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INTERNET OF THINGS IN SERVICE INNOVATION

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Abstract

Last decade has witnessed rapid growth of Internet of Things (IoT) literatures by scientists from technology domain such as computer science, telecommunication and engineering, but very few studies have been done by sociologists and even fewer by economic geographers in service research. The great impact that IoT will bring to service offerings and its spatial consequence is disproportionate to how much research has been done in this area. The paper aims to understand how the adoption of IoT affects the spatial ramification of service offerings and service business. After the theoretical framework and research method, part three explains what the implications of IoT in service context are, why and how IoT enables innovation in services and the current obstacles. Part four further discusses what could be the spatial ramification with the case of China emerging IoT industry in city Wuxi.

Keywords

service innovation, internet of things, economic geography, digital economy

JEL Classification

L86 - Information and Internet Services; Computer Software

L96 - Telecommunications

O33 - Technological Change: Choices and Consequences; Diffusion Processes

Introduction

Understanding the relationship between emerging information and communication technologies (ICT) and service activities is a constant job for service research (Bryson, Rubalcaba and Ström, 2012, p651; Daniels, 2012, p631) as the adoption of new technologies has been the driving force of innovation in services (Gago and Rubalcaba, 2007; Miles, 1993, 2006), which impacts the spatial ramification of service offerings and service business (Beyers, 2012, p665). Such imperative is reflected in the IBM global CEO study this year, which results that technologies factor (71%) is considered as the most critical external forces in the next 3-5 years, which is over people skills (69%), market factors (68%), macro-economic factors and globalization. CEOs saw technology inspiring entirely new industries and fundamentally disrupt others and mentioned the new possibilities driven by the physical world equipped with networked sensors (IBM, 2012,

p13). Linking the physical world with networked technologies and equipped with networked sensors is the emerging technology revolution that some call “the Internet of Things” (IoT). IoT is much more than a technological revolution; it is also a social process. Think about how the internet has changed our daily life and work, and this is just the beginning. We are living in an increasingly connected and digitalized world, which is transforming how goods and services are produced. Ericsson (2012) predicts that by 2017 85% of the world’s population will have 3G internet coverage, while data traffic will grow from 2011 by 15 times. In 2010 the internet economy accounted for 4.1% of GDP (\$2.3 trillion) in G-20 countries and by 2016 it will reach 4.2 trillion (Dean, et al, 2012). What makes it more striking is the growing interactive penetration between the cyber space and our physical world both in quantity and quality. Quantitatively it is between the years 2008-2009 when the number of connected devices exceeds the number of world population and by 2020 this number is estimated to reach 50 billion (CISCO, 2011; Ericsson, 2011, p3). Qualitatively many are not only connected but with sensing abilities to “feel” the condition and changes in its environment such as temperature, speed, body movement, lightness and so on. If internet is likened to brain, now it has started to have eyes, ears and hands. When billions of daily objects not only smart phones, TV or tablets, but everything such as lake, road, apple tree, shampoo, shoes, furniture and cars are connected in intelligent systems, it won’t be hardly to believe that the IoT revolution, such quantitative and qualitative integration of the cyberspace and the physical world will dramatically change the world.

Last decade has witnessed rapid growth of IoT literatures by scientists from technology domain such as computer science, telecommunication and engineering, but very few studies have been done by sociologists and even fewer by economic geographers in service research¹. The great impact that IoT will bring to service offerings and its spatial ramification is disproportionate compared with how much research has been done in this area. Such importance is two folds. One of the core values of deploying IoT infrastructure to connect the physical world sits in offering smarter and new services for individuals, communities and regions. Such extension of Internet from cyberspace to the physical world will inevitably deal with places: from the spatial forms of service business transforming to multi-agent frameworks, to the emerging service offerings for instance location-based service (LBS) which is enabled by embedded GPS sensors in connected devices. Considering the exponential growth of Internet services during the recent decades, the scope of change will be probably colossal. For example in China where IoT is anchored as one of the most important strategic high grounds in the world’s next economic and technical development trend by the country’s 12th Five Year Plan (MIIT, 2011), the market size of the industry is expected to top \$117 billion by 2015 with 30% annual growth rate (CIT-CHINA, 2011). This figure represents more in China’s ambitious rather than the market size assumption. Actually at this early stage it is difficult to measure IoT’s potential

¹ Out of 1065 published items (including proceedings) under the topic “Internet of Things”, 167 papers are Internet of Things focused and most of them are in Computer Science (86 papers, 51%), Telecommunications (61, 36%) and Engineering (59, 35%), while there are only 2 papers from social science and 17 papers from Business Economics. Among those none-technology 19 papers, some of them are showing cases in emerging business opportunities, or tap its geographic impacts indirectly during the core discussion, but so far there has not been papers directly link Internet of Things, innovation in services and geography together from the result of this database. (Source: Web of Knowledge, by 2012-08-22)

market size as Michael Nelson, the former director of Internet Technology at IBM described “Trying to determine the market size of the Internet of Things is like trying to calculate the market for plastics, circa 1940. At that time, it was difficult to imagine that plastics could be in everything” (Valhouli, 2010, p3). Therefore studies in this domain are not only necessary but of great importance.

The paper aims to understand how the adoption of IoT impacts the spatial ramification of service offerings and service business. After the theoretical framework in part one and research method in part two, part three discusses what the implications of IoT in service context are, why and how IoT enables innovation in services and the current obstacles. Part four further discuss what could be the spatial ramification of IoT in services with the case of China emerging IoT industry in city Wuxi. In the end part five draws conclusion and future study implications.

