2009

Structural Analysis and Visualization of Ecosystems: A Study of Mobile Device Platforms

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ABSTRACT

Platforms enable and drive the creation of new products and services; they also shape and transform industries in fundamental ways. Consequently, platforms have become a core feature of many emerging business models. The success of a platform is inextricably linked to its network, or ecosystem, of enablers and complementors. Drawing on models and theories of complex systems, innovation, and network analysis, this study analyzes the evolving structure of interfirm relations in the mobile device platform ecosystem. This domain is of particular interest due to the emergence of promising new platforms and competition for platform leadership between open and closed business models. The visual approach presented in this study provides insights to the complexity of interfirm relations in the mobile device platform ecosystem, determines a platform's competitive position, and identifies structural configurations that characterize various types of business strategies. Both theoretical and practical implications are discussed.

Keywords

Platform, Business Model, Innovation, Ecosystem, Interfirm Networks, Visualization.

INTRODUCTION

Recent studies have suggested that platforms not only enable and drive the creation of new products and services, but also shape and transform industries and business strategies in fundamental ways (Evans et al., 2006). Commonly identified examples of highly successful platforms include Cisco, Intel, Wal-Mart, Visa, and Microsoft to name a few (Cusumano and Gawer, 2002, Eisenmann, 2008). Platforms play a particularly critical role in technology intensive industries (Parker and Alstyne, 2008). As a result platforms have become a core feature of many business models in industries such as enterprise software, electronic commerce, or mobile communications (Evans et al., 2006, Gawer and Henderson, 2007, Rochet and Tirole, 2003). Platforms providers are often the hub or orchestrating actor in a complex interfirm network (Chesbrough and Appleyard, 2007). Firms, through various types of interfirm relationships, collaborate and coordinate activities to create and deliver products and services that complement, enable, and drive the platform (Chesbrough and Appleyard, 2007). In addition, interfirm relations and the resulting ecosystem structure have been shown to significantly influence innovation (Schilling and Phelps, 2007) and provide and enable access to resources, knowledge, and information for competitive advantages (Dyer and Singh, 1998).

The purpose of this paper is to examine the structure of competing platform ecosystems in the mobile industry from 2006-2008 with a particular focus on three key segments, namely mobile device manufacturers (MDM), mobile network operators (MNO), and mobile platform providers (MPP) from 2006-2009. This context and timeframe is particularly interesting for the study of ecosystems, as the market is rapidly transforming and new relations and affiliations are continously formed (Basole, 2009). Similar to the issues the desktop computing industry faced in the 1980's when the choice was between Microsoft Windows and IBM's OS2, the mobile industry is facing a significant milestone in the mobile device platform market that could either impede or accelerate the growth of the industry. IBM's OS2 was considered far more robust and technically superior, but Microsoft's dominant market share of the PC market and successful business model by partnering with developers and hardware manufacturers won it the battle over the desktop OS for the desktop PC. Can the mobile industry learn from past historical lessons to chart a brighter future?

Given that one of the critical functions of the business model is to understand and describe the position of the firm within its ecosystem (Chesbrough, 2006), the fundamental objective of this research is to analyze and visualize the structure and evolution of the mobile device platform ecosystems. Drawing on complex systems, innovation, and network theory, this study provides insights to salient network characteristics (e.g. network size, connectivity, and centralization) and proposes a set of research proposition on how these could influence innovation. In doing so, the study contributes to the growing literature of network analysis in the organizational sciences and provides important theoretical and managerial implications to the design and creation of effective business models.

The paper begins by discussing the theoretical foundation for the study. Next, the context of the study, mobile device platforms, is discussed. The following section outlines the research method. Structural analysis and visualization results are then presented. The study concludes with implications for business models and suggestions for future research.

