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# A Socio-Technical Framework for Internet-of-Things Design

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Abstract

This study presents a case application of a socio-technical framework to assess and predict the development of the Internet of Things (IoT) in Korea. Applying a socio-technical system approach to the IoT, this paper seeks a clear understanding of how the IoT will evolve and stabilize in a smart environment. It investigates the complex interaction between social and technical aspects of the IoT, by highlighting the co-evolution, interaction, and interface, which constitute the next generation network environment. It describes the challenges in designing, deploying, and sustaining the diverse components of the IoT, and provides a snapshot of Korea's current approach to meeting this challenge. Finally, the findings of this study provide insights into these challenges and opportunities, by offering a socio-technical analysis of IoT development. The insights help to conceptualize how the IoT can be designed and situated within human-centered contexts.

*Keywords:* Internet of Things; Contextual approach; South Korea; Socio-technical perspective

A Socio-Technical Framework for Internet-of-Things Design:
A Human-Centered Design for the Internet of Things

## 1. Introduction

With the explosive growth of smart phones and tablets, wireless technologies have become a fundamental tool for everyday life around the world. The coming wave of connected devices, appliances, vehicles, sensors, meters, and countless other "things" represents the next generation of a hyper-connected world, the Internet of Things (IoT). The IoT aims to extend the benefits of the regular Internet—constant connectivity, remote control ability, data sharing, and so on—to goods in the physical world. All would be tied to local and global networks, through embedded sensors that are always on. Often called the Internet of everything, the term IoT was coined in 1999 by Kevin Ashton, who dreams of a system where the Internet is connected to every physical object, via ubiquitous sensors.

Recently, building the IoT has become a global trend of governments across the globe. As the government initiatives form the foundations in creating a smart infrastructure, governments initiate projects to improve infrastructures, and to construct new channels that are more advanced and accessible. Governments and industry worldwide are investing billions of dollars to develop IoT computing. Such projects include Japan's u-Strategy, China's National IoT Plan by the Ministry of Industry and Information Technology, the Italian National Project of Netergit, the European Research Cluster on IoT (IERC), and the UK's Future Internet Initiatives. As IoT is increasingly seen as a priority in national ICT strategies, the IoT is being planned to develop an advanced computing environment, to pool computer resources to process, store, and access large amounts of data (Gubbi et al., 2013).

While the IoT is expected to have a massive impact on society and wider cultural milieu, these are still early days, and many challenges lie ahead. There is no standard definition of the IoT as of yet, and protocols and standards are still in early development. Questions arise such as what will the IoT landscape look like, and what will its impact be? As the IoT rapidly develops, it sheds light on serious problems. For example, as the IoT expands the number of connected devices integrated into our everyday lives, they have the potential to allow cyber attackers into the physical world in which we live, as they seize on security holes in these new systems. As Winter (2013) points out, the discussion of the IoT so far has been predominantly focused on the

technical aspect of design, such as network development. This may be even more true of Korea, where IT has been the key national agenda, and the IoT is considered as one kind of IT. Up to the present, most IoT efforts have been focused on the development and integration of IoT technologies and resources. Fewer efforts have focused on the immense repercussions of the social dynamics and organizational, policy, management, and most importantly user issues inherent in developing and deploying the IoT. Such choices, and the social, cultural, and behavioral impacts of how we develop, manage, and evolve the IoT, will be critical to its success. This study argues that the IoT is a socio-technical ensemble (Bijker, 1995), and thus its design and development should be based on human needs, and its ultimate status should accordingly be a human-centered system. This argument supports the idea that the analysis of infrastructure should be based on contextual analysis (Shin, 2010). According to Holtzblatt, Wendell and Wood (2005), contextual analysis examines the processes of technology development, offers heuristics to improve problem formulation, and equates better designs with improved problem formulation, improved understanding, and improved communication. These approaches are indeed *in situ* contextual, in the sense that they heavily scrutinize local features of the decision situation. They argue that the very meaning of a real environmental problem is anchored in a place, which includes the physical features of a geographic location, and also the users who live there, and their institutions and politics.

