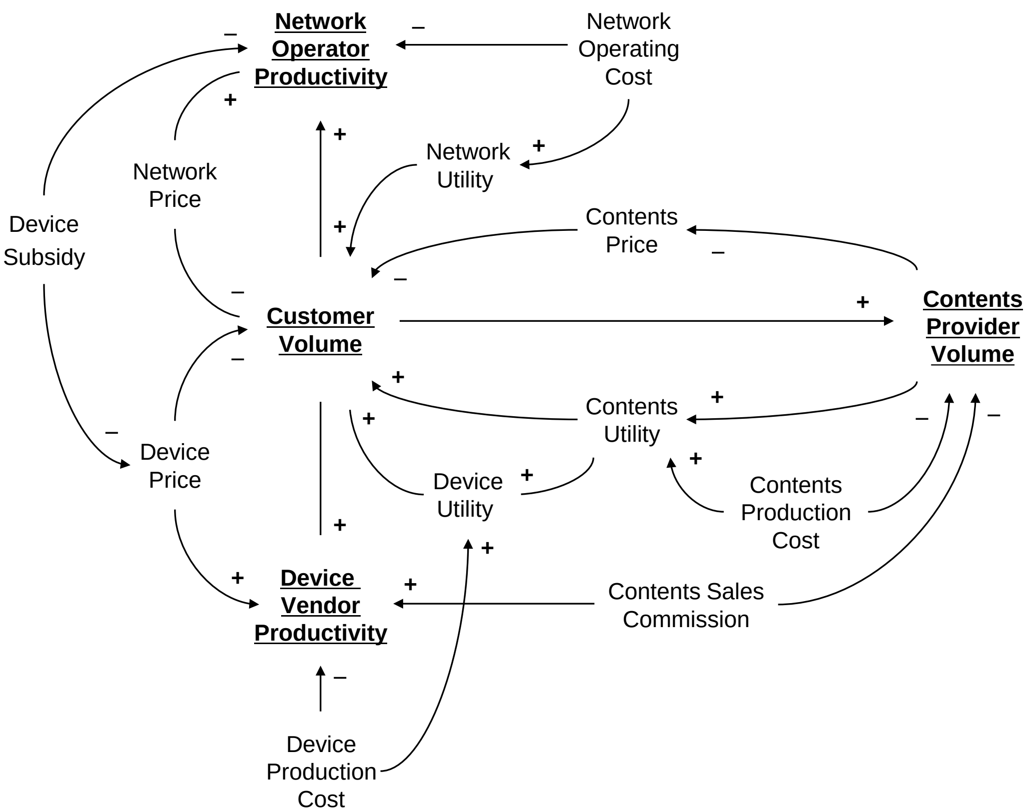


Figure 2. Influence diagram of a smart phone ecosystem

models of individual players.

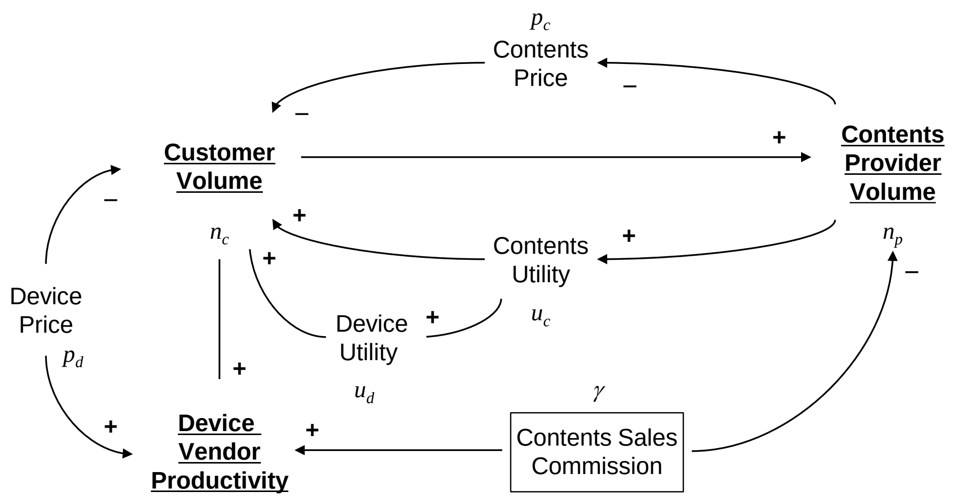
The example of Figure 2 also shows influence links initiated by requirement architecture and network behavior. As illustrated in Figure 1, mobile contents for smart phones require a proprietary device platform. In this situation, utility of contents directly improves utility of a smart phone device. Consequently, a device vendor has pretty high incentive to improve contents utility. Another feature of this ecosystem is that it has two-sided network externality which is illustrated in two closed loops between customer and contents provider volume. First, more customers attract more contents providers to join for bigger revenue of contents sales. As more providers join, they provide various and high quality contents having higher utility, and their prices also drop by severer competition. These consequences establish a virtuous cycle that increases customer volume again. A device vendor and a network operator endeavor to attract more contents providers as well as customers who directly increase their productivity because of this two-sided network externality.