1. Theoretical Framework

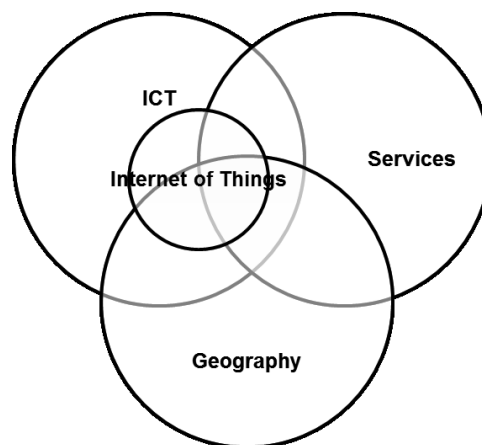


Fig. no. 1 Research Gap

Understanding how the adoption of IoT leads to spatial ramification of service offerings and service business is to understand the interconnections among IoT revolution of ICT, innovation in services and the changing geography. A large number of researches have been done in the interconnections between ICT and services, ICT/technological changes and geography, or geography of services (Kellerman, 2002; Davis and Heineke, 2003; Bryson, Daniels and Warf, 2004; Coe, Kelly, and Yeung, 2007; Mackinnon and Cumbers, 2007; Malecki and Moriset, 2008; Dicken, 2011; Beyers, 2012; Bryson, Rubalcaba and Ström, 2012; Daniels, 2012). For IoT, as the concept diffused across the globe, there has been a rapid growth of literatures from the technology domain (over 90% of the published papers focusing on IoT are in computer science, telecommunications and engineering: see footnote 1), global commercial players in promoting IoT (CISCO, 2011; Ericsson, 2011; IBM, 2012) as well as from international organizations and policies (ITU, 2005; US National Intelligence Council, 2008; European Commission CORDIS FP7; MIIT-China Academy of Telecommunication Research, 2011; CIT-CHINA, 2011). The research world of ICT, services, geography and the world of IoT so far have remained separate more than

connected. However, the rise of IoT changes the ICT sphere, impacting the service offerings and geography of services. For example the world's leading IT services company believes that the world has become increasingly instrumented, more interconnected, and things more intelligent therefore smart infrastructure is becoming "the basis of competition between nations, regions and cities"². Now we are standing on the blink of change and it is time to bridge this research gap (Fig. no. 1).

1.1 The Internet of Things

1.1.1 The rise of Internet of Things

In one decade, IoT has rapidly evolved from research centres to business communities, from disruptive technologies to national competitive strategies. Although the idea behind it has a long history, it is believed that the term "Internet of Things" was firstly introduced in 1999 by Kevin Ashton from the MIT Auto-ID Centre in a presentation about RFID and supply chain management innovation prepared for Procter&Gamble (Ashton, 2009). It was introduced by Technology Review (2003) among the 10 emerging technologies that would change the world. In year 2005 the trend was captured and pushed forward to a global scope by International Telecommunications Union (ITU). ITU launched a special report which has broadened the definition of IoT from disruptive technologies into an ecosystem of the future internet, predicting a new era in which "today's Internet (of data and people) gives way to tomorrow's Internet of Things".

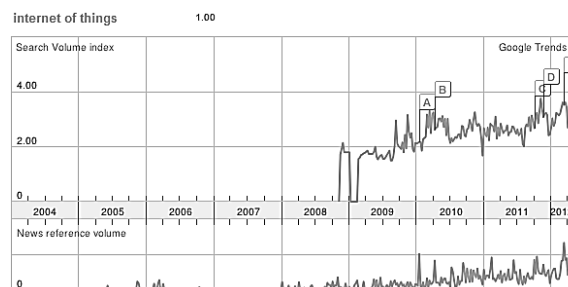


Fig. no. 2 Google Trends of Internet of Things (Source: Google Trends by May 8th 2012)

2008-2009 is the "big bang" of Internet of Things. The timing is revealed by Google Trends which shows the general public interest towards IoT starts late 2008 and since then has kept a steady increasing curve in search engines (Fig. no. 2). In September 2008, a new industrial alliance IPSO is formed by 25 members including Cisco, SAP and Sun. In the US, Internet of Things was regarded as one of the 6 Disruptive Civil Technologies with Potential Impacts on US Interests out to 2025 (the US National Intelligence Council, 2008). IBM launched Smarter Planet Strategy. In EU, the first international conference of Internet of Things was held in Zurich in March, followed by a series of reports and projects in EU FP7 such as Internet of Things Initiative (IoT-i), Internet-of-Things Architecture (IoT-A)

² The big idea was kicked off in November by IBM CEO Palmisano during a speech at the Council on Foreign Relations in New York City, which later became the differentiating competitive framework for IBM.

and European Research Cluster on the Internet of Things (IERC). In China the term Internet of Things caught the Prime Minister Wen Jiabao's attention during a visit to Wuxi at east Jiangsu Province. He proposed an equation "Internet + Internet of Things = Wisdom of the Earth" and called for building the Sensing China centre. By the end of 2009, China R&D Centre for Internet of Things (CIT-China) was set up in city Wuxi with a joint force of Chinese Academy of Science and Jiangsu province. Since then the consortium of IoT industry in China has rapidly grown to the major cities and regions.

The emergence of IoT is a both global and local phenomenon. On one hand is the knowledge and technological trend which diffuse rapidly across the globe and are pushed forward by global players such as international organizations (ITU) and multinational companies (IPSO), while on the other hand is the diverged way of landing in different geographical contexts. Once integrated at a place, the development trajectory differs according to the cultural, economic and institutional patterns. For example, comparing with the EU bottom-up market driven tradition, the aggressive actions driven by the Chinese government on creating IoT industry has a top-down pattern with the government acting as the initiator, investor, regulator and major player. In the U.S. the term is more scattered into different application fields such as smart health, smart grid, smart logistics and smart food. Therefore it is fair to say that this global trend is implemented differently in varied places.

1.1.2 IoT as new dimensions of ICT: definition, key components and IoT services

There has been so far no universally accepted definition of IoT, but the key components are able to identify. The IoT definitions given by official documents although varied from different resources can shed lights on its key components. Here I am using the definitions from MIIT of China (MIIT, 2011, p2) and IERC to abstract the core components of an IoT system. The reason to choose them is that on the national level of China and transnational level of EU, the term IoT is widely accepted and promoted.

"IoT is the extended applications and extension of communication network and the Internet, which uses sensing technology and embedded intelligence to sense and identify the physical world. It is interconnected through the network transmission, by calculating, processing, and knowledge mining to enable information exchange and seamless links between people and things or things to things, so that real-time control, accurate management and scientific decision-making of the physical world can be realized". (Author translated it into English from MIIT 2011 China IoT White Paper)

"IoT is an integrated part of Future Internet and could be 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, virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network". (Europe Research Cluster on IoT)

These two definitions although differed in terms and emphasises, show the key components of IoT system. It is the things embedded with sensors in physical world being seamlessly connected to information network, so that we have dynamic information exchange between people and things and between things and things. This implies the communication is based on information network, information flows from end to end, and the whole process requires

information processing. The same as the other ICT systems, in the end it is the application of such information exchange (such as real-time control, accurate management and scientific decision-making) counts for the value of IoT system. Therefore information network infrastructure, connected things with embedded sensors, information processing capabilities and the applications are the four major components.