THEORETICAL BACKGROUND

Technology Platforms

The value, design, and management of technology platforms has been a topic of increasing interest to both researchers and practitioners (e.g. (Cusumano and Gawer, 2002, Eisenmann, 2008, Parker and Alstyne, 2008, Rochet and Tirole, 2003)). Armstrong (2006) and Rochet and Tirole (2003) suggested that technology platforms are multi-sided markets since they bring together various types of participants, or sides, such as buyers and sellers. Consequently, studies have examined pricing and commitment incentives to market participation (Hagiu, 2006). Other studies have used various lenses to understand platform competition (Rochet and Tirole, 2003), emergence (Iyer et al., 2007), strategies (West, 2003), strategic differences (Economides and Katsamakas, 2006), and the role of complementary markets (Gawer and Henderson, 2007).

(Gawer and Henderson, 2007) suggest that many high-tech products and services can be considered as "systems of interdependent components, built around and on top of platforms" and are often provided by a complex network of firms, or ecosystem (Iansiti and Levien, 2004). In this ecosystem, technology platforms can be considered hubs (Economides and Katsamakas, 2006), keystones (Iansiti and Levien, 2004), or orchestrators (Nambisan and Sawhney, 2008). Technology platforms provide other constituents the ability to build and provide complementary products and services (Parker and Alstyne, 2008). Platform providers can hold dominant positions in the industry, but they also face the challenge of managing the evolution of the platform by cultivating an effective ecosystem of enablers and complementors (Cusumano and Gawer, 2002).

From Interfirm Networks to Ecosystems

An ecosystem consists of interdependent firms that form symbiotic relationships to create and deliver products and services (Basole and Rouse, 2008). The conceptualization of markets as ecosystems is a result of theoretical extensions of work in interfirm networks, alliances, and innovation. In her seminal work, (Oliver, 1990) suggested that interfirm relations are a result of six fundamental determinants, namely asymmetry, reciprocity, efficiency, stability, and legitimacy. With the increase in complexity of product and service development and markets becoming increasingly disintegrated vertically and horizontally, there has been both a need and opportunity for the creation of interfirm relations (Iansiti and Levien, 2004). In emerging technology industries, networks and alliances were found particularly beneficial due to ability for firms to share risks and develop and have access to synergistic knowledge (Eisenhardt and Schoonhoven, 1996). Studies have shown that interfirm networks are an effective organizational form to improve firm performance, speed of innovation, and organizational learning (Gulati et al., 2000, Ahuja, 2000).

Previous research has used several different theoretical lenses to understand the structure and dynamics of interfirm relations and alliances. Studies adopting a resource dependency perspective examined exogenous factors of why and when interfirm relations are formed (Eisenhardt and Schoonhoven, 1996). The fundamental conclusion from these studies was that firms engaged in interfirm networks primarily to combine and integrate complementary knowledge and capabilities in order to improve innovative performance, reduce time-to-market, and identify new opportunities (Dyer and Singh, 1998). Another theoretical approach is the embeddedness perspective, which views interfirm relations as a network of social interactions (Granovetter, 1985). This approach investigated the endogenous factors that affect a firm's action, outcome, and behavior in a system in which firm's are directly or indirectly linked.

More recently, studies have adopted a complex networked systems perspective to examine why, when, and how interfirm networks and alliances form and change (Gulati et al., 2000). This view combines both the resource-dependency and embeddedness perspective and suggests that interfirm networks are complex systems characterized by co-evolving actors engaged in collaboration and coopetition (Iansiti and Levien, 2004). The complex networked systems approach has been used to study value network and ecosystems in a variety of industries (Basole, 2009, Basole and Rouse, 2008, Rosenkopf and Schilling, 2007)

Structural Analysis and Visualization

Given the importance of interfirm relations in the technology platform context, it is valuable to gain a greater understanding to the underlying structural characteristics of different platform ecosystem and the resulting business model implications. Organizational network analysis has its roots in the social sciences. Researchers have used network theory to explain the mechanisms and structures individual actors commonly use to generate social capital in networks (Wasserman and Faust, 1994). Unlike other theories, network theory can be applied at various levels of system analysis. Broadly, an ecosystem can be described as a networked system that contains a set of objects (e.g. actors, nodes, etc.) that are tied to each other. In platform ecosystems, these objects tend to be firms and ties are often buyer-supplier relationships, alliances, or partnerships. Depending on the relationship, ties can be directional, indicating an origin and destination, or non-directional. The conceptualization of ecosystems as a combination of objects and ties is particularly useful as researchers can base their model and hypotheses testing on the established mathematical field of graph theory (Newman, 2003).