4.3 Assessment of sensitivity of benefit and cost elements to productivity

The final step is analysis of sensitivity of benefit and cost elements and sustainability. Because of interrelation between benefit and cost elements and system variables, each player's decision or performance on their offerings has complicated consequences to his own and other players' productivity. This study defines impact of such consequences as sensitivity to productivity. Because each player wants to maximize its own productivity, the architectural sensitivity finally determines sustainability of an ecosystem.

The underlying basic of the assessment is to track influence links that increase or decrease benefit and cost elements and system variables. By using the influence diagram, one can easily find direct and indirect changes of elements and variables induced by a change of the target element. Let us take a look at 'contents sales commission' element in Figure 3. Tracking positive and negative influence of its increase is illustrated in Figure 3. Its positive influence, increased commission income, is directed to 'device vendor productivity'.

On the other hand, it negatively influences 'content provider volume' since it charges addition cost to contents providers. The decreased volume damages 'contents utility' and raises 'contents price', both



Assume 'Contents sales commission' is increased by γ

Positive influence	Negative influence
	Contents provider volume ($\mathbf{N}_p$) = Provider elasticity to commission rate × γ
	Customer volume ($\mathbf{N}_c$) = Network externality to provider volume × $\mathbf{N}_p$ (aggregation of price increase and utility decrease)
Device vendor productivity ($\mathbf{P}_d$) = Average downloads per customer × $p_c \gamma n_c$	Device vendor productivity ($\mathbf{N}_d$) = $p_d \mathbf{N}_c$

Figure 3. Sensitivity analysis example of 'Contents sales commission'

of which make less customers to join the ecosystem. Those consequences imply that an ecosystem with high sales commission is hard to grow without other incentives. Additionally, the damaged 'contents utility' lowers 'device utility' that also reduces 'customer volume'. The decreased 'customer volume' has negative influence to productivity of a device vendor who formerly gained additional commission income.

As seen in the above analysis, a decision on a benefit or cost element has both positive and negative influence to productivity of the player leaving the price-demand curves aside. Each player makes decisions comparing the both sides. The assessment on sensitivity enables estimation on each player's decisions. When influence relationships are quantitatively known and decisions are engaged with only two players, the optimal decision can be found using game theory models as Tian *et al.* [21] showed. However, rough assessment on positive and negative sensitivity identified by an influence diagram could provide meaningful implications in usual cases, in which the form of quantitative relationships and specific parameter values are not exactly known, and more than two players are engaged with a decision. The next section shows how failure of contents business in a traditional mobile ecosystem is explained by such rough assessment.

The analysis on player decisions also provides implications on sustainability of an ecosystem. In commercial ecosystems, each player wants to maximize its profit, which is interpreted as productivity in this study. A decision of a player that maximizes his own productivity may harm productivity of other players. If it cannot be compensated by other incentives, they will leave the ecosystem. The architectural difference between ecosystems, i.e., who owns what benefit and cost elements and how they are interrelated, make them have different decisions. For example, contents providers pay less sales commission for smart phones than feature phones, which promotes their participation in smart phone ecosystems (why it happens will be explained in the next section). Such difference determines sustainability of an ecosystem.

5. DISCUSSIONS: WHY DO TRADITIONAL MOBILE ECOSYSTEMS FAIL TO ESTABLISH CONTENTS BUSINESS?

In this discussion, we want to concentrate on a decision on level of 'contents sales commission'. It is a one of the major cost elements of a contents provider. As illustrated in the previous section, it is related with many other elements and system variables through complex propagation paths. The lower commission rate promotes more participation of providers, and it also attracts more customers by the two-sided network externality. Obviously, an ecosystem with lower commission rate is more advantageous to successfully grow. Nonetheless, a player who charges it to the providers cannot make it free because it is also a source of his benefit. In a traditional ecosystem, a network operator charges the commission since he distributes the contents that are proprietarily dedicated to the network. In a smart phone ecosystem, this role is transferred to a device vendor or platform holder who provides a platform on which contents and applications are operated.

