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ABSTRACT

With fast development and application, the Internet of Things (IoT) brings more opportunities to business. This research aims to investigate how IoT could lead to a co-evolving business ecosystem rather than a supply chain. It develops the 6C framework to analyze the data collected from case companies, and identifies three patterns of IoT-based business ecosystem. It also provides a summary of practical implications to guide practitioners building an IoT-based business ecosystem.

Keywords: Internet of Things (IoT), business ecosystem, supply chain, 6C, construct, capability.

1. Introduction

In the last decade, the Internet of Things (IoT) has attracted attention from both academia and practitioners. The phrase "Internet of Things" first emerged at the MIT Auto-ID Center in 1999 (Ashton, 2009). There is still no standard definition for IoT, but according to the IoT European Research Cluster (IERC), IoT is regarded as "an integrated part of Future Internet including existing and evolving Internet and network developments and could be conceptually defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities, use intelligent interfaces, and are seamlessly integrated into the information network" (IERC, 2011).

IoT has spearheaded the fourth phase of the evolution of Internet (McKinsey, 2013). Considering the growth potential of IoT, National Intelligence Council has included it among the list of six disruptive civil technologies having the potential to impact US national power(National Intelligence Council, 2008). The adoption of IoT has many potential benefits, including improvement in operational processes, value creation, and cost reduction and risk minimization thanks to transparency, traceability, adaptability, scalability, and flexibility (Chui et al., 2010). For example, the mobile Taxi app is becoming increasingly popular. It provides information about the nearest available taxi service and helps taxi drivers respond to passenger requests in real-time and manage e-payments (CRIEnglish, 2014). Businesses in the future will be influenced by emerging IoT technologies and its applications can be summarized in four main areas: (1) Personal and Home; (2) Enterprise; (3) Utilities; and (4) Mobile (Gubbi et al., 2013). Cisco predicts there will be 25 billion devices connected to the Internet by 2015 and 50 billion by 2020 and the Value of the IoT business will be $14.4 trillion for companies and industries worldwide in the next decade (Cisco, 2011). McKinsey also estimates the potential economic impact of the Internet of Things to be between $2.7 trillion and $6.2 trillion per year by 2025 (McKinsey, 2013). Following this global trend, there is a need for present day companies to think about how they can adopt IoT to facilitate their current businesses, develop new business and market opportunities (Miorandi et al., 2012) for sustainable development.

Through unique addressing schemes and standard communication protocols (Atzori et al., 2010, 2012), IoT connects a variety of things or objects around us that can interact with each other. This also means that IoT technologies not only connect a specific industrial system or supply chain, but also stakeholders who connect with that IoT. However, this could lead to more complex supply chains with many players and complicated interactions. Therefore, this research looks at the IoT technology through the lens of "business ecosystem" rather than through that of supply chain. Moore (1993) proposed the business ecosystem as a loosely connected business community made up of different levels of organizations that share a common goal and co-evolve with each other. This concept could provide businesses with a broader view of cross-industry collaboration, rather than only collaboration with directly linked partners in the supply chain (Rong et al., 2013).Henceforth there is a business ecosystem around IoT based industries with cross-industry stakeholders, in which different stakeholders can add value to the IoT based business ecosystem. Meanwhile, in order to tackle the challenges like privacy and security issues, stakeholders such as government and IP industrial organizations also need to be involved in the business ecosystem. The IoT based business ecosystem should comprise an interdependent community including industrial players, government, industrial associations and other customers, beyond the boundaries of traditional industry relations. Within such a complex system, how it works and how all those stakeholders can co-evolve with each other has arisen as key concerns by both academia and practitioners.

However, there is very limited research on IoT ecosystem in current literature. Privous studies on IoT focus on technological aspect (Miorandi et al., 2012; Gubbi et al., 2013), business applications such as health care (Paschou et al., 2013; Turcu and Turcu, 2013), surveillance (Miorandi et al., 2012), social networking (Atzori et al., 2012) and logistic service (Karakostas, 2013). Others discussed the social aspect of IoT technology, such as privacy (Roman et al., 2013) and security (Alcaraz et al., 2013; Kothmayr et al., 2013). Therefore, this research aims to investigate how IoT can lead to a co-evolving business ecosystem rather than a supply chain. The technology cross-fertilization(Calia et al., 2007; Björkdahl, 2009; Johnson and Suskewicz, 2009) aruges that the integration of new technologies (herein IoT) into the technology base of a product or service can open up the interaction of cross-discipline knowledge, which would enable companies develop new subspaces in the existing technical performance and functionality space, trigger changes in the company's operational and commercial activities, and then shift the focus from developing individual technologies to nurturing whole new ecosystems. Our study advances the literature of business ecosystem, suggesting that new technological innovation per se has no inherent value(Chesbrough, 2007; Chesbrough and Appleyard, 2007) so that a healthy ecosystem needs to be developed in order to fully realize commercial potential of the new technology (Rong et al., 2013c).

This paper is organize as follow: in the literature review section, a 6C framework is developed based on the original 3C framework to analys network system in general; in addition to this 6C framework, case study methods are adopted for this research and is explained in the methodology section; with the findings presented in the case studies section, patterns of an IoT-based business ecosystem are summarized in the data analysis section; theoretical contributions and practical implications are discussed in the discussion section; in the conclusion section, some future research directions are discussed.

2. Literature Review

The literature review includes two interrelated sections: the first section introduces the concept of business ecosystem, considering IoT as a Business Ecosystem rather than simply a supply chain (Moore, 1993). This section systematically reviews the literature on the business ecosystem to ascertain how it is currently perceived. This is necessary for the conceptual study of the IoT-based Business ecosystem. The second section, grounded in business ecosystem and traditional networked system studies (Hayes and Wheelwright, 1984; Shi and Gregory, 1998; Zhang et al., 2007; Srai and Gregory, 2008), proposes a 6C framework for future research into the IoT based business ecosystem as a whole. And this 6C framework is adopted as a research framework for the case studied of this research.

2.1 From supply chain to business ecosystem

Different industry structures have emerged to meet customer requirements and the potential of technologies (Wirtz et al., 2007). As an industrial system theory, supply-chain management claims to offer solutions to help industrial practitioners better manage the whole supply chain from suppliers to end customers(Lambert and Cooper, 2000). Supply chain management theories mainly focus on production efficiency, information flow and financial flow, but do not consider the uncertainties in information, cash or logistics(Rong et al., 2013c). Thus, previous supply chain theories seem to have failed to explain the emerging process of a supply chain. IoT technology could help the industrial system to manage these uncertainties very well and improve the productivity of the supply chain.

The challenges of uncertainty were also witnessed in emerging industries (Br\öring et al., 2006; Kenney and Pon, 2011) with technology, application and organization uncertainties, and the lack of a supply chain. Hence there is a need for a new business model or novel technology to connect ecosystem stakeholders and initiate a new supply chain to commercialize the business model and technology. This second challenges requires stakeholders to achieve interoperability between different levels of organizations to cope with that uncertainty (Gassmann et al., 2010; Lin et al., 2010; Rong et al., 2013c). These two issues are very challenging to the existing industrial system and supply chain theories.

The concept of business ecosystem was firstly proposed by Moore in 1993, expanding previous supply chain network theories to include other organizations such as universities, industry associations and other stakeholders, as well as their interactions (Moore, 1993; Perkmann and Walsh, 2007). Since then several industrial practitioners have adopted the business-ecosystem concept to explain the challenges of uncertainty and the requirements concerning partners' interoperability (Kenney and Pon, 2011; Rong et al., 2013b). This concept aims to highlight the process of co-evolution of industrial systems and their dynamic environment full of business opportunity (Breslin, 2011; Moore, 1993) Business ecosystems can be divided into two sections, the first being the lifecycle and second the stakeholders. The business ecosystem lifecycle includes birth, expansion, authorities and renewal (Moore, 1993); The business ecosystem stakeholders portray specific cooperative behavior during the business ecosystem lifecycle (Shang and Shi, 2013). For instance, in the early stages of a business ecosystem, there are fragmented industrial systems with separate roles.