While an analytical approach provides valuable insights to the structure and dynamics of ecosystems, important knowledge can also be gained through the visualization of complex network data. Contrary to the perception that visualizations are merely artistic approaches to depicting structure, they have been used to explore, interpret, and communicate data in order to aid humans in overcoming their cognitive limitations, making structure, patterns, relationships, and themes visible, and providing a means to efficiently comparing multiple representations of the same data in fields such as medicine, dentistry, computer science and engineering. Indeed, visualization has been identified as an integral part of the scientific approach and a way of transforming data to knowledge. Examples are plentiful: it has been used to portray food webs, telecommunication networks, citation networks, crime networks, electric grids, flow of intellectual property, the Internet, and genetic networks (Newman, 2003).

Given the ubiquity of complex networks in economies, markets, firms, and societies, it is surprising that only few studies in the organizational and management sciences have taken advantage of its potential power. It has been suggested that visualization approaches can be extremely valuable for understanding and analyzing business issues, including strategy, scenario planning, and problem-solving (Tufte, 1983).

An explanation may be that visualization of complex systems is not only a very challenging and difficult task and but also, if not developed, implemented or applied correctly, may lead to non-conclusive results. Particularly in visualizing complex interfirm networks or ecosystems, node-link configurations are not necessarily unique and results may be misleading. The boundary-setting problem, or inclusion of nodes, is often artificial. Conclusions based on these models must thus be carefully scrutinized for the possibility of alternative explanations. Along the same lines, the amount of information that is captured and presented can often be overwhelming to the end-user. In many instances, what and how complex network data is visualized depends on not only on the nature of the data but also on the question that is being asked and ultimately the cognitive abilities of the user. In order to overcome the aforementioned challenges, researchers must therefore ensure a balance between detail, abstraction, accuracy, efficiency, perceptual tension, and aesthetics in their complex network visualizations. These observations highlight the importance of setting the context and defining the elements in an ecosystem visualization study very carefully. Table 1 provides a non-exhaustive summary of relevant network elements and their attributes that should be considered when visualizing platform ecosystems.

Element	Description
Vertex (Node)	Actor (Firm), Player, Entity in the Platform Ecosystem
- Label	Actor Name (e.g. Symbian, Google, Nokia, T-Mobile, Vodafone)
- Type	Type or Class of a Firm (e.g. Supplier, Partner, Competitor)
- Attribute	Segment (e.g. Device Manufacturer, Silicon Vendor, Network Operator), Company Size, Company Revenue, Geospatial Position (e.g. Country, Location)
Edge (Link)	Tie, Connection, Relationship
- Attribute	Strength of Relation, type of Relation, Length of Relation, Type of Value Exchanged (e.g. Knowledge, Money, Material, Product, Service)
- Direction	Directed (e.g. flow from source to destination node), Undirected

Table 1. Summary of Platform Ecosystem Elements

THE MOBILE DEVICE PLATFORM ECOSYSTEM

The mobile industry can be described as a complex system with numerous inter-firm relationships across multiple segments (Basole, 2009, Rosenkopf and Padula, 2008). One important segment of this industry is the MPP segment, which provides operating systems for next-generation mobile devices. In the past, the operating system of a mobile handset did not get a lot of attention. MDM used to have their own proprietary OS built into their product lines; only few native applications were included, and useful and compelling third-party applications were generally very limited. Today, mobile phones have computing capabilities equaling those of personal computers of just a few years ago. Indeed, the capabilities of the handset, particularly on the hardware side driven by Moore's law, have advanced at a rapid pace, far beyond the speed of software innovation. Examples include the tremendous increase in processing power, memory, screen resolution, and specialized digital signal processors (DSP) for video and audio. The major limiting factor to the adoption growth of these next-generation mobile devices, however, has been the lack of existing applications that can take advantage of the available hardware.