In conclusion, a traditional ecosystem is prone to charge a higher commission than a smart phone eco-

Table 4. Comparison of influence of commission rate increase (by $\$\gamma$) in traditional and smart phone ecosystems

Traditional ecosystem	Smart phone ecosystem
<u>Contents provider volume</u>	<u>Contents provider volume</u>
Positive : 0	Positive : 0
Negative : - 1% × γ	Negative : - 1% × γ
<u>Customer volume</u>	<u>Customer volume</u>
Positive : 0	Positive : 0
Negative : - 1% × γ	Negative : - 1% × γ
<u>Network operator productivity</u>	<u>Device vendor productivity</u>
Positive : 99%·10M × \$γ = \$0.99γM	Positive : 99%·10M × \$γ = \$0.99γM
Negative : - \$5 × 1%·10M × γ = -\$0.5γM	Negative : - \$300 × 1%·1M × γ = -\$3γM

* base customer volume: 1M customers, base provider volume: 1M providers
** average downloads per customer: 10 dls
‡ average network price per downloads: \$5, average device price: \$300
‡ provider elasticity to commission rate: 1%, network externality to provider volume: 100%

system. Let us refer Figure 3 that shows positive and negative influence of commission rate increase. A traditional mobile network operator and a smart phone device vendor have different parameters for those influence relationships. Table 4 shows how much quantitative impact is propagated to each system variable under some assumptions. Focusing on productivity of the network operator and the device vendor who decides the commission rate, we can find that increase of γ commission rate has much bigger negative impact on device vendor's productivity (\$3γ millions) much more decreases than network operator's (\$0.5γ millions), while their positive impact is same. Although raise of the commission rate makes contents providers and customers to leave in both of the ecosystems, its impact is larger for smart phone vendors because its unit price much higher than the price of network usage. It means that the network operator in a traditional ecosystem has higher incentive to raise the commission rate pursuing more profit. As noted earlier, the contents business is hard to prosper in an ecosystem of high contents sales commission. It is one of the reasons that traditional ecosystem was unsuccessful to grow contents business.

6. CONCLUSIONS AND FUTURE DIRECTIONS

In this study, we proposed a representation model of an ecosystem augmenting the requirement architecture that was usually omitted in previous representation models, and a framework for analyzing productivity and decisions of players that determine sustainability of the ecosystem. The representation model supports to find benefit and cost elements of players that constitute their productivity and predefines their influence relationships. One who wants to analyze his ecosystem and predict its sustainability first represents the ecosystem with the proposed model and utilizes the analysis framework based on the representation.

Planning and designing an ecosystem has been considered as an art greatly relying on decision maker's intuition. Whereas some studies have proposed value chain oriented representation models for supporting systematic analysis, they lack investigation on a complicated structure of interrelation between benefits and costs of individual players. This study provides a general framework that describes how to measure and represent such interrelation and assess sensitivity of each player's decision propagated through the relationships. The framework would simulate research on more elaborated ecosystem analysis models.

In discussion, we interpreted unsuccessful establishment of contents business in a traditional mobile ecosystem driven by a network operator with respect to its requirement architecture and interrelation of benefit and cost elements. A monumental change in a mobile industry driven by introduction of smart phones has been widely discussed in many studies and news articles. The presented interpretation reveals network operator's dilemma in determining network usage price by clarifying his benefit and cost elements, and his higher incentive to keep a high contents commission rate by assessing its sensitivity to his productivity. It shows that intuitively and qualitatively conjectured previous arguments can be explicitly revealed and quantitatively derived by the proposed analysis framework.

A further study is directed to identify effective strategies that improve sustainability of an ecosystem beyond analyzing it. The analysis results may reveal what bottlenecks that retard growth of an ecosystem are. Various strategies could be adopted to resolve them, and many of them could be found in existing practices. The proposed ecosystem model is also appropriate for representing product and service strategies embedded in an ecosystem since it clearly denotes the requirement architecture of product and service offerings. Therefore, representation of existing ecosystems with the proposed model will help identify the effective ecosystem strategies. The analysis framework will also be utilized for evaluating their effectiveness.

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