As the ecosystem evolves, the ecosystem develops several dominant supply chains and then successfully formulates the well-established industrial system so as to create value for all stakeholders in the mature stages (Rong et al., 2013b).

Business ecosystem theories have developed from supply chain theories by embracing the idea of uncertainties and co-evolution. However, it is still an emerging area, and the studies are fragmented. By reviewing previous studies on business ecosystems, as well as the process view discussed above, this paper argues that these studies have addressed only a section of the ecosystem domain and its strategies (Adner and Kapoor, 2010a; Marco Iansiti and Levien, 2004; Kapoor and Lee, 2013; Moore, 1993; Peltoniemi, 2006; Rong et al., 2013a, 2013b, 2013c). We divide the studies into three broad categories.

The first research stream deals with the **constructive** elements of a business ecosystem, for instance the role of a business ecosystem and their strategies. The keystone or focal firms provide the platform while the niche players add value to the platform (Iansiti and Levien, 2004). The platform strategy also helps the business ecosystem to co-evolve. The openness of such a platform as a way to manage innovation is discussed in detail (Cusumano, 2011; Leten et al., 2013; Rong et al., 2013b). Other scholars have addressed the other constructive elements of a business ecosystem. Some key elements can be identified: the area of opportunity/business environment (Moore, 1996, 1993); community of interdependent organizations (M. Iansiti and Levien, 2004; Adner and Kapoor, 2010a; Battistella et al., 2013); and co-evolution with visions (Leten et al., 2013; Li, 2009; Rong et al., 2013b). With the growth in the information and communication technology sector, including the IoT, technology factors have more impact on business-ecosystem operations (Power and Jerjian, 2001; Rong et al., 2013c). However, research mostly focuses on technological tools rather on the nature of a business ecosystem. This research aims to explore the extent to which IoT will impact business ecosystem operations.

In the second stream, the Adner and his colleagues have proposed the basic **configuration** of a business ecosystem, which is an integrated arrangement of those constructive elements (Adner and Kapoor, 2010b). For example, the Structure of Technology Independence configuration was proposed to demonstrate how the different roles are connected, where the focal firm succeeded in obtaining full support from complementors in order to commercialize their products. They addressed the structure of connections between focal firm, customers and complementors (Adner and Kapoor, 2010b; Kapoor and Lee, 2013).

The third stream addresses the overall operation of a business ecosystem (Peltoniemi, 2006; Rong et al., 2013b, 2013c). The studies in the first two streams highlight the co-evolution of ecosystem stakeholders and the relevant strategies they implement, but fail to cover the exact mechanisms by which the different roles interact or how those micro-role interactions impact on the business ecosystem as a whole during the business ecosystem lifecycle. Therefore, it is important to present the process (including **lifecycle and cooperation**) by which ecosystem stakeholders interact and see how they result in different ecosystem patterns.

To sum up, business ecosystem studies have developed from dynamic supply chain theories. In order to fully understand the IoT-based business ecosystem, it is necessary to develop a systematic framework to explain how an IoT based business ecosystem operates; to emphasize the link between competition and cooperation; and to highlight the stakeholders shared-fate process (Peltoniemi, 2006). Some key elements discussed above need to be taken into consideration, such as the process (lifecycle and cooperation), the construct and the configuration of a business ecosystem. However, previous research has only addressed a part of the business ecosystem rather than presenting a comprehensive, systematic overview. The present authors believe there is a need to address the business ecosystem as a whole.

2.2 From 3C to 6C framework

It is necessary to understand the IoT based business ecosystem systematically in terms of lifecycle, cooperation, construct, and configuration. Besides this, 3C framework, which is used to analyze a network systems in general (Zhang et al., 2007; Lin et al., 2009), also provides useful information, as do other system studies like manufacturing networks and global supply chains (Hayes and Wheelwright, 1984; Shi and Gregory, 1998; Srai and Gregory, 2008). This research combines all these system studies into a 6C framework in order to fully understand the complex network that makes up the IoT-based business ecosystem. The proposed 6C framework is summarized in Table 1.

Table. 1. 6C framework: An extension of the 3C framework

3C (Zhang et al., 2007; Lin et al., 2009)	**6C**
Context The environmental features of the supply network, such as the driving forces, main barriers and key missions from the perspectives of complexity and dynamism (missions, drivers, barriers)	**1. Context** From the view of the lifecycle, different stages of the business ecosystem have different missions, drivers and barriers. - lifecycle stages （Moore, 1993） - missions - drivers - barriers
Configuration The constructional elements and typical configuration patterns of the supply network, including role structure, process structure and information architecture (roles, relationships, information architecture)	**2. Cooperation** Reflects the mechanisms by which partners interact in order to reach common strategic objectives - coordination mechanism - governance system
	3. Construct (Hayes and Wheelwright, 1984; Shi and Gregory, 1998; Zhang et al., 2007) - structure - infrastructure
	4. Configuration (Bertalanffy, 1950, Lin et.al 2009) - pattern - external relationship

Capability The key success features of the supply network from the functional view of design, production, inbound logistics and information management (design, production, inbound logistics and information management)	**5. Capability** (Shi and Gregory, 1998; Zhang et al., 2007) The key success features of the IoT-based business ecosystem: - communication and accessibility - integration and synergy - learning ability - adaption and mobility
	6. Change Reflects the pattern renewal and evolution of the business ecosystem (how it evolves in regard to its business environment from one pattern to another at the ending stage of lifecycle; pattern shift also reflects from the dimensions of configuration and cooperation of a business ecosystem respectively) -renewal -co-evolution

The ***context*** dimension aims to identify the environmental features of a supply network, such as the driving forces, main barriers and key missions from the perspectives of complexity and dynamism (Zhang et al., 2007; Lin et al., 2009). It mainly answers questions such as why a certain type of supply network emerges. Meanwhile, co-evolution in different stages of a lifecycle is an essential feature of the business ecosystem (Moore, 1993); hence it is important to include lifecycle stages in the context dimension in order to demonstrate firms' statuses at different stages. Moreover, this dimension means that organizations in a business ecosystem should expand their perspective beyond their core business supply-chain partners. The context includes other non-direct business partners, such as government agencies, industry associations, stakeholders, and also competitors who shape the industry greatly (Rong et al., 2013c). The business environment can also be regarded as an opportunity space in which the interdependent organizations share their ideas and visions for future development (Moore, 1996).

In the original 3C framework, the configuration dimension is used to define the constructional elements and typical patterns of the supply network, including role structure, process structure and information architecture, which help to answer questions about how to establish a supply network to achieve certain capabilities in a certain context (Zhang et al., 2007; Lin et al., 2009). Due to the significantly complex nature of a business ecosystem, the present research broadens this dimension into three dimensions: construct, configuration pattern, and cooperation.

The ***construct*** dimension defines the fundamental structure and supportive infrastructure of a business ecosystem. Exploring the constructs of a business ecosystem give us an understanding of what could be gained from further exploration of its constructive elements as a system (Pittaway et al., 2004; Von Bertalanffy, 1969). In 1984, Hayes & Wheelwright (1984) highlighted a constructs study with the framework of "structure-infrastructure" model, since constructive elements had a significant impact on system-manufacturing strategy. This model became popular and was frequently adopted by scholars in other manufacturing-system levels, such as the intra-firm level (Shi and Gregory, 1998), inter-firm supply-chain level (Harland, 1996), global-engineering network level, and global-supply network level (Webster, 2002; Zhang et al., 2008; Srai & Gregory, 2008). As a result, in order to remain in line with traditional theories such as manufacturing system and supply-chain management theory, the framework of "structure-infrastructure" is adopted here to deconstruct a business ecosystem.

Configuration mainly seeks to identify the external relationships among partners in the business ecosystem and its configuration patterns. According to general system theory, the individual constructive elements and nurturing process cannot provide a complete picture of a system because there are further system activities to coordinate constructive elements and processes(Bertalanffy, 1950). The way the constructive elements and processes of each system are integrated delivers various configuration patterns, which demonstrate the typical manufacturing strategy. Hayes and Wheelwright used two elements, process and product, to categorize different patterns of manufacturing system, such as project-based, job-flow, batch, line-flow and machine-paced flow (Hayes and Wheelwright, 1984, 1979). Shi & Gregory (1998) extended the configuration-pattern concept to network level with geographic dispersion and manufacturing coordination, which assumed that an international manufacturing network demonstrated the typical way of organizing a manufacturing network. Subsequently, configuration is now adopted as an essential dimension in the study of global engineering networks (Zhang et al., 2007), supply networks (Srai & Gregory, 2008), and modular supply networks (Lin et al., 2009). All of the above-mentioned studies, to some extent, followed a structure-infrastructure perspective by proposing the configuration pattern.