The new dimensions IoT brings to information and communication are:

- 1) Information: The information provider is extended from today's only computer and people to things in the physical world. Smart phones, TV and tablets have already connected to the internet world, becoming both the information receivers and providers. In the IoT vision, anything should be able to connect to the cyberspace with its own IP address. Therefore things in the physical world can actively provide information about itself or changes in its environment to the cyberspace as well as receive information from the cyberspace.
- 2) Communication: By adding things to the communication network of today's people-computer-people, it enables information exchange between people and things and between things and things (M2M).

The impacts on services are two kinds: the creation of new applications and the upgrading of related ICT services. MIIT (2011, p9) defined four categories of IoT services: 1) IoT applications (such as public services and industry-based services); 2) IoT infra-structure services (such as cloud computing, data storage, data centre, infrastructure components services); 3) IoT software development and system integration (such as system integration, software development, software services, intelligent information processing); 4) IoT network services (such as M2M information and communication services, industry-based ICT network services).

1.2 ICT and changing geography of services

ICT and other space shrinking technologies have brought great flexibilities for business activities to locate where they can benefit the most from reducing the transaction cost and from economic externalities (Coe, Kelly&Yeung, 2007, pp150). As a result it is changing the global service division of labour. The second trend, which is partially enabled by the first, is in the transformation of conceptualising service as co-production between a client and a service provider to the multi-agent frameworks of a plurality of providers, suppliers and varied agents interacting and competition with each other. This is defined by Bryson, Rubalcaba, and Ström (2012, p651) as one of the challenges drives service research in the next decade. For example in social network services such as facebook, twitter and weibo, users are both the content creators and consumers. Similar complex network trajectory can be captured generally in how innovation has been organized. Dodgson and Gann (2010, pp117) summarized innovation activities have been evolved from 18th century individual entrepreneurs to the 19th century formal research organizations and mid to late 20th century large corporation R&D departments to the nowadays multi-contributors in distributed networks of innovators facilitated by new ICTs. Consequently services processes are simultaneously more footloose and more agglomerated (Daniels, 2012, p631). The changing geography of services is part of the transformation of world economy. Dicken (2011, pp6) pointed that the world economy has been qualitatively transformed in the nature and degree of interconnections, as well as in the speed with which such

connectivity occurs, including both a stretching and an intensification of economic relationships. One of the key driving forces is the changing forms, speed and interactive ways of information enabled by ICT. This change contributes to the acceleration of complex globalization process and globalization in turn “determines the acceleration of international circulation of ideas and information (said by Joseph E. Stiglitz, quoted in Androniceanu and Drăgulănescu, 2012, p367).” Consequently innovation activities and dissemination of innovation are increasingly condensed (Plumb and Zamfir, 2009, p379). A growing digitalized and connected world leads to the changing geographies of production, distribution and consumption of goods and services. For innovation in services, new technologies from the microelectronics revolution since 1970s till the tipping point of computerised technologies in the process of production, has resulted rounds of innovations which thoroughly reshaped how we live, work, move and entertain (Bryson, Daniels and Warf, 2004, pp157).

1.3 Information economic geography

Previous research shows that geography matters for information economy (Kellerman, 2002, pp1), and digitalization has not created a completely footloose economy, rather it contributes to the distortion of economic space resulting in both convergences and divergences from micro to macro scale of individuals, communities and regions (Malecki & Moriset, 2008, pp219). This character is proved by the geography of information infrastructure, which is neither decentralized nor concentrated but rather complex (Kellerman, 2002, pp21). The economic geography of information can be understood in three aspects:

1) Information as a commodity

Kellerman (2002) assumes that information per se is similar to other commodity with production, processing, transmission and consumption prices and the prices are varied at different places. Information always exists and being created all the time, the differences lie at how much useful information we can capture and utilise it. Information is not a consequence of technology; rather it existed long before ICT (for instance culture as information). What technologies have changed are the scale and forms of information, how we produce, store, transmit and consume information, the speed of processing information and the channels where such interactions occur. Electronic and information age has brought us all kinds of gadgets to produce, disseminate and exchange information such as telephones, faxes, TVs, Walkman, CDs, digital cameras and computers, which are facilitated by telecom networks and later the Internet. Such changes have led the rise of information society and information has increasingly become a commodity in its own right (Kellerman, 2002, pp14).

2) Information both has and do not has a location

Information in its abstract form does not occupy space, but the producing, transmission and consumption of information are dependent on “containers” which usually occupy locations. The most common containers are humans. The transmission process is highly dependent on network infrastructure which is unevenly developed in the world. Similar to other products, the consumption and dissemination of information and knowledge differ from place to place, which relates to contextuality such as language, culture, education, economic

condition and so on (Kellerman, 2002, pp9). Therefore seemingly placeless information commodity is dealing with location all the time.

3) Information, knowledge and innovation

The mechanism linking data, information and knowledge to innovation is explained by Kellerman in the information sequence (Fig. no. 3). He pointed out that information in nature is transformative, communicative and follows four basic sequential processes:

- a) Data to information by meaningful patterns and context;
- b) Information yields information by interaction for instance between people speaking or writing;
- c) Information to knowledge by its application. But knowledge also produces information and as Roberts (2000) pointed out that knowledge is required for the additional development of information;
- d) Tacit knowledge, codified knowledge and information are the basis of Innovation and innovation creates new information and information technology.