Because the notion of the IoT has evolved from a different context, it is essential to investigate the IoT within the context where such IoT is being placed and used. Thus, contextual analysis is a particular imperative in this study. With the contextual analytical focus, this study attempts to identify opportunity, prospectus, limitation, and risks embedded in the IoT design in Korea. By identifying such socio-technical challenges, this study conceptualizes a human-centered IoT that finds an optimal point among appropriate regulation, industry dynamics, and market receptiveness, addressing issues such as how the IoT should be developed and stabilized in Korean society, and what its social and regulatory issues are. To this end, a socio-technical approach is used to uncover the underlying ongoing IoT issues, which in turn help to design a human-centered IoT. The Korean IoT has a tendency to be designed in a technology-oriented fashion, as its name implies. A socio-technical perspective can provide an integrative and comprehensive framework, to reflect diverse human-technology interaction in the IoT. The socio-technical framework used in this study is to drive a wedge between the technical and social

understanding of the IoT (Shin, 2012). This relationship, between technology and society, between technical artifact and the context that surrounds it, provides an essential insight into the way infrastructure has been designed, deployed, and developed (Sawyer & Eschenfelder, 2005). In particular, the Korean Internet case offers an excellent example of such socio-technical interaction. Since Korea has been pioneering the development of IT infrastructure and services, it has become a leading country in the world in introducing a series of advanced smart technologies (Shin & Jung, 2012).

While the development of IT hardware has been very actively pursued in Korea, other non-hardware aspects have not been so well developed, compared to those of hardware. Such contrasts provide nice analytic materials for the IoT, where a large part of socio-technical interface and interaction issues arise. In this light, it is worthwhile to see how Korea develops the IoT and what might affect its IoT design. The following research questions guide this study:

1. What socio-technical obstacles and problems are encountered in the attempts to develop the IoT in Korea?
2. How can the IoT be designed as a human-centered system, as opposed to a technology-oriented one?
3. What elements may be considered to be constitutive for the IoT as a human-centered system?

With these inquires in mind, this study delves deeply into Korea's IoT development, by tracking the ongoing activities and discourses for infrastructure, and examining the social trends building around the IoT, and the future demands they will meet. In the road to the IoT, a number of socio-technical challenges are being identified (Winter, 2013). This study focuses on an evolving vision of what IT can do, and the challenges of sustainability, openness, integration, and control that it presents. The approach allows a prospective analysis regarding future uses of IoT in a socio-technical system, satisfying the call for more prospective and prescriptive research into the use and acceptance of the IoT (Boos & Grote, 2012). The findings in this study give the implications of designing an optimal ecology for humans and the IoT, drawing on what can be done with technology, software, organizations, and policy.

This study is structured as follow: Section 2 provides a literature review on socio-technical theory and approach, followed by the definition and trends of the IoT; Section 3 then describes the method used in this study; Section 4 introduces and traces the history of Korean information infrastructure development; Section 5 presents critical socio-technical insights; Section 6 draws on the Korean model for IoT architecture, and Section 7 discusses some implications for practitioners; Section 8 presents topics for future studies; and finally, Section 9 ends with the conclusion of this study.

## 2. Literature review

### 2.1. Theory of socio-technical systems

Shin and Jung (2012) argue that when it comes to the investigation of systems and the applications, technical aspects traditionally have been in focus. This traditional approach is rather narrow, and studies need to highlight the interaction between the technology itself, the people who use it, and the organizational and environmental context in which it is embedded. By studying the different layers and the interaction between them, a more comprehensive view of the system will be revealed. Besides looking at the technical core, it is necessary to consider the manufacturers that control the technical equipment. The working conditions affect the system's function on the whole. The organizational infrastructure is also of great importance, since all parts of the organization need to function together, in order to enhance system performance. The environmental context in which the system is embedded also affects the operation. Depending on the type of system, environment factors could include laws and regulations, market competition, or societal factors. Shin (2010) emphasizes that a holistic approach to system analysis is central, since all the layers together define the overall performance of the system. Similarly, Sommerville and Dewsbury (2007) highlight the need for a cross-disciplinary framework that represents all the aspects of technological systems. This includes the technical equipment, the market, the users, and the society for which the system is adopted. If all aspects of the system have not been adequately considered, a new design runs the risk of being a failure.