Cooperation reflects the mechanisms by which partners interact (collaboration mechanism and governance system) in order to achieve the common strategic objectives. The relationship among partners in the business ecosystem is no longer that of supplier-customer; such organizations are now dependent on each other and share in a common fate (Iansiti and Levien, 2002; M. Iansiti and Levien, 2004; Iyer et al., 2006; Moore, 2006, 1996; Power and Jerjian, 2001). Cooperation demonstrates the linkage between the constructive elements and the ecosystem configuration. The cooperation process will vary along the lifecycle (context) of a business ecosystem.

The ***capability*** dimension investigates the key success features of a supply network from the functional view of design, production, inbound logistics and information management, which helps to answer questions such as why one type of modular supply network operates better than another (Zhang et al., 2007; Lin et al., 2009). Instead of a responding reactively to the new industrial environment, it is more important for firms to organize their system construct and achieve capability establishment (Hayes et al., 1988), and they need to focus on their firm's capabilities (Wang and Ahmed, 2007). Since a configuration has a particular structure and operational mechanisms, it also has its own unique capabilities to achieve strategic requirements (Shi and Gregory, 1998). Shi and Gregory further extended intra-firm network capabilities from previous literature (Ferdows, 1989) into four aspects, including strategic targets accessibility, thriftiness ability, manufacturing mobility, and learning ability. Later, the capability dimension was also categorized in global supply-network levels which included the capabilities of communication and sharing, integration and synergizing, innovation and learning, and adaptation and restructuring

(Zhang et al., 2008; Srai & Gregory, 2008); these will be the focus in this research at business-ecosystem level in terms of different ecosystem configurations.

Furthermore, ***change*** in the business ecosystem is also investigated by many academics to demonstrate how a system configuration pattern shift dramatically from one type to another. For example, the Global Manufacturing Virtual Network (GMVN), derived from the global manufacturing network, international strategic alliance as well as virtual organizations, are examples of the pattern shifting of manufacturing systems (Shi and Gregory, 2001). The open innovation paradigm also allows exchanges of internal and external ideas (Chesbrough, 2005) in order to leverage resources to improve both central firm performance and partners' innovation performance, which evolved from a less or close innovation. The change takes place at the end of the lifecycle, which means the pattern shift into a brand new one by comparing with original. Thus, the system starts a new lifecycle with the new pattern. The system pattern shifting indicates specifically systems' configuration and cooperation evolution which indicates the renewal of the general way that key firms interacted with their business environment as well as with core business partners. This would result in the renewal of the connection among partners. Thus, change is the dynamic aspect of systems' dramatic growth instead of incremental development, which generates a new lifecycle of the system evolution. Hence change would demonstrate how the configuration pattern of a business ecosystem is renewed.

To sum up, this 6C framework is adopted as an integrated way to systematically study the networked system based on IoT to gain a comprehensive understanding of the IoT-based business ecosystem. The Context is the setting for network development, while co-operation reflects the mechanisms that partners use to interact so as to attain their strategic objectives. The construct is the fundamental skeleton of the network, which can also determine the integrated configuration of a network with specific objectives. Configuration represents the way elements in the construct are combined together. The different capabilities are a reflection of the specific configuration. Finally, each networked system will undergo change to evolve with regard to its business environment. These 6Cs are interrelated in the system's architecture and provide the theoretical framework for both academic researchers and practitioners to study networked systems from a comprehensive perspective. Thus, it is necessary to further understand each Component of the 6C framework in the context of business ecosystems.

3. Methodology

This research aims to obtain a broader perspective on the IoT-based business ecosystem within the 6C framework, by defining the following research question:

How can the IoT-based business ecosystem be comprehensively understood through application of the 6C framework (Context, Cooperation, Construct, Configuration, Capability, and Change)?

3.1 Case study

To investigate this contemporary issue this research uses case study methodology, together with the 6C framework to analyse the data collected (Yin, 2008). In order to enhance the results, this research uses multiple case studies, which provide more compelling evidence and produce more robust conclusions (Herriott and Firestone, 1983) than a single case study. In this research, theory and practice are linked together by case studies.

In order to improve the quality of our theory building(Weick, 1995, 1989), we have the included following clear steps: firstly, identification of case selection criteria; secondly, identification of interviewee and interview questions; thirdly, detailed presentation of data analysis using the research framework. These three steps ensure that the theory development process includes an explicit framework and accurate and detailed representation (Gibbert et al., 2008; Weick, 1989). The interview questions and interviewee list are included in order to present the case data and data sources. The data coding and analysis with 6C framework is proposed to link the raw data, research framework and research findings. Thus we ensure the internal validity and construct validity of the research (Gibbert et al., 2008).

For the first step, suitable firms were chosen using the following six criteria as shown in Table 2.

1) The companies should be involved in the IoT based business ecosystem.
2) The chosen companies represent a wide variety of sectors. The aim is to cover as many industries/ecosystems as possible to obtain a comprehensive view. Hence Case A is from the car hire sector; Case B from the mobile internet (Instant messenger) sector; Case C is in the automotive industry; Case D represents television, Case E is in the cartography sector; and finally Case F is from the Security industry.
3) The case companies, as the focal firms, are at the centre of a business ecosystem since they own the product platforms which other stakeholders could add value to. This was also verified by the interviewee.
4) The chosen business ecosystem should be at different stages of development in regard to their product maturity. Among the chosen cases, C and E are at an early stage of development, cases A and D are in the growth stage and cases B and F are at a mature stage of development.
5) The companies should have product platforms for their partners' participation and contributions.
6) For the chosen cases, we should be able to obtain relevant data concerning the 6C of a business ecosystem.

Table 2 shows the differences between these cases in terms of the six criteria which aim to cover a wide range of different sectors and stages of development. The first four criteria are used to select specific companies for the main case studies while the last two criteria are to help identify the relevant interviewee within the selected main cases.

Table 2 Criteria for main cases studies

Cases Criteria	Case A	Case B	Case C	Case D	Case E	Case F
1)In IoT based ecosystem	Yes	Yes	Yes	Yes	Yes	Yes
2) Firm background	Car rental	Mobile internet	Automotive industry	Internet TV	Maps	Security (CCTV)
3) Central firm	Yes	Yes	Yes	Yes	Yes	Yes
4) Stage	Growth	Mature	Early	Growth	Early	Mature
5) Product platform	Less open	Highly integrated	Highly open	Less open	Highly open	Highly integrated
6) Data available	Yes	Yes	Yes	Yes	Yes	Yes

Using the six criteria as applied to each case, the key interviewees were identified as in Table 3.

Table 3. Interview list

	Company	Country	Role of interviewee	Number of interviewees	Average time (hrs/person)	Total (hrs)
Case A	Car2go	Germany	EV project manager	3	4	12
Case B	Tencent (Weixin/WeChat)	China	Department director; Project manager	2	4	8
Case C	Continental	France	Business Development Manager and two assistants	3	4	12
Case D	BesTV	China	COO; department director	2	5	10
Case E	MapBar	China	Vice-president; product manager	2	4	8
Case F	Hikvision	China/ UK	CEO; vice-chairman; international division director	4	3	12
				16 interviewee		62hours

3.2 Data collection

Data was collected mainly through semi-structured, in-depth interviews with managers between June and August, 2013, aiming to obtain personal insights from managers. The interviews were conducted using pre-designed guidelines (see Appendix), which focused on the 6C dimensions in the proposed conceptual framework, to ensure data reliability and construct validity (Yin, 2008). The interview details are listed in Table 3.

The reliability and validity are two factors which any qualitative researcher should be concerned about while designing a study, analysing data and maintaining the high quality of the study(Gibbert et al., 2008; Golafshani, 2003; Patton, 1990).