In order to build robust applications and generate rapid innovation of software, developers require a very responsive, powerful, and compelling platform. The personal computer (PC) industry and Microsoft's win of the desktop OS market in the 1990's in particular provides an excellent historical analogy. Compelling third-party applications were abundant, because developers were able to take advantage of Windows OS, a rich platform that enabled core services and scalability and provided consistency for development. Microsoft built a successful ecosystem around this platform by building strong relationships with hardware and software vendors and supporting a large developer community. Developers thus concentrated on the Windows platform as they saw more opportunities in selling more applications. This led to a continuous reinforcing cycle: greater number of apps generates more customers, draw more developers, which in turn attracted more customers.

It has been posited that a mobile OS can be a similar catalyzing force for the mobile industry (Evans and Schmalensee, 2007). (Basole, 2009) found that platform providers play a particularly critical brokering role in the converging mobile industry since they enable and drive the creation and delivery of new applications and content. Indeed, a mobile OS has the ability to lower the difficulty threshold of bringing content and applications to market thus benefiting all players in the mobile ecosystem. MDM are trying to sell many variations of their products to a broad range of segments: the use of a standardized mobile OS enables them to reduce their built-in costs. Instead of requiring a different OS for each and every device (mobile phone, gaming platform or PDA), MDM can use a single operating system to deliver new and unique handheld devices to consumers and enterprises. MDM can thus create unique form factors for different market segments. For MNO, it offers a way to differentiate their service offerings by provisioning and customizing existing applications and content to consumers and enterprises, thus allowing them to increase data revenue and margins per user. A mobile OS provides developers a platform on which to build consistent and scalable applications. Studies have shown that developers spend large amounts of time rewriting or tuning their applications for a myriad of software environments. In contrast to traditional development, a mobile OS can reduce development costs and time significantly. Ultimately, the main beneficiaries of a mobile OS are end-users. In addition to faster access to a richer set of compelling applications like mobile TV and location-based services, the overall user experience of using a handheld device is greatly improved. A key function of mobile OS is to manage hardware and software resources more effectively. As applications such as video and gaming become increasingly computing intensive, the need for handheld power management is more critical. A mobile OS provides this ability.

These benefits have led to a tremendous growth in the mobile OS space; however, it has also led to a highly fragmented market with numerous different OS variations and no real standard. This "broken" ecosystem generates a myriad of challenges to developers, MNO, and MDM and poses as a serious roadblock to the growth of the mobile industry. Answers to questions such as what OS should developers develop for, what OS should MDM adopt, which OS provides network operators the greatest increase in ARPU, and what OS will generate the most compelling applications to end-users are of tremendous interest to all stakeholders in the mobile industry.

Pundits argue that complete elimination of market fragmentation is virtually impossible. Contrary to the philosophies of the PC market, it is questionable if the "one OS wins all" perspective will hold true in the mobile industry as well. However, it is clear that the number of mobile OS must be reduced to promote innovation within the industry. There are over 40-50 different operating systems, but 5 of them hold approximately 97% of the entire market. Key players include Symbian, Windows Mobile, RIM Blackberry, Linux-based platforms, and more recently Apple and Google's Android. While there are several mobile ecosystem segments that MPP interact with as shown in Figure 1, this study focuses on interfirm relations among MDM (e.g. hardware provider), MNO (e.g. service providers), and MPP (e.g. providers of the aforementioned mobile device platforms).