A socio-technical approach has been frequently used in the research of information infrastructure (Mumford, 2006). Tapsott (1996) discusses the national information infrastructure (NII) of Asian countries, based on a normative framework that describes the plans undertaken by the country's main players, to create resources and opportunities for economic and social

development. Borgman (2000) conceptualizes information infrastructure as a socio-technical system: a NII is an idea about forging a network that provides society-wide information access. Such an infrastructure is perceived as a way of maintaining a vision of an open and democratic society (Hedstrom & Wallace, 1999). This view is in line with Shin's case study (2008), which argues that a national information infrastructure is a social construction artifact. In all, a socio-technical perspective can be a powerful tool when looking at dynamic technology development, and where sustainable technology development takes place. When governing for sustainable network development, all other innovations besides technological innovations, having effect on this socio-technical domain, should be considered. This covers the establishment of an industrial policy, which would provide incentives for, and support development and diffusion of technological innovations. Institutional and social innovations can act as drivers for industry, towards undertaking technology development.

The rise of the IoT has important socio-technical implications for individuals, organizations, and society overall. While ubiquitous and wireless technologies are developed to enable new ways of working, to increase safety and to facilitate coordination, they may interfere with established work practices, undermine productivity and individuals' satisfaction, and have an unforeseen impact on relations of power and control. Despite the influx of new products and considerable enthusiasm around the IoT, from a design and technology point of view, we are in a blank slate moment. It is obvious that connected devices are possible, but we're not exactly sure why we need them. This is a question of socio-technical perspective. These kind of questions, however, are rarely addressed in development and research projects for the IoT, and in the public discourses surrounding it. The goal of this study is to clarify a practical and theoretical point of view of the conceptualization of the IoT as a human-centered system, by clarifying a series of innovations that are required for the IoT. Socio-technical systems can show a specific kind of complexity, because these systems are of a hybrid nature, which consists of a different nature of elements that interact with each other.

## 2.2. Definition and scope of the IoT

The IoT is developing rapidly, challenging assumptions underlying the future Internet business, market, policy, and societal models (Schindler et al., 2012). The IoT describes a future computing scenario, where everyday physical objects will be connected to the Internet, and will

be able to identify themselves to other devices (Chen, 2012). The term is closely identified with RFID as a method of communication, although it could also include other sensor technologies, other wireless technologies, QR codes, etc. The *thing* in IoT can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when the tire pressure is low—or any other natural or man-made object that can be assigned an IP address, and provided with the ability to transfer data over a network.

In this study, the scope of the IoT has been expanded, so that this study regards the IoT, beyond its technical application. The technical aspects of the IoT have been extensively pursued, but little research has tackled the problem of the IoT in the context of the entire socio-technical system, with the interactions between the social and technical parts. If fully developed, the IoT will be a full information infrastructure, serving society as a whole. While a traditional infrastructure is required for an industrial economy, the IoT may be required for a future knowledge economy. In this light, the IoT can be viewed as an extension of information infrastructure that has been implemented for decades. And the principle of information infrastructure can be applied to the IoT, because what information infrastructure had tried to be is falling into the IoT vision (Winter, 2013). Focusing on this underlying principle as a normative framework, this study investigates the role of government, in helping a country forge its path into the IoT environment. Although the envisioned IoT alone cannot cure the possible problems in IoT development, it could have a significant impact if it is properly guided by government, and effectively linked to industry collaboration. Thus, this study focuses on the processes involved in the planning of IoT projects, and evaluates its prospects. It examines the direction, nature, and future of the IoT, by focusing on the human, social, and political economy of informatization.