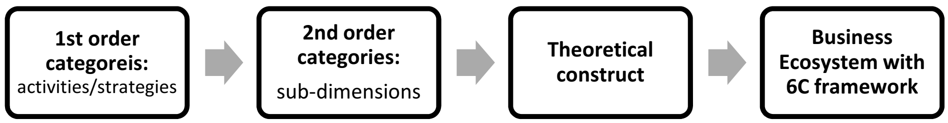
Reliability of the collected data is mainly achieved and enhanced through using the structured research design and the interview question guideline. It is consistently used by all researchers in the research team, even for different researcher conducting interviews with different cases companies, which substantially increase the reliability of the case study(Golafshani, 2003). This interview question guideline is developed earlier in the research process, which also help to avoid mismatches and conflicts in the long run of the research project. Our research team members are experienced and have tightly followed our conceptual framework and coding guidelines derived from comprehensive literature review. We also presented the coding results to other academic colleagues so that they can scrutinize the quality of our research. Questions and comments from peer well enabled us to develop a greater explanation of research design, refine our findings and strengthen our arguments in the light of the comments.

The validity is ensured by adopting the multiple cases, data triangulation and multiple investigators method allowing for replication, which has been successfully utilized in previous comparable projects (Amit and Zott, 2001; Yin, 2008). Each case in this research was coded by multiple researchers and served to test and re-test the theoretical insights gained from the examination of other cases. This replication logic enhances the validity of our research that is free of researcher bias (Eisenhardt, 1989), and allows for a close correspondence between theory and data(Glaser and Strauss, 2009; Amit and Zott, 2001). Our case study method is especially useful in the early stages of research on an emerging research topic, when the literature is lack of prior theorizing (Eisenhardt, 1989) and when 'the boundaries between phenomenon and context are not clearly evident'(Yin, 1981). Finally, data triangulation is another way in which we enhanced the validity of our research (Gibbert et al., 2008; Yin, 2008, 2010). Whilst our interview data may suffer from some common methodological shortcomings, we collected secondary data from both internal and external sources to provide a background to help interpret the first hand data under scrutiny, as well as to verify particular details that informants have supplied. We also used a wide range of informants from each company so that individual viewpoints and experiences can be double verified again each other(Maanen, 1983).

3.3 Data analysis

After data collection, the data was coded for further data analysis to discover patterns (Auerbach and Silverstein, 2003) as shown in Figure 1.

For data analysis, several steps were followed: firstly, the collected data (interview transcripts, direct notes, field observation, news, annual reports and firm internal documents) was systematically reviewed and cross-compared; secondly, we followed the guidelines of Gibbs (2007) and of Creswell (2013) to adopt a hybrid coding approach. Our pre-set codes (for example, lifecycle, governance, platform) derive from our 6C framework and relevant literature. A small amount of pre-set codes in each category were used in order to avoid overloading the coding process as Table 1. The codes were then aggregated into the first order categories as key activities, strategies, states, meanings, participations, relationships, conditions, consequences, and settings. Some new codes emerged from reading and analysing the data and first-order code to capture the key insights. For example, in terms of 'capability', the new code 'complementor creation ability' in Figure 1 emerged from the raw data. The complementor creation capability demonstrates how the business ecosystem would creation more space so as to encourage more specialist contribute to the ecosystem. In terms of 'change', two new codes shown in Figure 1 are product platform pattern and stakeholder's interaction pattern shift. The raw data helps clarify the two different patterns' shift. The first-order and second-order categories were further clustered into the theoretical construct of six categories (context, cooperation, construct, configuration, capability, change) pre-defined in the conceptual framework. Finally, the coded data was analysed through pattern matching (Yin, 2008), a strategy that compares the empirical results with the proposed research framework; the resulting correlation enhances the internal validity of the case study. Pattern-matching is applied as major technique of data analysis in this research. Following the pattern-matching logic (Yin, 2008), this study compares the empirical patterns derived from the case evidence with a predicted pattern concluded from the conceptual framework. The pattern coincide will enhance the internal validity (Yin, 2008) of this case study. The other analytical technique used in this research to analyse the collected data is case explanation building, which is a complex and iterative process (Yin, 2009) that helps to refine the research results of case analysis.



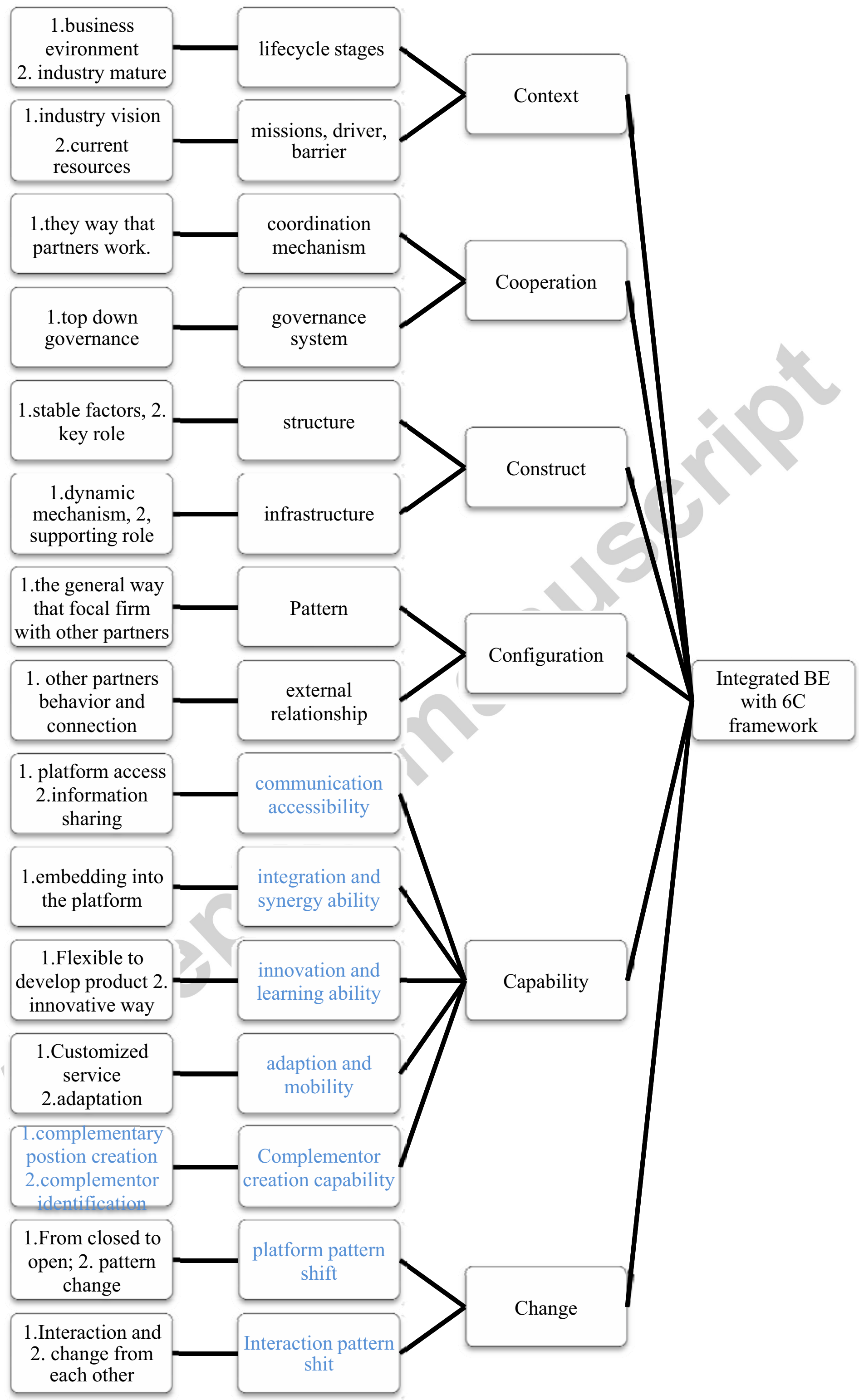


Figure 1 Data Analysis Process

4. Case studies

4.1 Case A – Car rental

The IoT concept has found prominence in the car-rental industry. Previously, one could rent a car from a physical Hertz store, which of course had the drawback of a lack of geographical proximity. Consumers had to check the car's availability and then go to the store to collect it. In order to improve the customers' user experience, new car rental companies have emerged, such as Zipcar and Car2go. They have made good use of the IoT-based technology to make it easier for customers to collect and return cars. Customers are easily able to ascertain car availability and location.