CONTEXTS

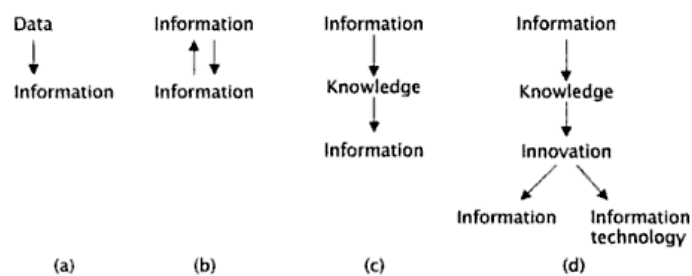


Fig. no. 3 Sources: Kellerman (2002) *The Internet on Earth: A Geography of Information*. pp4

If geography matters for information, then it matters even more for knowledge and innovation. Although ICT and business globalization explicit knowledge more universally accessible, implicit knowledge is still spatially sticky (Asheim and Gertler, 2005; Cooke, 2008), which leads knowledge-intensive economic activities to be more geographically clustered. However, it is wrong to equal implicit knowledge to local and explicit knowledge to global, because both of them can be exchanged from local to global (Bathelt, et.al, 2004, p32). These distinction of knowledge builds the foundation of space and place relating to knowledge/technology diffusion, which makes place (innovative milieu) where a specific social-technological context embedded, an important factor of knowledge creation and this specific context usually includes three aspects (Dicken, 2011, pp104):

- 1) Economic, social, political institutions
- 2) Knowledge and knowledge of know-how which evolved over time in a specific context
- 3) Local buzz: take-for-granted conversations between partners in different kinds of relations defined by uncertainty.

To sum up, these three aspects of information explain the current characteristic of spatial implications of ICT, which is not to eliminate geography but rather redefine geography, causing new networks of centrality and peripherality (Li et al, 2001; Moss and Townsend 2000; Graham and Marvin, 2001). Kellerman (2002, pp21-22) argues that this process may imply the evolution of urban specialization of information economy into two lines. First is the phase in the handling of information from production to consumption. The second lies at the types of information production in general, which includes information, knowledge and innovation. A city which specializes in more than one phases within any of the two lines, will become a leader in information economy.

1.4 The economics and creativity of networks: Metcalfe's Law and Cantor's theorem

Why a future with 50 billion or more connected devices is so exiting for CISCO and Ericsson, or why CEOs see the new possibilities driven by the physical world equipped with networked sensors from IBM's survey? This relates the power and creativity of networks. The uniqueness of information which is not similar to other material products is its re-production almost cost nothing (for instance once a computer game is created, the mass production of the software is very fast and cheap). Gilder (1993) named it the law of increasing returns: Usually when people share a piece of equipment, the return diminishes; when more people are engaged in the network, more value is returned to the users. Ideas and knowledge follow the law of increasing returns, which indicates economic value can be created from non-material resources.

Metcalfe's law is often used to explain the power and economic value of a network increases exponentially by the number of nodes connected to it (Shapiro and Varian, 1998, pp184). George Gilder (1993) applied Metcalfe's observation to Metcalfe's Law as "connect any number, 'n' of machines whether computers, phones or even cars - and you get 'n' squared potential value." The mathematical foundation is the number of potential interconnections between two nodes in a network. Therefore by equalling the total value to its potential interconnections of a network that consists of n nodes, the value of a network is:

$$V(n) = n*(n-1)/2 \quad (n=N)$$

V(n): the value of a network with n nodes

The economic implications of such network effect are striking in two aspects. One is the nature of network effect, and the other is the exponential pattern of growth: since the potentially N square value, Metcalfe's law is initially used to explain the exponentially growth of the Internet and social network. In fact the growth patterns of network value are many which varied by how to define value. Tongia and Wilson (2007, 5) summarized a list of such patterns to specify the value of a network based on the number of people or nodes connected. They found all of them show monotonically increasing value with growth ranging from linear to factorial: N (Sarnoff), N log (Odlyzko), Nc (Nivi), 2n (Reed) and N! (Haque).

Cantor's theorem is named after German mathematician Georg Cantor who first proved it, which states that for any set A, the set of all subsets has a strictly greater number of

elements than A itself. Ogle (2007, pp118-119) used the principle to indicate that “there are always more sets of things than things...relationship between groups of things (some real, some arbitrary) are spontaneously generated”. A set is a collection of things sharing common property. Ogle used a set defined as married men as an example. The set of married men is large, but the subsets it contains are even larger such as those who like baseball, who vote for Ralph Nader and those who own SUV and the list is endless. Combined with Metcalfe's Law, it also suggests that by adding one thing into a set immediately creates a multitude of subsets, and these spontaneous emergences of relationships give rise to new meaningful patterns. Cantor's theorem shows the mathematical necessity of subsets outnumbering the members of a set, while in reality the value of meaningful patterns of those subsets depend on where, when, how, and to whom. The economic implications of such new meaningful patterns hint that 1) there is a value underlying because if we say something is meaningful then it has a value no matter if it is material, practical, emotional or spiritual value and 2) “new” signals creativity and innovation. The essential point is that both of them can be generated spontaneously from a dynamic network, which makes a dynamic network as a magic field of economic externalities.

2. Research methods

This paper draws empirical analysis based on data gathered from desktop research and field trips in China.

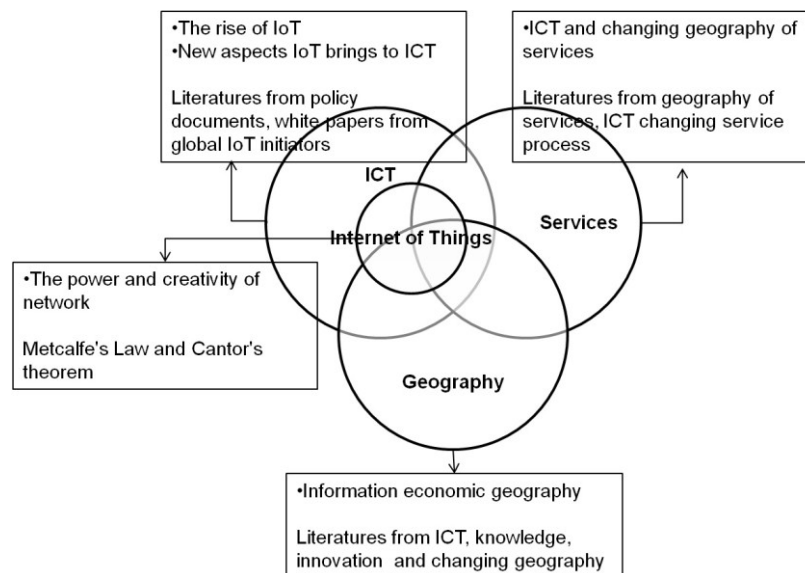


Fig. no. 4 Four streams of literatures bridging the research gap

In the theory aspect, the paper aims to fill in the research gap of IoT (as a revolution of ICT) impacts to spatial ramification of service offerings and service business. The previous

studies are either focused on the relations among ICT-services-geography, or purely IoT in technology and policy domains. Therefore a desktop research to combine literatures from different streams of studies is necessary to build the theoretical framework. Four streams of literatures are explained to bridge the research gap identified in the beginning of part two (Fig. no. 4).