### 2.3. International trends

IoT activities are gathering momentum around the world, with numerous initiatives underway, across industry, academia and various levels of government. Large scale initiatives are underway in Korea, Japan, the US and Australia, where industry, associated organizations and government departments are collaborating on various programs, advancing related capabilities towards an IoT. This includes smart city initiatives, smart grid programs incorporating smart metering technologies, and the roll-out of high speed broadband infrastructure. The need for consensus around IoT technical issues has seen the establishment of

the Internet Protocol for Smart Objects Alliance, now with more than 60 member companies from leading technology, communications and energy companies, working with standards bodies to specify new IP-based technologies, and promote industry consensus for assembling the parts for the IoT.

In China, the IoT has been developed with M2M, which is expected to grow from $642 million in 2014 to $2.76 billion in 2016, with smart meters and smart grid being a significant portion of the market. M2M has a solid place in China's national economic strategy. China's latest economic five-year-plan has placed the IoT as a key, strategic national industry initiative for the country. The IoT has been included in China's Twelfth Five-Year plan (2011-2015). The Five Year Plan specified IoT investment and development to be focused on: smart grid; intelligent transportation; smart logistics; smart home; environment and safety testing; industrial control and automation; health care; fine agriculture; finance and service; and military defense.

In Europe, extensive effort is underway to consolidate the cross-domain activities of research groups and organizations, spanning M2M, WSN and RFID into a unified IoT framework. The European Commission 7$^{th}$ Framework program (EU-FP7) strongly supports IoT project, the IERC. Encompassing several EU FP7 projects, its objectives are: to establish a cooperation platform and research vision for IoT activities in Europe, and become a contact point for IoT research in the world. At the same time, the IoT Initiative (IoT-i), started in 2010, is a coordinated action established to support the development of the European IoT community. The IoT-i project brings together a consortium of partners, to create a joint strategic and technical vision for the IoT in Europe. Simultaneously, the SmartSantander project is developing a city scale IoT test-bed for research and service provision, deployed across the city of Santander, Spain, as well as sites located in the UK, France, and Germany.

## 3. Method

As to methods, the study was informed by a literature review, key informant interviews and a survey. Qualitative data analyses are important tools of investigation for socio-technical research. In particular, content analysis and interviews allow researchers to explore the formation and development of networks, and examine the alliances built along the way. In this particular research study, interviews allowed feedback in clarifying questions, allowed the interviewer to probe for a clearer response, allowed a lengthier period of questioning, and generally afforded a

much higher response rate. Interviews are now a well-established means of qualitative data collection in the information systems field.

Qualitative and factual data were collected using multiple data collection methods—surveys, in-depth and face-to-face interviews, telephone interviews, and e-mail exchanges—with people (government officials, regulators, industry players, professors, and researchers) associated directly with the design and development of IoT. The interviewees were thoughtfully selected, and a total of 71 in-depth interviews were conducted, either by telephone, or face-to-face over a two-year period. In most cases, the author visited the host organizations where respondents worked, and in other cases, the meetings took place at other venues, at the request of the respondents. Participants were government officials, industry representatives, and academic researchers (Table 1). The interviews usually lasted no longer than two hours, but several lasted five hours. All interviews used a combination of structured and unstructured stimulus items. E-mail exchanges followed the interviews. In addition to face-to-face interviews, a total of 23 interviews were conducted by telephone. Overall, phone interviews lasted as long as the face-to-face interviews. To make data from telephone interviews compatible with face-to-face data, a structured template of interview questions guided the telephone interviews.

The minutes of each interview were taken by an assistant, and they were re-written afterwards. Interview scripts were coded simultaneously, but independently. Inter-coder reliability, a simple percentage agreement to assess consistencies between the coders, was 91%. This is regarded as satisfactory (Weber, 1990). Computer-assisted qualitative data analysis software, Atlas.ti, was used to explore complex data, and to extract a few compelling themes, from a huge amount of primary text documents.

Survey questionnaires were sent to those who could not schedule interviews, such as people in high-level strategic positions, and officials in industry and government. The survey was composed of open-ended questions and short-answer questions related to government roles. A total of 147 questionnaires were mailed out, and 33 of those were returned via mail. In addition, survey questionnaires (133) were individually e-mailed, and a total of 40 responses were returned. Of the returned surveys, only 14 usable responses were selected for analysis. Survey questions were composed of structured and unstructured items. Unstructured questions (open-ended questions) asked respondents to express their opinion, or write essays on specific

subjects. To integrate the survey outcomes to the interview scripts, the survey questions were based on the actual interview script questions.