Zipcar began to change the conventional rental model by embedding RFID technology in their cars, whereby mobile apps could be used to identify the location of available cars and could even unlock the car upon the customer's arrival. As a result, the customer could discover the location of the nearest available car and pick it up from that point. This kind of IoT technology makes it very easy for customers to collect and return cars. It has redefined the way people think about transport by developing the idea of sharing cars everywhere. Zipcar has improved the traditional car rental business model by making it a self-organized car network rather than necessitating collection of the car from the store. But as most Zipcar pickup and drop off points are located on the outskirts of cities, it still is not very convenient for a number of customers.

To make the system even more convenient, another car rental company – Car2go – allows the car to be parked at any public parking points. For example, the cars could be parked at any City of Austin or State of Texas controlled meters[1] in identified street locations. This kind of service expands the flexibility of parking and reduces parking problems hugely. Car2go has also introduced electric vehicles into its fleet to suit the low-speed driving patterns of drivers within city limits (Rong et al., 2013) and hence matches the needs of daily transportation in the city. In order to sustain its electric vehicles business, Car2go has provided an adequate number of location-based charging services. Car2go has not only followed Zipcar's car-sharing business model but has also expanded it by introducing electric vehicles.

The reason for the rapid growth of this new car rental business model is the high level of customer involvement and the implementation of IoT technologies. This has created a business ecosystem around the car-rental platform. Ecosystem partners include but are not limited to: the government, which provides the parking spaces and develops the charging services; customers, who self-organize the car network and maintain the car-rental business; and software developers, who develop many mobile apps to locate the cars and provide relevant services.

4.2 Case B – Instant messaging: QQ and Weixin (WeChat)

Instant messaging was originally introduced to connect people online. However, due to the convergence between real life and virtual life, more functions were embedded in the instant messenger. For example, Weixin in China, which was the most popular instant messenger with 300 million registered users, began to embed location based and payment functions. Thus, it is now possible to search for points of interest nearby, such as restaurants and hotels.

[1] https://www.car2go.com/common/data/locations/usa/austin/Austin_Parking_FAQ.pdf

The company Tencent was founded in 1998, and it has become the largest Internet service portal in China. Recently, Tencent has started to embed more IoT technologies into their product line.

QQ, an instant messaging platform first introduced in 1999, is one of Tencent's most successful products, with 818.5 million monthly active users (MAU).[2] Originally, it supported only basic online-communication-function text messaging, but now it can provide comprehensive functions including video and voice chat, as well as online (and offline) file transmission. It also supports cross-platform communication between PCs and wireless terminals.

However, QQ has experienced a slowdown in the year-on-year user growth rate in the last few years, and it seems to be reaching the mature stage of its product lifecycle. To confront this challenge, the company has developed a new product that was released in January 2011.The Chinese version is named Weixin and the international version, supporting 13 languages, WeChat. At the end of August 2013, its combined user number had reached 235.8 million with a year-on-year increase of 176.8%.[3]

The rapid user growth of WeChat and Weixin can be attributed to its innovative features, including multimedia communication with text messaging, hold-to-talk voice messaging, broadcast (one-to-many) messaging, photo/video sharing, and contact information exchange extended from QQ. But it was the totally new user experience of location sharing that gave it an edge over its competitors. The *location-based social plug-in* combines the social networking experiences of chatting and connecting with both local and international users through their mobile devices. This actually extended Tencent's position as the leading smart-phone-only community in China. In August 2013, a new version of Weixin/WeChat was introduced that integrated services such as online games, stickers and payment, which allowed Tencent to broaden its service offerings to users and explore new business opportunities. In Tencent's strategic plan, more functions are being planned, involving several external business partners in its business ecosystem for sustainable development in the era of IoT.

Another reason for the success of Weixin/WeChat is that Tencent is strongly committed to enhancing its development and innovation capabilities while strengthening its nationwide branding for long-term development. In fact, more than 50% of Tencent employees are R&D staff. In 2007, Tencent invested more than RMB100 million in setting up the Tencent Research Institute, China's first Internet research institute, in order to focus on developing core Internet technologies, pursuing development and innovation for the industry.

4.3 Case C – Car-operating platform: Continental Automotive Group

Now more than ever, consumers depend on their smart phones to stay connected to the world. However, distracted driving caused by texting or calling is one of the major causes of road traffic accidents. Many drivers are aware of the

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[2] Tencent, 2013. Second quarter and interim results, available at http://www.tencent.com/en-us/content/at/2013/attachments/20130814.pdf

[3] Tencent, 2013. Second quarter and interim results, available at http://www.tencent.com/en-us/content/at/2013/attachments/20130814.pdf

potential dangers but they do not want to cut themselves off from communication whilst driving for as long as 15 hours per week.

PSA and Continental, like many other car makers, understand people's desire to be connected and have decided to embrace drivers' digital lives. They recently launched a project to organize separate cars into the Internet of things. The project intends to develop a smart dashboard operating system that is capable of collecting sensor data from cars' embedded systems and providing drivers with immediate feedback regarding critical information, such as road hazards and engine performance. The system uses open SDK (software development kit) solutions and enables OEM and third-party applications to provide connectivity, safety and convenience telematics services to drivers. Their ambitions are to establish a new connected-car ecosystem around focal firms such as PSA and Continental. The technological outputs of upstream suppliers such as Nexyad (image processing) and university laboratories (wireless communication) are bundled by the focal firm into the system as components, while the unique applications created for the car are seamlessly integrated into the system as add-ons.

This innovative ecosystem will significantly enhance the overall in-vehicle and ownership experience. After the initial vehicle purchase, customers will be able to download approved apps and services from an online apps store. This means the in-car infotainment is no longer fixed but becomes upgradable, and gets ever better with new features over time. On-board apps will also enhance traffic safety in new ways. Auto-diagnostic apps can provide detailed fuel consumption information to make driving more energy efficient. Mechanics can be informed about car maintenance issues before the driver even reaches the garage. What is more, connected cars will communicate not only with each other, but also with the road infrastructure, which will enable safety apps to generate warning signs for dangerous driving behaviors, such as wrong-way driving, failure to stop at signs or lights, red-light trespassing and speeding. Sharing real-time road information among drivers can also help reduce traffic jams thus improving fuel efficiency. When the built-in accelerometer detects a driving scenario, apps will actively warn drivers to refrain from texting or browsing on the handset or the car's dashboard system. Instead, apps will read a text out loud, allowing users to dictate a response, or direct all incoming calls and texts to voicemail.

PSA and Continental have started active engagement with third-party developers by releasing a software-developer kit that allows registered users access to SDK solutions to create their own applications. Hundreds of developers are now participating in this connected-car project. There is no doubt that when a car changes from an information-isolated island to a new Internet-of-things platform there is huge scope for apps developed for a connected embedded system. By carefully configuring specific value-chain positions through an innovation ecosystem, focal firms, component suppliers and complementors will be able to take advantage of the value created by IoT technology.

4.4 Case D – Internet TV: BesTV

Internet TV has changed the way that customers watch TV, offering a customized service to match user preferences. Initially TV was a single-directional device meant only to broadcast TV programs. Later on, with technological developments, it became possible to broadcast on-demand TV programs. However, this still did not involve interaction between TV providers and customers. The companies failed to create more value out of TV broadcasting.

Currently, several companies are discovering the convergence of real and virtual life and are considering how to combine online and offline, or virtual life and real life, by launching location-based services. Customers may wish to engage with offline interests when they are watching TV. The company BesTV, for example, has started to open up the TV broadcasting platform interface. Thus, any third software vendor can develop apps based on their platform by introducing offline services from different points of interest like banks and hotels. In this way, all the services and points of interest are connected. As a result, customers are able to gain access to the apps via their TV interface and connect with offline services and products. They have achieved a high level of bidirectional communication.