In the practice aspect, I conducted field trips to China during April 2012. Field trips are in two places: 1) the 2nd Expo of Internet of Things Technology and Application in Suzhou China and 2) the National IoT R&D Center at Wuxi, China. For the visit to the IoT R&D center in Wuxi, I interviewed with people working in or facilitating IoT industry about their thoughts, experiences and concerns of applying it into practice. For the Expo in Suzhou, the main task is to gather the latest IoT applications tapping emerging service offerings.

People who I have interviewed are:

- Miss Jing Wen and Deputy Direct OuWen from CIT-China at Wuxi,
- Ph.D Guanxi Yin: former Vice President of Wireless Sensing Network, Wuxi China
- Miss Da Yin and Dr. Xiang Wang: Shanghai Institute of Microsystem and Information Technology Wireless Sensor Network of China Academy of Science
- Mr. Yanlin Ren: IBM Shanghai

The new dimensions of IoT brings to ICT is discussed in theoretical framework. Based on the information and knowledge from desktop research and field trips, the implications of IoT in service innovation and the geographical impact are discussed in the following arts.

3. IoT in service innovation context

3.1 Linking theories to the definition of IoT in service context

The challenge of defining IoT in service context is actually in the lacking of a unified definition of IoT itself. This leads to two implications. One is although the fuzz of IoT definition causes terminology problem, it is not necessary to give a definition for the sake of definition, if defining will narrow the potentials of its applications. The other is in fact it might be easier to define IoT in a certain context (for instance the services) than to abstract one general definition to fit all. Therefore the definition can be summarized by answering two questions: 1) what is the value of linking cyberspace into the things of physical world in service context? 2) What are the key components of IoT system?

The first question can be explained by the network effect. As we know from the economics of network: the power and economic value of a network increases by the number of nodes connected to it and such growth could be exponential; The law of increasing returns: usually when people share a piece of equipment, the return diminishes; when more people are engaged in the network, more value is returned to the user. Moore's law provides the possibility that computers can be integrated in a wider range of applications on devices from a gigantic bridge to a tiny button. Having both the incentives and abilities to connect more, it appears the possibility of the next round exponential growth. The rise of social network such as facebook, twitter, google+, and weibo is an example of network effects by

connecting people. Therefore what will happen if we connect the things? The value of connecting things is the value it can bring back to people. In the service innovation context, information plays a key role. Some services are in forms of information such as software, data mining, business consulting, financial services, public information in city management, and more are facilitating for new and better services, as Richard Barras pointed in many ways the information technology revolution was an “industrial revolution” in the service sectors (Miles, 2006, p440). The four categories MIIT defined as IoT services are either providing new applications (services) or upgrading existing ICT related services. Therefore the value of connecting things in service context in general is providing useful information and valued services.

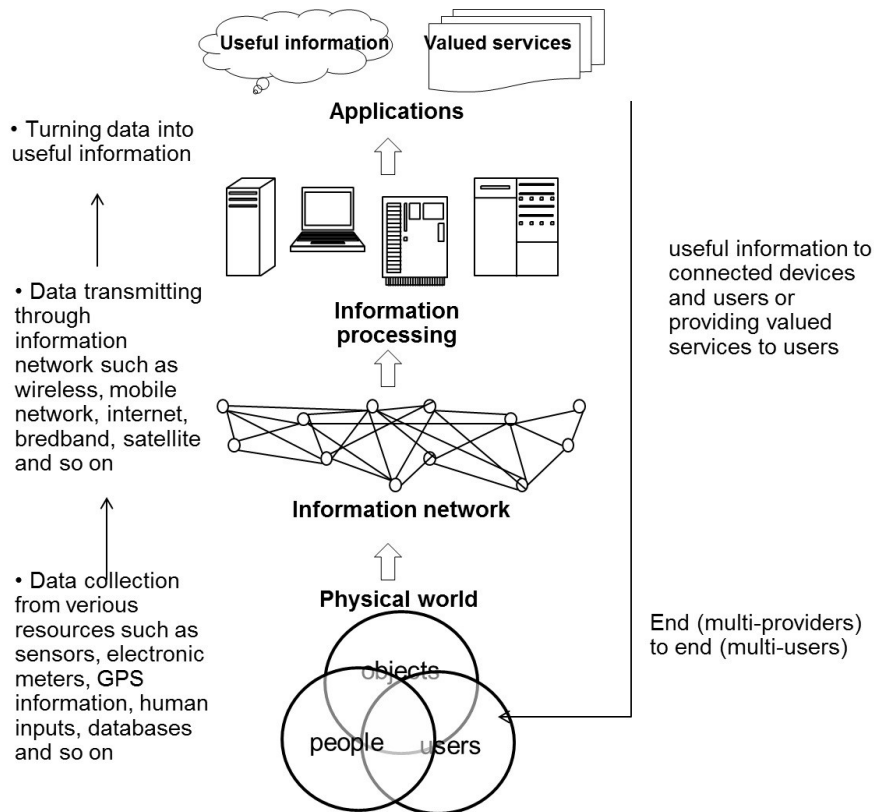


Fig. no. 5 IoT core components

The second question is already discussed in part two, and they are information network infrastructure, connected things with embedded sensors, information processing capabilities and the applications. Therefore in the service context, IoT can be defined as a dynamic end to end information network seamlessly linking physical and cyber space by which data from objects are connected, interacting and processed to enable people, objects and systems turning data into useful information and valued services to the users. It contains at least four core processes (see Fig. no. 5). By doing so, we can connect the physical objects integrated in the cyber space, which is a bit like providing a "nerve" system into the physical world.