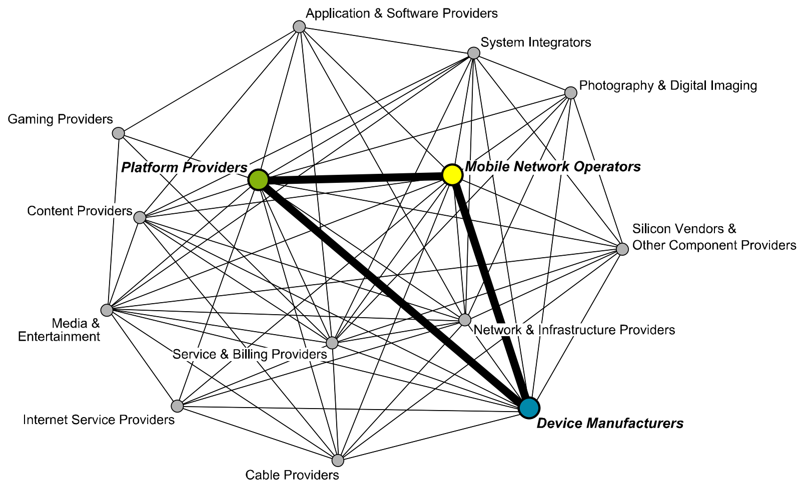

Figure 1. Mobile Ecosystem Segments (Basole, 2009)

METHOD

Data

This study uses a unique dataset that was built by integrating two primary data sources, (1) Thomson's Financial SDC Platinum database, a source frequently used in the study of interfirm networks, and (2) Connexiti database, which captures supplier information from public filings, company publications, annual reports, major news feeds, and financial databases. The dataset was seeded through the identification of member companies participating in open platform foundations and leading companies in the mobile industry as provided by Fortune 1000 lists for 2006, 2007, and 2008. This timespan was chosen due to rapid rise in mobile device usage and emergence of three platforms, Apple's iPhone OS, Android, and LiMo.

Given the very large number of actors and various segments in the mobile industry that influence the mobile device platform ecosystem (Basole, 2009), this study constrains its analysis to three key segments: MPP, MDM (North American Industry Classification System (NAICS) code: 33422), and MNO (513322). Company inclusion criteria were as follows: all leading mobile device platform vendors were included; mobile network operators (> 10 million subscribers) that offer high-speed data network services; and all leading device manufacturers (98% market share).

The resulting set included 67 global companies and over 200 relationships. For each of these companies, the date they entered into a relationship with another actor in the platform ecosystem was identified using the Lexis-Nexis database; company-specific data, such as size and financials, were also captured as provided by the D&B Million Dollar database. All data was collected and organized in a MySQL database.

Visualization

To visualize our interfirm network data, the study used Pajek (Version 1.24). Pajek is a general, non-commercial program, for analysis and visualization of very large and complex networks (Batagelj and Mrvar, 1998). While other visualization programs exist, Pajek was chosen due to its available functionalities for handling and analyzing large complex. Custom scripts were developed to automatically generate source code from the MySQL database for use in Pajek.

There are several network layout algorithms implemented in Pajek. For the purpose of this study, the Kamada-Kawai (KK) algorithm was used (Kamada and Kawai, 1989). The KK algorithm is a multi-scale layout algorithm for the aesthetic drawing of undirected graphs with straight-line edges. It is based on the idea of optimizing a balanced spring system through energy minimization. Nodes that are close will pull on each other, while those who are distant will push one another apart. The algorithm seeks to find an optimum in which there is minimal stress on the springs connecting the whole set of nodes.

RESULTS

Figures 2-4 show Pajek-generated visualizations of three different years (2006-08) of the mobile device platform ecosystem. MPP are depicted as light grey circles, MNO as grey circles, and MDM as black circles. The size of the platform provider node indicates the global market share for that year. A link connects a firm to a platform if (i) a MDM sells a device with that platform or (ii) a MNO offers a device with that platform. Table 2 shows evolutionary network characteristics of the mobile device platform ecosystem.