Archival materials, such as industry reports, government publications, technical reports, and any materials pertaining to planning and development, were collected and analyzed. Archival materials were useful in obtaining factual data, such as figures and statistics of IT-related usage. Such archival data complemented possible missing data from key stakeholders who could not be interviewed, or who were mistakenly excluded from data analysis. For example, this study collected large amounts of second-hand data from the news media, which had conducted extensive interviews with various individuals, such as government ministers, or the head of a government agency.

Table 1

*Data collection*

| Sectors | | Methods | | Responses |
|---|---|---|---|---|
| Government | | Face-to-face | 5 | 22 |
| | | Phone | 8 | |
| | | Email interview | 5 | |
| | | Mail survey | 4 | |
| Industry | Content/Service provider<br>System/Telecom<br>Electronics<br>IT manufacturing | Face-to-face | 6 | 27 |
| | | Phone | 6 | |
| | | Email interview | 10 | |
| | | Mail survey | 5 | |
| Academia | | Face-to-face | 7 | 22 |
| | | Phone | 8 | |
| | | Email interview | 3 | |
| | | Mail survey | 4 | |
| Total | | | | 71 |

## 4. Korean history of building the IoT

In some ways, the IoT is not a completely new concept in Korea. With different names and projects, the IoT has been progressively pursued since the 2000s. It is useful to review cumulative efforts in the past and present, in order to draw implications for the IoT for future development in Korea. Bijker (1995) argues that historic reviews reveal how current technologies are contextually linked to past, and also show future trajectories. He theorizes the social construction of technology theory, through extended historical accounts that contextualize and theorize his theory. In this light, this study traces the history of Korean NII, to see how the past NII trajectories influence the current IoT project, and how the future Internet will be projected.

### 4.1. National Basic Information System (NIS)

In 1984, the Korean government started the first national IT project, in which five major networks were planned: the National Administrations Information System, the Financial Information System, the Education and Research Information System, the National Defense Information System, and the National Security Information System (Shin, 2008). The goal of national computerization was to use IT for economic growth. It was thought that if Korea had been exposed to economic activities during the industrial revolution of the past century, the country would already be at the same level of development as the economic powers. The development of the NIS has been explicitly aimed at promoting IT use in Korea. In some areas this has been successful. For example, the National Administrations Information System's early stage (1987-1991) saw the installation of minicomputers and PC's in various administrative offices, and the building of networks and relevant databases for internal operations and provision of services to the public. Nevertheless, the NIS strategy has been ineffective in some areas, because the project was largely a supply-push enterprise that did not account for demand. The government maintained leadership in the process, from the beginning of planning, through implementation. A more compelling reason for ineffectiveness may be the government's withdrawal of financial support from the NIS strategy. At the beginning of the project, about $200 million in funding was set apart in advance for the National Administrations Information System. In the following stage, however, the project virtually stopped further development, due to budget cutbacks, and reduced support from the government.

### 4.2. Korea Information Infrastructure (KIS)

Having built upon the NIS project, the second Korean NII project, KII, started in 1993. KII uses a dual-channel information superhighway, one component for government information, known as KII-G (government), and one for public information, known as KII-P (public). The KII-G component is to provide basic physical infrastructure in government agencies, and also in important cases where the private sector cannot financially justify an investment, to experiment with networking technologies, and to induce the private sector to make investments, where appropriate. The KII-P was aimed at building advanced local loops to provide multi-media applications, and secure these services to businesses and organizations, to enhance its competitiveness. The project of KII, however, ceased, during its rollout. The KII project faced unexpected setback, when the first phase of construction was completed in 1998. While there was plenty of supply of bandwidth, there was very little demand. Abundant supply with little demand led to an aggressive price war in the area of data communications and leased line services, critical resources for the start-up ISPs and corporate users of the Internet. As the government is a major user of the infrastructure, KII should have prepared for the general public to use the new technologies and services, so they could benefit from the enhanced capabilities. Both KII and its predecessor, the NIS, were deemed to be a means to boost the economy, and infrastructure was a simple tool to such industrial goals.