3.2 Why and how IoT enables service innovation

3.2.1 Information Sequence Loop

An obvious feature of IoT is capacity in connections of objects, time and place. The next generation internet Protocol (IPv6) which formally launched in June 2012 globally is able to provide every connected object with identifiable and addressable address because of its immense capacity³. Objects cannot talk. To make them “talk” we need sensor imbedded intelligence to enable objects to monitor the change in environment such as temperature, moisture, movement and pressure. Miniature nanotechnologies make it possible to insert sensor on almost anything from a gigantic bridge to a little button (ITU, 2005). The global diffusion of wireless, 3G/4G mobile network, and broadband forms a networked global information high way to increase the mobility (anyplace) and flexibility (anytime) of such connection. The immense capacity in connected objects (heterogeneity), time and place (scalability) offers a new horizon for services to realise its potential.

Capacity in size, time and place means IoT infrastructure greatly extends the selections of resources from which we can capture data. Capturing more data to transform into useful information and valued services opens new grand for innovation. Baudrillard (1990, pp219) said: “Information can tell us everything. It has all the answers. But they are answers to questions we have not asked, and which doubtless don’t even arise”. While Brackett (1892) argued do not seek for information that you cannot make use of. Perhaps both of them are right and IoT will extend the first and narrow down the second. The mechanism linking information to innovation is explained by Kellerman (2002, pp2-7) in the information sequence. Based on Kellerman’s analysis, I would like to add a 5th process that is information technologies enhance the collection of data, optimize its transformation to useful information and hence helps the generating of knowledge and innovation. In other words, information technologies optimize the earlier four processes and turn the information sequence in to a loop of sequence. Therefore based on Kellerman’s version, I illustrated my interpretation of the information sequence loop as in fig. no. 6.

For example IoT is applied in Taihu Lake at Wuxi China to overcome the shortcomings of acquiring data for algal bloom forecast system. Taihu Lake is the 3rd largest lake in China and the most important source of drinking water supply for cities around. The lake suffered from complex nutrient and chemical pollution and in 2007 the progress of algal in the lake jammed the water plant’s intake and caused water supply incident. Traditionally the accuracy rate to predict a blue algal bloom is low due to two reasons: the formation of algal is complex and uncertain; the monitoring is lacking of synchronization and continuity. By applying IoT to build a three layered system, the new platform achieves an overall accuracy of 80% in forecasting blue-green algal blooms (Yang, et al, 2011). The new forecasting system can’t direct fix the algal bloom, but by monitoring the formation of algal, more data can be collected and analyzed to help experts finding treatments. By providing more accurate forecast, people can be more proactive, preventing it jamming the intake of the

³ The IP protocol using now is 32 bits IPv4 which has total 322 (4.29 billion) addresses. IPv6 is 128 bits which means theoretically it can provide 1282 (3.4×1038) addresses. The earth is 5.98×1027 grams, and it means every gram on earth will get almost 5.7×1010 addresses.

water plant. By more information to the public about the condition of blue green algal in Taihu Lake, we can increase the public awareness of the quality of water.

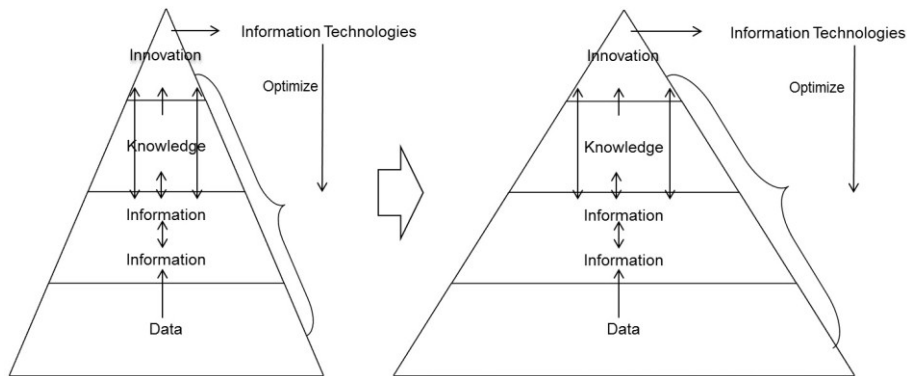


Fig. no. 6 Information Sequence Loop, which is developed from Kellerman's information sequence (2002, pp4)

3.2.2 Smart

Smart is a core feature. "Smart" things/services such as smart buildings, smart health, smart grid, smart transportation, smart city and the most common one smart phone are frequently mentioned in the ambitions of IoT vision. Despite the preference in marketing, the word "smart" is ambiguous: how smart is smart? Does it mean IoT enables things to think and act like humans? ITU (2005) explained smart as implying a certain processing power and reaction to external stimuli. I would argue that smart is a relative concept and it is by implying IoT, objects and systems are provided new abilities to create values that they previously cannot. Therefore it is a context based services. By connecting things in different contexts, we can create new services. It can be explained by Cantor's theorem which claims new meaningful patterns can be generated spontaneously in a dynamic network. For instance Echelon Corporation helped the city of Oslo in Norway to launch a pilot E-street lighting system. The pilot project connected 120 individual street and roadway lights installed with sensors into a smart network. The sensors can measure the degree of lighting around and the traffic volume, collect these data and send back to the central management site through ELON's internet edge server. The central management site can remote control each street light's lighting status based on the weather (raining, sunny), traffic volume (demand-based) and time of the day (daytime or night). As a result we see a smart street light which knows when to be off, when to be on, and how much brightness is needed.

Smart can be realized through automation and telematics. The value of making things "smart" is to enable them provide smart services. Telematics enables remote control, which creates a kind of "wormhole effect" to overcome the spatial distance. The power of innovation in services has been underestimated historically (Sheehan, 2006). Such bias is partly explained by the interactivity (services are customized according to client needs) and simultaneity (producing and consumption of services often happen at the same time) nature, which constrain services in "small scale" and "local basis" (Miles, 2006, p437). Telematics

is like our hands directly operate a connected device far away through a “wormhole”. Such wormhole effect enables real-time control. For example remote printing allows people to print documents at office from home. Remote medical systems make surgeons to operate from another place and in the future you may water your home flowers from a beach in vacation. Automation usually means without human intervention when it works (but still needs people to design, maintain and improve the system). Automation in IoT vision aims to offer smart, personalized services as it is complex events-based. For instance High-end fashion brand Prada tags Texas Instruments chips to their clothing and accessories at their boutique in Soho district New York, so that when clients hang over the products they want to buy into the dressing room, a flat panel TV is activated to play the models wearing those selected clothing with tips of accessories by designer Miuccia Prada (Schoenberger and Upbin, 2002).