The ecosystem around the Internet TV platform has been developed by adopting IoT technologies. Many ecosystem partners have engaged in this ecosystem. Government agencies are beginning to license the TV channel to third party companies, while many content providers are offering programs to the company. Third party software vendors are developing apps based on the company's platform hence allowing customers to use the location-based apps to reach their interests from their TV.

4.5 Case E – E-Map: Mapbar

Currently, many e-map-based companies are providing location-based services to customers and industrial customers. This kind of service is linked with the data generated from IoT that captures data and then networks it with a specific location. This helps in stakeholders to create extra value. The e-map business has changed people's daily lives; it is regarded as one of the most important access points in the information era besides web browsers and search engines like Google.

Previously, the e-map was used merely for searching for directions and routes. Now, the development of Web 2.0, has enabled more and more interactions between third party complementors and map providers. Map providers have started to open their API (application-programming interface) and thus encourage partners to make good use of their location services. For example, the company Mapbar provides their partners with an SDK (software development kit) and API. Now, many partners such as hotel chains embed the Mapbar map in their website to show the location of their hotel using Mapbar's open API services. Simultaneously, they provide open API services to Mapbar App that lets the user browse the same information on the App Many banks and restaurants also make similar connections to E-Map (Mapbar). All these services help customers to find guided routes to nearby points of interest, such as hotels, restaurants and cinemas.

Furthermore, Mapbar also provides a service for industrial customers, such as tobacco companies. They use a GIS (geographic information system) to create a tobacco delivery system for locating and tracking the tobacco delivery vehicles in real-time. This system also helps the vehicles to design effective delivery routes and monitor any issues during delivery. The vehicles can easily communicate with the central department and receive online orders as well.

As a result, through online maps different kinds of businesses are connected to Mapbar, and a business ecosystem has developed around the map platform. The ecosystem partners include end customers (either personal or industrial), basic data providers, software vendors, and many providers of points of interest. These stakeholders have made great value out of the business by capturing, networking and applying data, which finally generates a very connected IoT-driven business ecosystem with highly effective and efficient operation.

4.6 Case F – CCTV industry: From company use to family use

Previously many companies used CCTV for security and monitoring purposes, but it was considered as an isolated information pool not capable of creating any value for relevant stakeholders. However, with the rapid development of the 3G network, more and more products are being introduced to make good use of the camera network by responding appropriately. For example, the Apple product Smart baby monitor makes it possible to monitor a baby via the Internet.

The company Hikvision was established in 2001, and has now become the top business player in the CCTV industry. The company has adopted the key principal of learning from the demand side and custom-designing products for the market. They have designed a camera-monitoring network based on the 3G network. This IoT network is made up of three key elements: device management (all camera devices), data collection and storage (video storage), and implementation. Any user can use the end-user devices to send orders after learning from the camera videos. This 3G-based IoT network has already been used for many applications, such as baby-monitor systems, transportation systems, chain-store-security systems, insurance-claim systems and so on.

One of the best-known solutions for family use is the baby-monitor network. After setting up cameras to video the baby's location, family members can gain access to the cameras via different end-user devices, such as smartphones, computers or TV. Furthermore, the improved technology also embeds some novel functions into this monitoring system, such as music and air-temperature-testing functions. Meanwhile the transportation system allows drivers to share real-time information, thereby avoiding potential traffic jams. Chain stores also rely on the monitoring system to control logistics issues, and city councils can monitor construction projects by adopting this IoT technology. Thanks to IOT, the stakeholders can now take quick and real time response action in case of an unexpected event. By making good use of the 3G network everywhere, Hikvision has been able to build up a strong IoT-based business ecosystem by connecting many stakeholders across different industries. The ecosystem partners include the government, industry and personnel. From computer-based to smartphone-based monitoring systems, many stakeholders have been involved in this IoT-driven business ecosystem. All of them have been able to create new connections by adopting these IoT technologies.

4.7 Summary of the case studies

Table 4 summarizes the results of each case from the perspectives of context, cooperation, construct, configuration, capability and change.

Table 4. Summary of the case studies

	Context	**Cooperation**	**Construct**	**Configuration**	**Capability**	**Change**
Car rental	Zipcar: self-organized car network, but fixed car-parking location Car2Go: flexible car-parking location	Self-organized Encourages customer use	Car rental company, government, software developers for mobile apps Car rental platform RFID facility	Car-rental platform integrates the company and customers	Parking space RFID facility Charging facility (if using electric vehicles)	From pickup i-store to pick-up anywhere From fixed to flexible car parking to provide more convenience for customers
Instant messenger	QQ: mature stage, and seeking to maintain the registered user number Weixin/WeChat: growth stage; an extension of QQ with more innovative functions with IoT; aims to explore global market	More business partners are getting involved in using Weixin/WeChat as a platform to develop their own apps and businesses	Weixin/WeChat as a platform is the key construct element in the business ecosystem	Closed platform and close relationships with other business partners in the business ecosystem	Strong commitment to R&D and innovation 50% staff in R&D Tencent Research Institute	Renews the business ecosystem through introducing new products, but developed from current products
Car-operating platform	Collect sensor data to provide drivers with real-time information	Manufacturer launches new project to integrate more partners in	Focal firms, component suppliers, OEM, and third-party application	Smart-dashboard operating system as a platform to integrate	Openness of the platform to facilitate communication and innovation;	From simple-function dashboard to smart dashboard

		the ecosystem to achieve mutual benefits Actively engages with third-party developers	developers Dashboard system SDK	more business into it Release SDK to third party	the platform also integrates 3rd party software	system
Internet TV	Increases the interaction between the TV provider and customers Launches location-based services	Open its TV broadcasting platform to get partners to develop new functions and provide new businesses to customers	TV companies, third party software vendors, government Internet-TV platform	TV-broadcasting platform integrates all partners in the ecosystem	Openness of the TV broadcasting platform for integrating more service, let 3rd party software developer to get access	From single-directional to bidirectional communication
E-Map	Provide location-based service	Open SDK and API to involve more partners to work together	Map-service company, software vendors, business partners (banks, hotels, restaurants), industry customers	Map service as a platform to involve more business partners	Easy communication and facilitate innovation: Openness of the platform; integration with other functions; adaptable to requirement	From simple function (directions, route) to an integrated business
CCTV	Creates more value for relevant stakeholders	3G network to facilitate the use of CCTV services	Government, industry and personnel	CCTV service as a platform to benefit more stakeholders	Accessibility of CCTV services; Adapt to customer requirement	Computer-based monitoring system towards smartphone-based monitoring system From simple function to smart functions

Table 5. Three patterns of IoT-based business ecosystem

6C		Pattern 1: High-Open IoT-based business ecosystem (**Case C – Car operating platform & Case E – Mapbar**)	Pattern 2: Medium-Open IoT-based business ecosystem (**Case A – Car Rental & Case D – Internet TV**)	Pattern 3: Low-Open (Closed) IoT-based business ecosystem (**Case B – Instant Messenger & Case F – CCTV**)
Context	Lifecycle stage	From isolated platform to shared platform	Towards interactive method	Closed platform with more interaction functions
	Missions	Serving the customers	Serving the customers	Serving the customers
	Drivers	IoT technology; open operating system; required communication	IoT technology (Case A); communication (Case D)	IoT technology; communication
	Barriers	Hard to persuade car manufacturer to open the platform (Case C), beneficial business model (Case E)	Economic beneficial business model; customers' way of life	Social barrier (Case B); communication difficulties (Case F)
Cooperation	Coordination mechanism	Stakeholders can gain access to the platform easily and communicate	Customers were engaged in product development	Only customers are allowed to use the functions; not engaged with third-party developers
	Governance system	Open interface encourages partners to work together	Focal firm opens the interface and encourages customers to contribute	Closed platform; the focal firm controls all the functions
Construct	Structure	Focal firm; third-party software vendor; industrial users	Focal firm; software vendor, customers (Case A&D) ; government (Case D)	Focal firm; customers
	Infrastructure	3G & IoT technology	3G network; IoT technology	3G network; IoT technology
Configuration	Patterns	One focal firm with other relevant stakeholders	Focal firm with active customers	Focal-firm dominated
	External relationship	Flexible connection	Customers are connected via IoT technology	Customers' community (Case B), or separate customers (Case F)