Several important observations can be made. First, while Symbian continuous to be the leading platform it has seen its market share shrink particularly due to the growth of the Apple, Blackberry, and Windows Mobile OS. Another key observation is that several MDM (e.g. Samsung, Motorola, and LG) provide devices with different platforms, suggesting a single leading platform has yet to emerge and multiple licenses exist.

In contrast to this are Nokia, Apple and RIM, who are closely linked to a single platform. Interesting is also the relative position of Windows Mobile in the ecosystem. While its prominence is growing, Windows Mobile does not appear to play a central role in the mobile platform ecosystem. A similar observation can be made for the two Linux based platforms, Android and LiMo. It can also be observed that some of the larger MNO (e.g. AT&T, Vodafone, Orange, T-Mobile) offer a greater number of platforms and devices. This has significant implications on cost, provisioning and support.

Figure 2 shows the mobile device platform ecosystem in 2006. Three distinct clusters can be identified; firms that are linked to Symbian, Windows Mobile, and Blackberry. Symbian is the clear dominant mobile device platform with nearly 75% of the total market. Virtually all major MDM and MNO use the Symbian platform. The next leading platform is Windows Mobile. It can be seen that there are several smaller MDM that exclusively integrate the Windows Mobile platform into their product line. On average, MNO support nearly 2.5 platforms.

