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Exploring Structure of Mobile Ecosystem: Inter-Industry Network Analysis Approach

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Abstract**—**As increasing importance of symbiosis and cooperation among mobile communication industries, the mobile ecosystem has been especially highlighted in academia and practice. The structure of mobile ecosystem is quite complex and the ecological role of actors is important to understand that structure. In this respect, this study aims to explore structure of mobile ecosystem in the case of Korea using inter-industry network analysis. Then, the ecological roles in mobile ecosystem are identified using centrality measures as a result of network analysis: degree of centrality, closeness, and betweenness. The result shows that the manufacturing and service industries are separate. Also, the ecological roles of some actors are identified based on the characteristics of ecological terms: keystone, niche, and dominator. Based on the result of this paper, we expect that the policy makers can formulate the future of mobile industry and healthier mobile ecosystem can be constructed.

Keywords**—**Mobile ecosystem, structure, ecological roles, network analysis, network index.

I. Introduction

FOR many years, the development of mobile communications has been mostly controlled and managed by manufacturing and service industries such as the mobile network operators (MNO), phone manufacturers, and some mobile application and content providers [1]. Traditionally, the MNO and phone manufacturer played a dominant role in the manufacturing and service industry of mobile communication industry, respectively. Recently, this relationship has changed with the arrival of new mobile smartphones such as iPhone and Galaxy series and mobile application platform such as iOS and Android. The mobile industry has been complex and its structure and value chain are evolving with change of actors [2]. Some actors lost their own dominant position in value network like MNO, while some play a critical role in interacting with other actors like platform and smartphone device manufacturers [1]. In this respect, the concept of mobile ecosystem is emerging to embrace this complex structure and relationship of major actors and their structure exchanged roles over time.

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This study explores roles and relationships between actors in manufacturing and service industries of mobile communication industry, especially focusing on ecosystem perspectives. Several previous studies indicate that the mobile ecosystem is more relevant for taking the recent change of relationships between manufacturing and service industries in mobile communication industry into account. Ecosystem perspective is important and useful in that the change of complex interaction in a system can be explained with familiar ecological terms based on key characteristics of their interaction such as symbiosis, platform hub, and co-evolution [3], [4]. Also, based on key characteristics of ecosystem, three ecological roles are usually suggested such as keystone, niche, and dominator [5], [6]. These roles are capable of identifying the complex relationships and making it easy to understand the overall system. Using these roles, the structure and value chain of mobile ecosystem can be more clearly explored. However, previous studies on ecosystem remain as conceptual framework and qualitative research.

Thus, this study aims to explore the relational structure and ecological roles in ecosystem quantitatively. To this end, in this paper, the network analysis is conducted for measuring centrality based on input-output flow of inter-industry network. The research purpose is twofold. First, using input-output resource flow, the network of mobile ecosystem is constructed and visualized. For analyzing mobile ecosystem, we use information of input-output resource flow. The network visualization is effective for exploring and monitoring the mobile ecosystem structure and relationships between actors. Second, by the combination of network index as major results of network analysis like centrality, closeness, and betweenness, the ecological role of each actor in mobile ecosystem is characterized and justified such as keystone, niche, and dominator. Based on these ecological roles, the core actors of value chain can be investigated in ecosystem perspectives.

The remaining part of this research consists of four sections. Following on from a background of the ecosystem perspective in Section II, Section III describes the research framework with data and inter-industry network analysis. Section IV shows the illustrative examples and finally, the paper ends with conclusions in Section V.

II. Background of Ecosystem Perspectives

A. Characteristics of Ecosystems

An ecosystem is an environment in which different species coexist through mutual interaction and the influence of various external forces. Within an ecosystem, one species affects and is

affected by other species [7]. Similarly, as mentioned before, the ecosystem perspective in industry and business has begun to suggest a biological ecosystem, which is a "powerful analogy for understanding business networks" [4]. Accordingly, the business ecosystem is defined as "a community of organizations, institutions, and individuals that impact the enterprise and the enterprise's customers and suppliers" [8]. The ecosystem perspective moves the analysis from the product or service level to the system level [9].