### 4.3. IT839

Since 2000, Korea has been quite aggressive in the planning and designing of ICT, and the Internet. In February 2004, the government announced a new strategy called IT 839 Strategy. This strategy was drawn up to give a new momentum to the economy after broadband. It is the first full-fledged NII project for Korea, since it lays out a roadmap for both developing technological infrastructure, and for building information capability. The government seems to realize that infrastructure would be ineffective, without proper applications. In that light, IT839 calls for greater attention to be paid towards developing digital content and services. It is dubbed 839, because it has three pillars — services, infrastructure and new growth engines — which have eight IT services, three infrastructures, and nine new growth engines. The underlying tenet of the IT839 project is that deploying new infrastructure and application will generate investment

in major industrial sectors, which will help develop key new growth engines. Compared to its previous projects, which were no more than technical roadmaps, IT839 has a more comprehensive view, focusing on interconnectivity among infrastructure, services and applications. Yet, with all these projects throughout the history, a legitimate question is still lingering, "Is this infrastructure and are these applications coming out of the contextual relations to market and society, or are they co-evolving with ever-changing contexts?" Or simply, "How does IT839 bring change to the lifestyles of (its) citizens?" Unfortunately, that is missing in the blueprint at this point in time.

### 4.5. Grid-infrastructure

Korea has begun to invest in grid infra, as part of a strategy to enhance information infrastructure. The government has proactively been involved in the development. The first effort building Internet infra was launched in 1995, with the Very High Speed Information Network (VSIN) by the Ministry of Information and Communication (MIC) (Park et al., 2006). The VSIN project aimed to build a nation-wide optical communication cable infrastructure. It has provided high-speed communication networks to most commercial buildings and apartments in Korea. The Korean government then built Internet services upon the infrastructure, which enabled e-government services, e-commerce services, and other IT application services with low cost and high quality. MIC spent 7 trillion won (about $7 billion US) for the implementation of VSIN. Since the implementation of VSIN infrastructure, MIC has focused on developing bio-technology and nano-technology. MIC further initiated a new project, the Korean National Grid Infrastructure (K-Grid). K-Grid began in 2002, and aims at building a high performance research infrastructure that can dynamically collect, integrate, and share distributed and disparate resources, such as supercomputers, large scale storage, and advanced instruments. Korea Institute of Science and Technology Information plays a leading role in the construction and operation of the production quality Grid infrastructure needed for large-scale collaborative research in scientific and commercial applications. The main goal of the K-Grid infrastructure, which integrates computing power, massive storage systems, and experimental facilities as a virtual single system, is to provide an extremely powerful research environment, for both industry and academia. The K-Grid project entails construction of the K-Grid infrastructure,

including Access Grid, development of its middleware, and research and development of Grid applications.

The construction of K-Grid infrastructure was divided into two phases: the first phase (2002-2004) was for constructing Grid test-beds, and providing basic Grid services, with 15 small-scale cluster systems, from computing centers and university laboratories. As diverse interests in the Grid have increased, the demand for a sustainable, production level Grid infrastructure has been rapidly growing, not only from users of the K-Grid project, but also from related projects, such as the e-Science project of Korea, and the Korea Construction Engineering Development project. The second phase (2005-2006) of the K-Grid infrastructure was the result of such requirements. Its objective was to construct a reliable Grid service infrastructure. The K-Grid infrastructure is expected to be used in diverse fields, far beyond the traditional applications of supercomputing.

## 5. The IoT as a socio-technical artifact: Applying a socio-technical perspective

Getting to the core of technologically-mediated phenomena requires understanding the interplay between social structures, industry, policy, and technology. By analyzing such interplay, this study contributes to the design of the IoT as a socio-technical artifact, and to the ongoing political and legal debates surrounding its continued move towards ever-increasing ubiquity in culture, politics, commerce, and society. Using a socio-technical framework, this study frames the IoT as socio-technical systems – networks of technology, information, market, users, and practices.