3.3 Obstacles

For deploying IoT in service innovation, there are as many obstacles as the benefits. Generally speaking, diffusion of any technology revolution requires standardization and interoperability while information security and privacy protection are trickier to handle since they are not only technological problems but have legal and social concerns (Schoenberger et al, 2002; ITU, 2005; Commission of the European Communities, 2009; MIT, 2011). A set of IoT standards is the first step of implementing IoT in various applications from hardware, software to services. Standards can also be used as trade barriers to prevent foreign companies entering the domestic market, therefore standardization takes time and it is a negotiation process among industry, national regional entities and international associations. Two implications can be summed up: standardization is crucial to IoT development to mass diffusion and it will take time. Most of the current IoT cases are realized based on independent systems, which are not really able to communicate with objects outside of their own “islands”. Because of the lack of standards, smart objects have not been able to connect and communicate freely in the global network at a large scale. Security standard is also part of the standardization of IoT. It is considered as one of the most important IoT governance tasks in almost all countries and regions. Without a safe information environment, IoT will not be able to fulfil its potential in contributing to economic growth and social progress.

Protection of privacy is a complex legal social problem in information society (ITU, 2005). Basically it relates to the paradox of information sharing and control. The IoT action plan in EU (2009) action 3 suggested to launch a debate on the technical and legal aspects of the ‘right to silence of the chips’ to make sure that individuals should be able to disconnect from their networked environment at any time. But even the control button of connecting to the network or not is in the hand of users, without a secure network environment, these private information can be at risk by hackers and system error. Considering how complex and pervasive that IoT system can be, all those concerns will be crucial obstacles for its development.

Digital identity is controversial. On one hand smart objects with self-configuration and virtual identity are able to actively participate in the business and social process, which contributes to valued services by autonomous activities with less or no human

interventions; on the other hand, when 50 billion or even more such smart objects are participating in social activities, it changes the proportion of "us" and "objects" in the constitution of human society. It could be disruptive to the human-centered way of perception of the world that we used to hold. Do we want to live in a world that machines make decisions for us? These concerns will prevent the public acceptance on the development of advanced IoT services.

Limitation of sensor technology, network availability and quality as well as the information processing capabilities are also constraints of implementing IoT in service innovation. In practice, industrial barrier is preventing the smart objects connectivity and information sharing cross existing segment boundaries. IoT services will remain more "local" in both geographic perspective and business segment perspective for a considerable period of time because it takes time to reach global standards and even after that it will take longer time to solve privacy concern. The digital identity issue differs in varied culture and social contexts. Limitations on sensor technology, network infrastructure and information mining ability differ as well in different cities, regions and countries. Therefore the obstacles of IoT services imply that its development patterns are varied in different places.

4. Impacts of spatial ramifications

4.1 Spatial dimensions of IoT

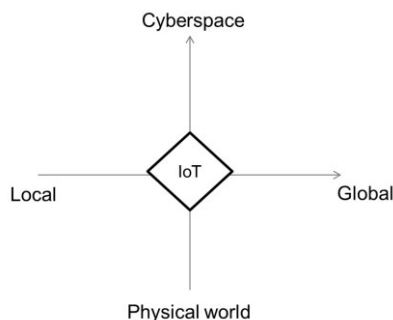


Fig. no. 7 the spatial dimensions of IoT

If geography matters for the internet, geography matters more for IoT. It is where local meets global and where the cyberspace and physical world interwoven (fig. no. 7). IoT service activities are place-rooted with complex local, global agents' frameworks.

For agents in IoT, the end to end flow shows that there are multiple data providers, multiple data processors and multiple users. Some users are also the data providers. Some services are automatically generated by information exchange; many are developed by specialised service providers. Therefore the co- production and consumption of services are becoming multi-agent frameworks. In a technological perspective, "space shrinking" technologies such as transportation and communication technologies which should have declared the death of geography by reducing the time-space constraints (O'Brien, 1992), in reality hasn't. Even in the ubiquitous Internet world, there are full of spatial inequalities (Coe, Kelly, & Yeung, 2007, pp125-148). This paradox characterizes the contemporary economy, which I

would argue that the presupposition of such paradox is incomplete. It might be because that how we name them (ubiquitous and space shrinking) are misleading our understanding of their spatial consequences. They do enable information and digital goods/services to travel around the globe in blink of an eye, while at the same time make information and digital goods/service much easier to concentrate at certain places. Therefore this geographic convergence and divergence is two sides of the same coin: either being footloose or agglomerated is up to how the economic activities are organized. Companies evolve through interactions with others from local to global environment, throughout the whole value chain as well as with their consumers, strategic partners and even competitors, and they constantly adjust location strategies by maximizing benefits from such dynamic local and global network to reduce the transaction cost and benefit from the economic externalities. Therefore IoT service activities are place-rooted with complex local, global agents' frameworks.

For IoT services, as it is a synthesis of information, things and users in the physical world, geography naturally plays a key role because even the information processing and storage can be footloose, the things from which data are collected and users will always have a geographic context. The value of such services is also context based: it relates to when, where, what, how and to whom. Especially in the current phase of IoT system, the majorities are local based. For instance the Shanghai city intelligent transportation system, data are locally collected, locally processed and locally consumed. The on-going construction of smart grid system is more on a national level in terms of management and investment but still it comes down to every electric meter. With the breakthrough in international IoT standards, it might be that in the future various connected devices and things are more or less universally communicating with each other like today's smart phones, tablets and TV, but still users in different geographic contexts are varied in services valuation and these services are strongly connected to local telecom operators. Moreover for those concerning critical social infrastructures for instance the smart grids for the power supply and some applications require handling private data like patients information in smart health, it also involves governments and authorities. Inevitably the "local" factor takes a crucial role.