As for the ecosystem thinking, three key characteristics are considered: symbiosis, platform (hub), and co-evolution. These characteristics were described by key phenomena observed in nature, such as competition, cooperation, learning, evolution, and growth [3]. In symbiosis, the business ecosystem has a loose network ranging from suppliers to customers, and they are affected by the creation and delivery of a company's own offerings [4]. Compared to a value chain, the relationship within an ecosystem has fluid boundaries between customers, suppliers, partners, and goods. The blurring boundaries make the business system shift from simple cooperation to complex cooperation. Thus, an increase in cooperation between players is necessary for symbiosis. The second characteristic is a platform that other members of the ecosystem can use to enhance their own performance [10]. An example is Google's Android OS, which is installed in smartphones. In a broad sense, the players that provide platforms are "hubs" of the ecosystem, and they play a central role in the ecosystem. Although, hubs trigger some antitrust concerns in policy, it is important that hubs tend to facilitate symbiotic [4], [11]. The final characteristic is co-evolution. The first and second characteristics help firms and industries to evolve simultaneously. For example, the Apple iPod has enabled other contents industries, such as music and entertainment industry, to add value to it, and vice versa. This indicates that the ecosystem allows firms to create value that no single firm could create alone [12]. At the industry level, the synergic co-operational value of an industry ecosystem becomes greater than the sum of its parts.

In terms of these characteristics, several roles have been proposed for players in the business ecosystem. Although, there is no consensus about the definition of roles and concepts, three roles are usually considered [5], [6]. These ecological roles are defined based on the inputs and outputs, impact, and coverage of players. First, *keystones* are players that provide resources as enablers and have a great overall impact although they are a small portion of the complete system. Second, the *niche players* focus on a narrow domain and develop specialized assets and capabilities. Finally, *dominators* are organizations that attract resources from the system, but do not function reciprocally. Compared to keystones, dominators focus on extracting value, whereas keystones focus on both providing and extracting value.

B. Emergence of Mobile Ecosystem

In 2005, Bill Gates focused on the ecosystem when launching a Windows Mobile OS. He said, "The idea is to create a real ecosystem, with operators, manufacturers, and developers." Since 2007, Apple and Google revealed their broader mobile strategy in the ecosystem perspective. They created their own ecosystem based on iPhone, iOS, and App Store as an alternative to the Android phone, Android OS, and Android market. Similarly, the term ecosystem has been receiving attention in the mobile communication sector; however, the term originated in the business ecosystem [10]. The mobile ecosystem is a specific case of the business ecosystem for the mobile communications sector.

In the initial period of the mobile communications era, there were only two players: device manufacturers and mobile network operators. Mobile communication was confined only to voice call services. The text message service was being delivered by mobile network operators. Due to the poor infrastructure of mobile broadband networks and the lack of technology in mobile devices, only two players remained in the market for a decade. With only two players, the interactions and strategic alliances were very simple. However, as the mobile broadband network evolved from 1G to 2G and from 2G and 3G, several service providers emerged, such as content and media service providers. Game or ringtone services were provided by collaboration between mobile network operators and content service providers. Device manufacturers also developed mobile phones that enabled customers to use these services. Software-implementing mobile phones were also developed as enablers.

Smartphones, such as Blackberry of RIM and iPhone of Apple, spearheaded the expansion of the mobile communication sectors from 2000 onward. Because smartphones allow Wi-Fi use, Internet service providers moved from wire communications to wireless communications. The Mobile Web is a result of Internet service providers entering the mobile communications network. In a major change of business model, the mobile communications sector developed open platforms and markets, such as iOS and App Store of Apple. This new model has led to a rapid increase in the number of application software developers. These applications create content and help media service providers promote their business. Games, utilities, and media services are being developed as application software used in smartphones. Thus, the platform plays a crucial role in interactions between device manufacturers, mobile network operators, and application developers. In addition, the open market provides the place where developers sell their application services. Finally, interactions between traditional and new players increase the size and complexity of the mobile communication sectors transforming them into mobile ecosystems. The roles and relationships of new players need to be verified to make the ecosystem healthier.