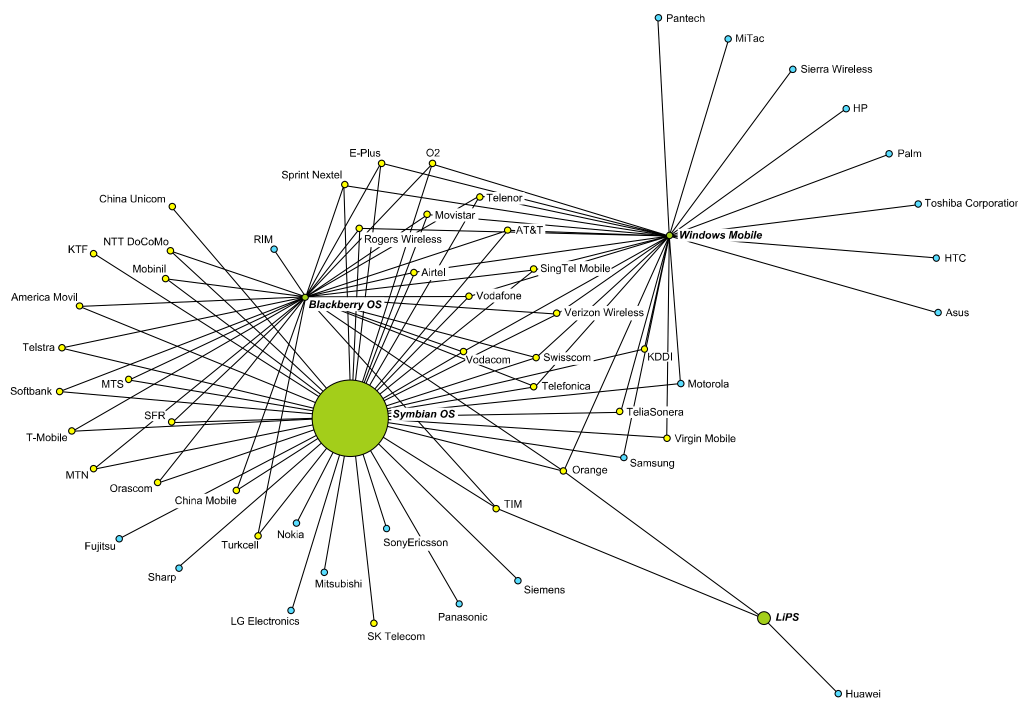

Figure 2. Mobile Device Platform Ecosystem - 2006

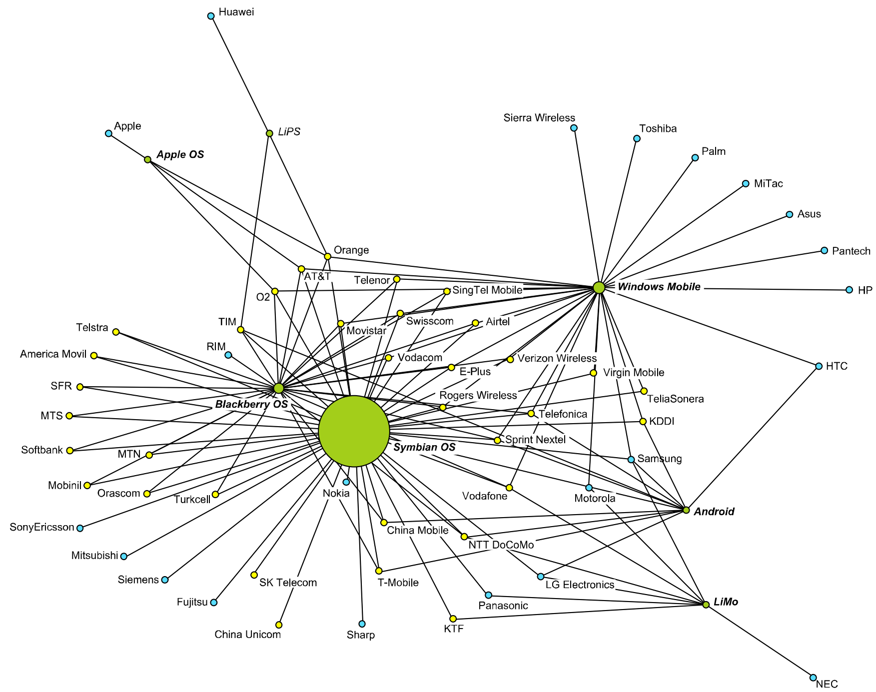

Figure 3. Mobile Device Platform Ecosystem - 2007

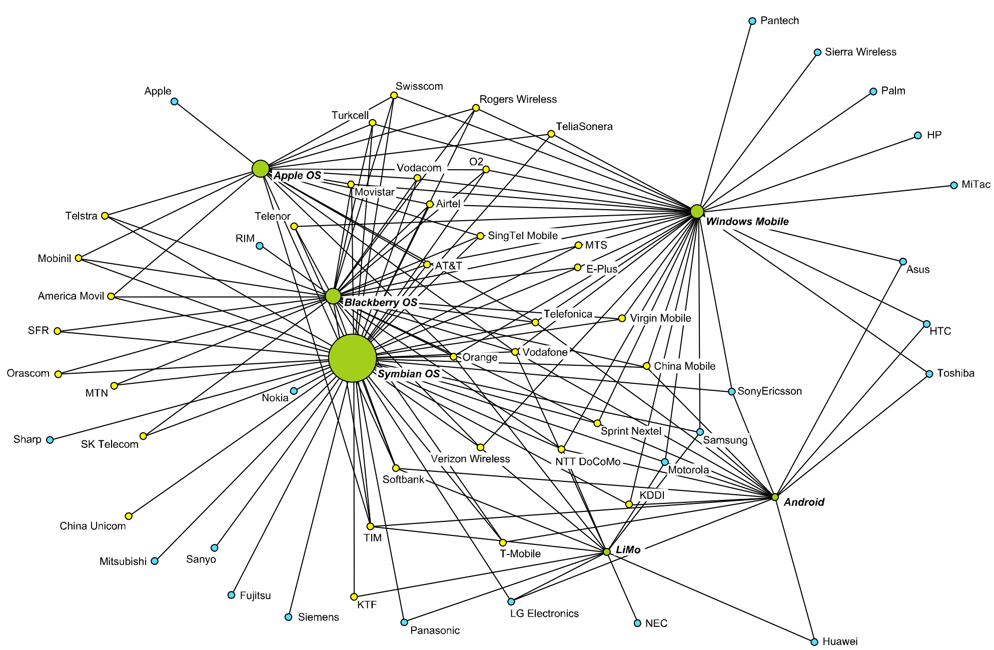

Figure 4. Mobile Device Platform Ecosystem - 2008

Figure 3 shows the mobile device platform ecosystem in 2007. This is the year when Apple released the first-generation iPhone along with its Apple OS. The Apple OS is based on a closed platform model and is only available on the iPhone. As a result, there are no linkages between the Apple OS platform and other MDM. Given the tremendous hype of the radical technological innovations and design of the iPhone, the Apple OS had an immediate impact on the mobile device platform ecosystem. Symbian experienced a significant decline in market share; both Blackberry and Windows Mobile experienced a flattening out or modest increase of market share from the previous year. In 2007, two other platforms made their debut. One was Android, a platform supported by Google and endorsed by the Open Handset Alliance, a group of leading technology and mobile companies. The other platform was LiMo, a Linux-based platform supported primarily by technology and mobile companies from Europe and Asia, and some members of the Android platform.

Figure 4 shows the mobile device platform ecosystem in 2008. The visualization shows that Apple OS, Blackberry, Windows Mobile, and Android have gained further prominence, while Symbian's platform leadership has decreased even further. MNO support on average over 3.5 platforms, indicating the growing platform diversity. Likewise, nearly 1.5 platforms are used by MDM. Table 2 summarizes the evolution of key network characteristics associated with the mobile platform ecosystem. A detailed explanation of network metrics used in this study is found in Basole (2009).

	2006	**2007**	**2008**
No. of Platforms	4	7	6
No. of Complementary Firms	43	56	60
No. of Ties	91	127	158
No. of Ties per Platform	26.000	18.143	22.571
No. of Platforms per Mobile Network Operator (P^{MNO})	2.412	2.794	3.529
No. of Platforms per Mobile Device Manufacturer (P^{DM})	0.846	1.231	1.462
Density (*D*)	0.047	0.057	0.071
Degree Centralization (*DC*)	0.639	0.628	0.629
Betweeness Centralization (*BC*)	0.431	0.469	0.398