Capability	Communication and accessibility	By opening the access to the platform	Customers are connected	Information sharing between customers
	Integration and synergizing ability	Embedding into the platform	Embedding the customers' behavior into the products	Only access to the platform
	Innovation and learning ability	Flexible to develop apps to enrich the platform	Customers are able to change the products	Hard to make innovation; there are no access points
	Adaption and mobility	Customized service for customers	Adapts according to the customers' behavior	Focal-firm-dominated adaptation
	Complement or creation ability	Diversified complementors with special function emerged to enrich the platform	Less diversified compelementors contribute to the focal firm's platform	Selected partners to contribute to the focal firm's platform
Change	Renewal (Platform pattern shift)	From closed to open	Partly open product level	Developed with more functions
	Co-evolution (Interaction pattern shift)	Interaction between focal firm and stakeholders	Co-evolve with customers	Only get feedback from the customers

5. Data analysis and findings

5.1 Clustering the cases

An analysis of the 6Cs in Table 4 demonstrates that there are three patterns of IoT-based business ecosystem. These three patterns are presented in Table 5 within the 6C framework.

The cases studied in this research can be categorized into three clusters in terms of their stage of development and the sub-dimensions of the 6Cs, so as to explore the nature of the IoT-based business ecosystem and its patterns.

The car-operating platform (Case C) and E-map (Case E) are still in the early stages of industry development. They both have similar strategies from the point of view of the 6C framework: their products have not been finalized and more functions and features remain to be explored; their product platforms are open to business ecosystem partners for adding more value for end-customers; and the ecosystem partners are very active.

With regard to the new mode of car rental (Case A) and Internet TV (Case D), these industries are well-developed and have expanded from existing mature industries. Hence they display mixed features, with traditional and novel factors. As a result, the products are open in a sense and allow customers to contribute and modify them. However, these industries do not actively encourage too many industrial players to work with them.

As for the instant messaging (Case B) and CCTV (Case F) cases, these are both very developed industries and at a mature stage in their product lifecycles. The focal firms are in charge of product development, no other stakeholders can engage in product development, and its ecosystems are rather more closed than the previous two categories.

5.2 Three patterns of IoT-based business ecosystem

Based on the business structures of the above cases, there are normally three key parts to a business ecosystem: the focal firm that provides the platform; the ecosystem product or service; and the customers or stakeholders who get feedback from the product/service and subsequently deliver changes or develop new products. These three parts interrelate differently in the three patterns of IoT-based business ecosystem. As a result, the Car operating system (Case C) and E-Map (Case E) follow Pattern 1, which is highly open; the Car rental (Case A) and Internet TV (Case D) follow Pattern 2, which is semi open; the Instant messenger (Case B) and CCTV (Case F) follow Pattern 3, which is less open. We have further deconstructed the business ecosystem, as shown in Figure 2.

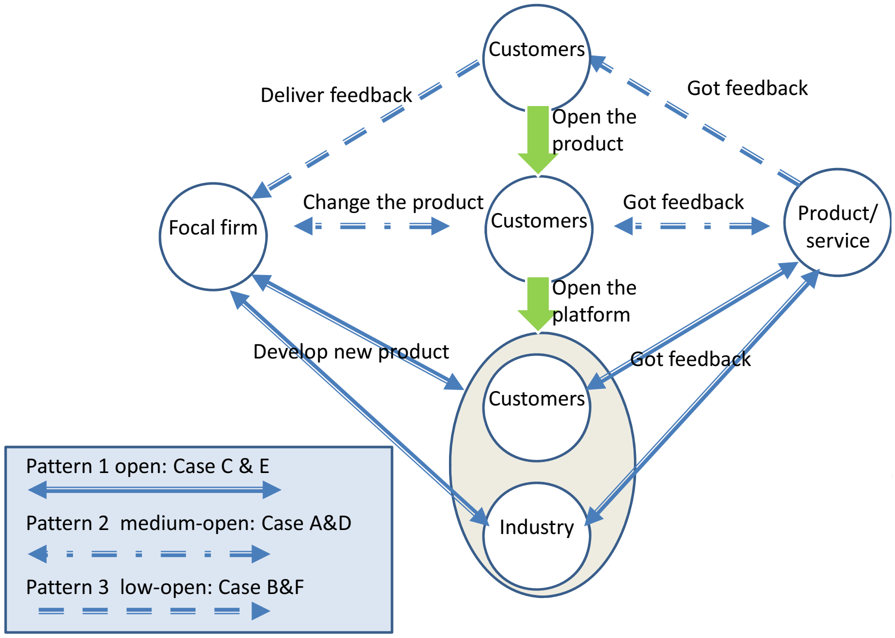

Figure 2. Three patterns of the IoT-based business ecosystem

In Pattern 1, highly open, customers as well as many other stakeholders, such as industrial players, are allowed to obtain data by using the products. They then get together to enhance the products, with assistance from the focal firm. For example, in Case C, third party players can obtain data from the focal firm's car operating platform. In this pattern, normally the products are still incomplete and have open access for further improvement. For instance, Case E allows cross collaboration with third party companies by letting them use E-Map's API services. Platform openness is one of the key capabilities required for the success of this pattern, which is popular in emerging industries.

In Pattern 2, semi-open, customers receive feedback by using the products and can then engage in changing the products themselves. The focal firm opens the product interface to other stakeholders in the business ecosystem. Taking Case A as an example, the customers can find the location of the rental car in the city in real time and are also allowed to park the car anywhere, where they also engage in revising the products. In Case D, the internet TV also allows the customers and third party companies to add services, hence adding value to the internet TV platform. Obviously, customer involvement and engagement are critical capabilities required for this pattern. This pattern is usually implemented when a mature industry has evolved by adding new features.

In Pattern 3, less-open, customers use the products and then deliver feedback to the focal firm. The focal firm then decides the next step in product development. Since the product and platform are less open than in the other two patterns, the R&D capabilities of the focal firm decide the success of this business ecosystem. For example, the instant messenger (Case B) and CCTV companies (Case F) control product design by embracing the feedback from customers, but do not allow other parties to directly engage in product design. This pattern is usually adopted when the industry is quite mature and one focal firm dominates the business ecosystem.

5.3 Evolution of the patterns

The three patterns of the IoT-based business ecosystem reflect industry lifecycles and match three development stages: emerging, less mature, and mature.

The Pattern 1 business ecosystem is very open since it positions itself at the early stage of an industry, where the focal firm needs more stakeholders to add value to the product platform. As a result, the product platform is open to ecosystem partners, and the focal firm and other stakeholders in the business ecosystem can co-evolve with each other to create and deliver value to customers.

Once the industry begins to mature, the focal firm in the Pattern 2 ecosystem is mainly able to control product development, but it still welcomes customers and third parties to modify the incomplete product and refine it with more functional features to ensure its success in the market.

As the industry becomes very mature, the focal firm in the Pattern 3 ecosystem will consider the product as a dominant design and will fully control product development. Thus, it will only get feedback from customers, and no access points will be provided for customers to change the products.

Comparing these three patterns, the Pattern 2 business ecosystem is different from Pattern 3 in terms of openness of the product interface, and The Pattern 1 business ecosystem opens the product platform even more than Pattern 2 system.

6. Discussions

6.1 IoT-based business ecosystem: An extended supply network

Originally, the IoT was regarded as the connected network between things. With the emergence of IoT technologies, more and more businesses can be involved, creating a business-ecosystem perspective instead of just a supply-network. The IoT-based business ecosystem is not just a supply network with connected items; instead, it is an extended supply network connecting all stakeholders. These stakeholders are players that can be connected with the IoT and thus contribute to the evolution of the business ecosystem. From a co-evolution perspective, these stakeholders may be directly or indirectly linked (Moore, 1993). The IoT platform is more open than ever before, hence stakeholders can potentially contribute to the IoT business even if they were not connected before.