III. Research Framework

A. Data from Inter-Industry Analysis

In economics, the major objective of the inter-industry analysis developed by Leontief was to evaluate the economic effects of exchanges amongst industries nationwide [13]. The input-output table includes inter-industry input-output flows,

which play a prominent role in the nationwide flow of resources. The input-output table is effective for assessing the economic impacts of the transfers of intermediate goods and services among industries [14]. An analysis of input-output flows and spillover effects between industries or sectors is especially prevalent to inter-industry analysis because nations pursue increasing overall economic growth and promoting resource distribution, whereas firms usually concentrate on increasing sales. Thus, the inter-industry analysis has more attention on involved issues on a national economy [15]. Based on resource flows, the effects of inter-industry can be used to explore the overall structure of the mobile ecosystem and to explore roles of ICT industries in the mobile ecosystem.

The basic structure of the input-output table is a matrix in which inputs are enumerated in the columns of each industry and the outputs are aligned in the corresponding rows. In the input-output table, the relationships can be represented in terms of inputs and outputs across a range of industries. The basic balance equations (1) and (2) can be expressed based on the input-output table as follows

$$X_i = \sum_{j=1}^{N} X_{ij} + F_i \quad (1)$$

$$X_j = \sum_{i=1}^{N} X_{ij} + V_j \quad (2)$$

Here, X_i is the total gross input in the sector i, where i = 1, 2, …, N; and X_j is the total gross outputs in the sector j, where j = 1, 2, …, N. X_{ij} is the inter-industry supply from sector i to sector j; and F_i and V_j denote the final demand of sector i and the value added for sector j, respectively. From input-output table of inter-industry analysis, we select the actors in manufacturing and service industry of mobile communication as shown in Table I. We collected the data of input-output table of years of 2010 in Korea. These industries are used to explore structure of mobile ecosystem and justify their roles in mobile ecosystems.

TABLE I
MANUFACTURING AND SERVICE INDUSTRIES

Main sector	Sub sector
Manufacturing industry	Electronic signal equipment
	Semiconductors
	Other electric component
	Wireless communication systems and broadcasting apparatuses
	Computer and peripheral equipment
Service industry	Telecommunications services
	Services auxiliary to finance and banking
	Business services
	Computer related services
	Education services
	Medical and health services
	Publishing
	Cultural services
	Amusement and game services

B. Network Analysis

Since many years, the interconnectedness of actors in network has been a major issue. Traditionally, this matter has been considered as graph theory or network analysis, and recently, as increase in ongoing interest of social network like *Facebook*, social network analysis is highlighted as one of the central issues in network analysis. Amongst others, a centrality measure to identify interconnectedness quantitatively has been studied so far.

In following, the three centrality measures are presented. First, as the simplest measure, we take the degree of centrality (DC) into account. The number of a network member's direct contacts is a concept of DC. The advantage of this interpretation of an actor's centrality, with DC as its standard representative [16], is the fact that the results are relatively easy to interpret and communicate [17]. Second, we adopt the closeness centrality (CC), where one is seen as centrally involved in the network if another requires only few intermediaries for contacting others and thus is structurally relatively independent. The second approach is based on the concept that nodes that have a short distance to other nodes and is possible to disseminate information on the whole network effectively. Finally, the betweenness centrality (BC) is widely used in network analysis. The BC of an actor's centrality is determined depending on the number of all shortest paths between actors based on their position in the network [17], [18]. It is implicitly assumed that the communication and interaction between two nodes in directly related actors depends on the intervening actors (For more information on the centrality measures, we recommend the reference of [17]).