Table 2. Evolution of Network Characteristics

CONCLUSIONS

Platforms have become a core feature of many emerging business models and are particularly important in the mobile industry. The success of a mobile device platform is inextricably linked to its ecosystem. This study used a structural analysis and visualization lens to explore the interfirm relations in the mobile device platform. In doing so, this study provides an important first step to understand the structure and dynamics of interfirm relationships in an emerging and rapidly changing domain and makes several important contributions. First, the visual approach presented in this study provides insights to the structural evolution of interfirm relations. Second, it provides a comparison of incumbent and emerging platform's competitive position. Lastly, it identifies structural configurations that explain business strategies. This study adds to the theoretical stream-of-thought that markets can be viewed as complex systems, consisting of various actors that co-exist and co-evolve to ultimately deliver a product or service to the end-customer (Basole and Rouse, 2008).

Visualization of ecosystem is an area with tremendous research potential for the information systems, technology management and innovation research community. Future studies could include the comparison of different configuration of technology alliances and their impact on firm performance and innovation. Similarly, visualization may help discover what structures and behaviors facilitate or inhibit growth of the platform ecosystems. The results in this study provide merely an initial step towards this vision.

The results and conclusions drawn in this study should not be overstated. Like any other exploratory research, this study has a number of limitations. The accuracy of the visualization depends largely on the quality of the underlying data. While every precaution was taken to validate the completeness and accuracy of the data, it is possible that some firms and relations were not captured. Likewise, the study did not capture all relevant segments that influence mobile device platforms. This simplification may have biased our results. Each of these limitations, however, represents an exciting area for future research.

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