6.2 6C framework to understand a business ecosystem

In order to improve systematic understanding of the IoT-based business ecosystem, this research develops an integrated 6C framework to study business ecosystems or complex supply networks. The results derived from the case studies conducted in this research confirm the 6C dimensions of the proposed framework.

The *context* is the environmental setting for the development of a business ecosystem, while the *cooperation*/process is the way of nurturing the business ecosystem in order to reach the strategic objectives. C*onstructive elements* consist of the fundamental skeleton of the business ecosystem, which also determines the *configuration* of specific ecosystems with their objectives. In addition, different *capabilities* reflect the constructive elements and cooperation strategies. Finally, each business ecosystem faces the challenges of *change*, including pattern renewal or evolution along with its business environment, technical innovation, or specific mechanisms.

The framework can be operationalized easily by clustering the 6C into three groups: the first group comprising context and cooperation with a process perspective. This group reflects the process of a business ecosystem lifecycle and, within the lifecycle stages, methods of nurturing a business ecosystem. The second group is made up of construct, configuration and capability. This group is more static, and takes more of a snapshot view. The constructive elements will structure a business ecosystem and those elements will combine to form a specific configuration pattern, which has different capabilities and advantages. The third group demonstrates how the ecosystem experiences significant pattern changes as the business environment and technologies evolve. As a result, the first two groups demonstrate the inner ecosystem operation and structure, while the third group of Change refers to change in the pattern of the whole system.

These 6Cs are inseparable but make up a whole-system architecture; they allow both academic researchers and practitioners to study the network from an overall perspective. The proposed 6C framework can be used as a method to carry out an overall, comprehensive analysis of a system. It could therefore be used to analyze the different levels of a system or a network. This paper proposes the general principle of the 6Cs, but each of the six components still requires further analysis and understanding.

6.3 Adding the process view to the concept of business ecosystem

The business ecosystem concept is viewed in two different ways: the first sees it as a network of interdependent stakeholders, who share the same fate and evolve together. This view mainly studies the different roles that make up a business ecosystem (Moore, 1993; M. Iansiti and Levien, 2004). The second stream studies how these roles interconnect, for example via the structure of technology interdependence (Adner and Kapoor, 2010b; Cusumano, 2011; Kapoor and Lee, 2013). This stream regards the ecosystem as an established value network with fixed, interconnected roles. These two streams address respectively the roles in the ecosystem and connections between these roles.

However, these two ways of viewing the concept need to be linked together, by an examination of how the roles become connected during the lifecycle of the business ecosystem. In other words, rather than taking a snapshot view of the business ecosystem, it needs to be viewed as a process. The snapshot view might be retained, however, as the fixed value chain of a mature business ecosystem.

The evidence from the IoT industry also supports this process view. The results show that the structure of a business ecosystem, particularly one based on IoT, evolves and experiences different growth stages; as the system evolves more indirect stakeholders, such as customer social networks, become involved and contribute to the IoT platform, because customer data is uploaded into the Continental car operating system. In fact, in its early stages the configuration of the business ecosystem is very fragmented; it is a very dynamic loose network or social network (Iansiti & Levien, 2004; Kumar et al., 2010; Rong et al., 2013). The results confirm that indirect players can become involved in a business ecosystem that relies on IoT technologies and finally became fixed. All this implies that the concept of a business ecosystem needs to involve the previous two streams and the new process view: a business ecosystem is not a fixed-value chain; instead, it contains different levels of organizations/roles that share the same fate and can transform themselves from being a fragmented social network in the early stages into a value network that gives benefits to the stakeholders.

6.4 Developing a business model for an IoT-based business ecosystem

The business model has evolved with the rapid development and application of IoT and the possibility of connecting numerous physical objects. The two key features of the business model, efficiency and innovation (Zott & Amit, 2008), can be exploited to a higher extent in the IoT driven ecosystem. The reason for this is that the openness of the focal firm's platform (Adner & Kapoor, 2010; Cusumano, 2011) allows more and more business partners connect with each other and create more value for end users. The development of any new business model should be adaptable via an open platform and diverse solutions, so as to allow participants' resources and capabilities to be fully utilized.

6.5 Practice guidance

This article briefly presents three typical patterns of IoT-based business ecosystem. When the industry is very mature, the IoT business ecosystem is quite closed; the focal firm should control the product/service platform as well as development of the product. If the industry is becoming mature, the IoT business ecosystem will be more open, since it will allow customers to modify and change the products. In the third situation, when the industry has just emerged, the focal firm prefers to open the product platform and to encourage customers and ecosystem partners to work together to contribute and define future products. Therefore, practitioners should analyze their industry, identify their position and adopt relevant strategies to make the most of the IoT business ecosystem.

7. Conclusion and Limitations

This paper has investigated the IoT-based business ecosystem within a 6C framework. It has revealed that the IoT-based business ecosystem is more than just a supply network with connected items; it is a much more complex network composed of different stakeholders, who can contribute to business and co-evolution in the business ecosystem.

In order to understand the IoT-based ecosystem, the paper also proposes a 6C framework to understand how a business ecosystem works. The "context" establishes the external environment for ecosystem development. The "Construct" demonstrate the elements to structure a business ecosystem. The "configuration" describes the patterns of business ecosystems with different capabilities. Ecosystems have different governance systems and coordination mechanisms, which are regarded as "cooperation." The ecosystem will also experience transformation and "change".

In summary, the 6C framework sets up a systematic benchmark for further research concerning business ecosystems, as well as building up a research method to understand a system as a whole.

In spite of very rigorous research methods, the data for this paper could only collected from IoT based ecosystems. Hence, it may not be easy to generalize this 6C framework to other emerging ecosystems. In the future more data is needed to confirm the 6C framework.

There is however a great deal of scope for further study of the 6 C framework. Some possibilities for future research in terms of each 'C' of business ecosystem theories could be as follows:

1) **Phase-based research**: more detailed research should be conducted to enrich the 'Context' in order to explore the different strategies and activities required during each phase of the business ecosystem lifecycle.

2) **Network capability and auditing** (Shi & Gregory, 1998; Zhang et al., 2007): Further research might investigate competence and performance in the different configuration patterns that reflect the fundamental factors of the business ecosystem. Furthermore, auditing work (capability evaluation) should be conducted to understand the performance of a firm's business ecosystem and its improvement.

3) **Types of roles as part of ecosystem construct**: more types of stakeholder should be added to the business ecosystem framework, such as government, industrial associations and other relevant organizations that contribute to ecosystem development. Further research could be conducted from the perspective of different organizations and their activities.

4) **Business ecosystem cooperation instead of firm-level operation**: more detailed study should investigate business ecosystem operational mechanisms, in other words how different firms interact during each lifecycle phase.

The findings of this paper already provide a good basis for future investigation and research.

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Appendix

Interview Question Guidelines

Description: These guidelines specify the questions that will be asked during the interview. The information collected in the interview is designed to target the six dimensions (context, cooperation, construct, configuration, capability, change) of the conceptual framework.

(If necessary, the concepts of IoT and Business Ecosystem will be explained at the beginning of the interview).

General Information

1. Please briefly introduce your company's business and history (context).
2. Please briefly introduce your responsibility in the company.

Questions about the IoT-based business ecosystem

3. Please describe the development of your company's business, in particular what techniques are adopted at different stages (context).
4. Please describe the relationships between you and your partner companies at different stages, and describe how partners work together (cooperation).
5. Please specify what stakeholders are involved in your company's business, and their roles in the business (construct).
6. Please describe the business processes and business models, and explain the importance of platform strategy in your business (configuration).
7. Please clarify what capabilities are essential to the success of your business (capability).
8. Please describe what changes occurred between two stages in your business development, and how your company managed these changes, in particular the pattern of business change.

Closing questions

9. If possible, can we observe the products, business processes, and check relevant documents for academic research purposes only?

Thank you!

Highlights

1. The Internet of things is not just a supply network, but a business ecosystem
2. We used a 6C framework to understand the IOT based business ecosystem as a whole
3. The 6Cs are context, cooperation, construct, configuration, capability and change
4. This 6C framework is regarded as a method to deconstruct a system
5. Three patterns of IOT based business ecosystem are identified