4.2 The case of China emerging IoT industry: City Wuxi

IoT came into the public view at full blast in China after Prime Minister Wen Jiabao's visit to the CAS Wuxi. Since then city Wuxi has become one of the leading promoters in IoT industry. In less than 4 years, Sensing China Centre and National IoT R&D centres have been built with joint force of Wuxi government and CAS, as well as the formation of National Sensor Network Innovation Demonstration Zone where by mid-2012 over 600 companies related to IoT industry with annual sales volume over CNY 1 million. In year 2010 and 2011 the IoT industry of Wuxi reached a growth rate at 16.9% and 25.8%⁴. In this part, city Wuxi and its fast growing IoT industry are discussed in both the aspect of "local context" (location, social-economic-political institutions, capital, labour) as well as the aspect of information handling and types.

⁴ Statistical data of city Wuxi on the 2009-2011 National Economic and Social Development. [online] Available at: <<http://www.wxtj.gov.cn/tjxx/tjgb/index.shtml>> [Accessed 20 July 2012].

4.2.1 Local context⁵

The Chinese government in this case as usual is the initiator and core player in creating the IoT industry. Prime Minister Wen Jiabao's visit to Wuxi in 2009 is the trigger. Mr. Guanxi Yin is the former Vice President of Wireless Sensing Network which is also known as the centre of Sensing China. The centre is located at a modern twin building in Wuxi national software park (iPark). During my interview he said the centre was set up right after Prime Minister's visit, as a response to his call for building the Sensing China centre. The government of Wuxi in this case took quick action and made big efforts to be the first. Da Yin from CAS Shanghai told me that CAS institutes have been working on IoT project, although not named as IoT quietly for many years in Shanghai, Jiaxing, Wuxi and other offices but have not attracted the government's attention. So in that sense Wuxi is lucky, however Wuxi cannot be successful without its own merit.

City Wuxi is located in the east Jiangsu province within the core of Yangzi Delta economic zone, with less than one hour by train to Shanghai. The city has enjoyed fast economic growth for decades, with annual GDP growth around 11%-13% even after 2008. 2011 GDP per capita reaches \$18000, and the tertiary sector shares 44% (primary sector 1.8% and secondary sector 54.2%). Therefore it is a city which is in transitional period towards tertiary civilization. As in developing countries the growth of tertiary sector is crucial to cities and regions going through structural change (Malecki and Moriset, 2008), the city is actively looking for new growth opportunities for sustainable development especially after the 2008 financial crisis. It is one of the leading cities in software industry and service outsourcing, which increased over 33% last year, and 44% in year 2010. Microsystem and Information Technology industry increased over 16.7% in 2010 and 15.1% in 2011. The Wuxi national software park (iPark) started from 2007 and is a combination of creative industry and software industry especially in service outsourcing with over 500 international and local companies. It is also co-locating with the National Sensor Network Innovation Demonstration Zone. Therefore city Wuxi has the motivation and capability to promote IoT industry.

By acting fast, it is able to attract national and regional resources to strengthen the first mover advantage. For instance the China R&D Centre for IoT is built at Wuxi aiming to build up a platform for linking public authorities, R&D institutions, companies and start-ups with investors and public funding. The centre has gathered around 700 specialists (many of them are from other parts of the country and abroad) with 15 million US dollars registered capital and 78-157 million US dollars start-ups funding. By 2012, the network has expanded to 13 research institutes, 10 universities, 4 investment companies and other local members from public and private sectors. Over 10 start-ups have been incubated. The development plan till 2020 of Wuxi National Sensor Network Innovation Demonstration Zone got approval from the State Council which often means it is able to get direct support and resources from the national level. Therefore the founding of National IoT R&D Centre enables the city to attract talents and resources from a national and global scope, which in turn strengthens the capability of the city to develop IoT industry.

⁵ The statistics of the city Wuxi is from the same source as footnote 4. The information about the China R&D Centre is collected from interviews and the field trip.

4.2.2 Information handling and types

Software, service outsourcing and Microsystem and Information Technology industry have been Wuxi's competitive edge in service sector. So the city is strong in information production, which also builds the basis of IoT services from IoT software development and system integration. However, as mentioned by Deputy Direct OuWen of CIT-CHINA, the biggest challenge ahead is to build the industrial value chain, to attract the market and companies from private sectors to join the business. At the current stage, many IoT projects are government funded, and the intention is to show examples to the market, so that in the end more companies and invests from private sectors can join and build the industrial value chain. Therefore, the phase of consumption is not yet achieved.

In terms of types of information, the creation of information, knowledge and innovation are intensively clustered in Wuxi and the resources are from local, national and global levels. During my visit there, I found they also educate IoT related PhD students based on the resources from CAS. Many of the 700 employees of CIT-China are from other parts of China, and with international background. 13 research institutes from CAS participating in the founding of the centre are from other parts of China. The main task for the centre is achieving more Independent Intellectual Property in technological innovation of IoT system.

From the case of Wuxi, we see a very strong government lead combined with the national will, local anxiety to meet the challenge of structural change and industrial upgrading. The realization of such ambition is also supported by geographical advantage (one of the core cities in the network of Yangzi Delta economic zone and the 1 hour network circle to the world's city Shanghai), local advantage as a leading city in terms of software and service outsourcing and the first mover advantage. The future is full of opportunities and challenges. The government push model is not sustainable. It must be followed by the fast adoption in industry and the creation of business model. Although we see some emerging patterns in division of labour among the members of current consortium, the competition from other cities and regions will increase in terms of national funding, R&D investment and with more local, national and international players join the IoT fest, the map of China's emerging IoT industry will keep on changing.

Conclusions

The capacity and smart characteristics of IoT enables innovation in services by 1) enlarging the data collection from human centered to the human-nonhuman network and 2) offering smart services realized by telematics and automation from varied embedded networked sensors. The future of more than 50 billion connected objects excites us from the perspective of economics of network and spontaneous generation of new patterns from a dynamic network. Information builds the foundation of innovation and the change of where and how we collect exchange and utilize information builds the competitiveness of the future. The IoT vision linking the physical world with cyberspace will fundamentally change the rules of the game and we are standing on this brink of change. Local factor plays an important role in IoT services from investing, organizing, and evaluating to executing and the current obstacles push such local factor further. IoT service activities are place-rooted with complex local, global agents' frameworks. The case of China's emerging

IoT industry shows how much the local factors play in the course of creating China's IoT industry. With more players from local, national and international level joining in this fest and the evolving of industrial value chain, we shall foresee the increasing competition and complexity, which will continue to change the map of IoT services. Therefore, more research in both theories and empirical cases should be done to better understand its consequences in spatial patterns.

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