From three centrality measures, we justified the ecological roles as shown in Table II. First, as a definition, the keystone is a hub of large clusters with small proportion. Although the keystone itself has low connection with other actors, it plays a critical role in linking with influential actors by taking a hub position. Thus, although DC is low, CC and BC are high. Second, the niche has many direct links but the degree of indirect connection is low because the niche focuses on a narrow and specific area. According to these characteristics, DC should be high, but CC and BC can be low. Finally, the dominator has many links with others in specific area and also plays a role as a hub. It means that all centrality measures of DC are high.

The input and output resource flow is used to measure three centrality and based on its measure the role of each actor in manufacturing and service industries can be justified. Compared to previous research, this network analysis contributes to a quantitative research on analysis of ecosystems.

TABLE II
ECOLOGICAL ROLES AND CENTRALITY MEASURES

	DC	CC	BC
Keystone	Low	High	High
Niche	High	Low	Low
Dominator	High	High	High

IV. ILLUSTRATIVE EXAMPLES

Prior to the complete research, we represented the illustrative examples of case study using the data of input-output table in 2010. The result can be summarized as shown in Fig. 1. The most distinctive findings are that the manufacturing and service

industry are quite separate. Some of actors in service industry such as "business and telecommunication services" are centered with large resource flow (as shown in node size) and related to some of actors in manufacturing industry such as "semiconductors" and "wireless communication systems and broadcasting apparatuses".

In addition, based on the centrality measures as a result of network analysis, we can match actors with ecological roles. First, "wireless communication systems and broadcasting apparatuses" and "services auxiliary to finance and banking" are identified as keystones. These actors have small direct connection, but it related to manufacturing industry as well as service industry. Second, "medical and health services" plays a role of the niche. This actor directly links with most of the actors in service industry and is close to many actors. Finally, "business services" and "telecommunication services" are identified as dominators. They take core position in service industry and also link with the actors in actors in manufacturing industry which have higher CC and BC such as "semiconductors" and "wireless communication systems and broadcasting apparatuses".

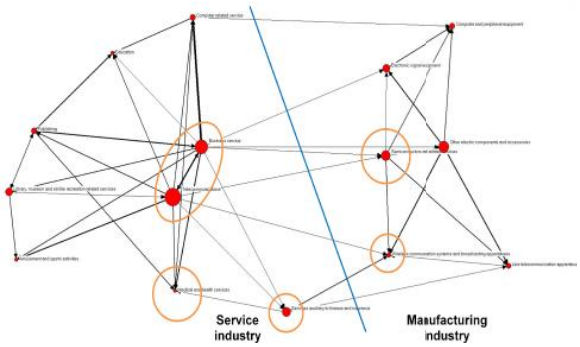

Fig. 1 Change of mobile ecosystem of Korea

V. Conclusions

The strategic gravity of structure of mobile ecosystem has been highlighted and considered a matter of grave concern as ecosystem is larger and complex. The role and position of actors in mobile ecosystem has been changed with the arrival of new actors and the core actor of value chain has been also exchanged. The structure of ecosystem become more complex over time and thus, the analyzing structure of ecosystem is timely relevant. The interest in ecosystem perspective is increasing and this perspective gives fruitful insight and implicit meaning using familiar ecological terms. To analysis structure of mobile ecosystem, network analysis is conducted based on input-output resource flow of the inter-industry analysis.

The contribution of this paper is twofold. First, we visually explore network structure of mobile ecosystem in the case of Korea. Using input-output resource flows, the industrial relationships can be explored and thus, the structure of mobile ecosystem is monitored. By visualizing mobile ecosystem as a network, the complex relationships can be effectively shown. Second, we identify an ecological role of each actor in mobile ecosystem. Although many studies have suggested the role of actors or players in ecosystem both conceptually and qualitatively, it is a first approach to identifying the roles using the quantitative network measures. Based on the result of this study, the policy makers can formulate the future of mobile industry and healthier mobile ecosystem can be constructed.

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