An information infrastructure has been defined as a socio-technical system (Hanseth & Lyytinen, 2004; Hanseth & Monteiro, 2000; Shin & Jung, 2012) that comprise networks of technology, information, people, rules, and practices. It is about information infrastructure's interactions with the larger world of work, institutions, knowledge, and society, as well as with the production of knowledge. The characterization of IoT as socio-technical systems is obvious, and it is important to consider all the aspects that constitute a socio-technical system, when the technology is analyzed. As indicated by Sawyer and Tapia (2007), it is difficult to distinguish between the different layers that make up a socio-technical system. As they are intertwined in a complicated manner, they cannot easily be analyzed separately. Thus, there has been an emerging trend to analyze information artifacts from an integrated framework, such as a socio-

technical ensemble perspective. The socio-technical model presented in this study is a comprehensive framework, which addresses environmental, social, content, and technical aspects of the information infrastructure. Each factor is explained in reference to other factors (i.e. the technical system is explained considering the social system, and vice versa).

### 5.1. Technology issues

#### 5.1.1. Architecture

The IoT architecture should be an open architecture, using open protocols to support a variety of existing network applications; In addition, it should also include some scalability, security and semantic representation middleware, to promote data world integration with the Internet. The IoT should be a five-layer structure; it contains a sensing control layer, networking layer, resource management layer, information processing layer and application layer (Figure 1).

| Layer | Legend | Description |
|---|---|---|
| Layer 1 | *Sensing and control layer* | This the foundation of the development and application of the IoT, including RFID readers, smart sensor nodes and access gateways, etc. A variety of sensor nodes sense the relevant information of the target environment, and pass it to the nearest gateway, then gateways submit their data. |
| Layer 2 | *Networking layer* | This is mainly responsible for the different types of networks integration, such as the Internet, Mobile Communications Network, and Broadcast Television Network. In addition, it will also provide routing, format conversion, address conversion, etc. |
| Layer 3 | *Resource management layer* | This will provide the initialization of resources, monitoring the operation status of resources, and coordination of work between various resources, and achieve cross domain interactions between resources. |
| Layer 4 | *Information processing layer* | This layer realizes the reasoning and semantic understanding of sensing data; it also provides data query, storage, analysis, mining, etc. Cloud computing could provide a good platform for sensing data storage and analysis. It is an important component of information processing. |
| Layer 5 | *Application layer* | After analyzing and processing the sensing data, this application layer uses the data to provide users with a variety of different types of services. IoT applications can be divided into network monitoring, control type, scanning |

| | | |
|---|---|---|
| | | type, etc. The IoT should also include some support technologies, such as network security, fault-tolerant mechanism and quality control throughout all levels, to provide application support. |

*Figure 1*. The IoT architecture

5.1.2. Key technologies

The key technologies for the IoT include (1) IPv6, which is responsible for things' identification, (2) sensor technology, which is responsible for dynamic information sensing, (3) communication technology, and (4) network integration technology, which realizes information transmission and intelligent information processing technology. They are called the four key technologies of the IoT.

-*Identification*

The IoT is a vast network that contains millions of things, with various items of intelligent equipment forming a network through multiple interconnection ways. Identification technology is associated with the things, and it is a globally unique value, which is used to unambiguously identify the object. The essence of identity is encoded and digitized to all things.

-*Sensing technology*

Data generation, access, transmission, processing and application are the important components of the IoT. Data acquisition is one of the important links; otherwise, the IoT is nothing but vain words. In the IoT, based on sensing devices, including RFID, sensors, infrared devices, and global positioning system devices, the real-time data are acquired to terminals. Sensor can detect external environmental signals, including heat, power, light, electricity, sound and others, which can provide the raw data for data transmission, processing and application in the IoT.

-*Communication and network integration technology*

The transmission of sensing data in the IoT mainly relies on network and communication technology, and the communication may divide into short distance wireless communication, and wide-area network, according to the transmission type. Network integration technology makes

full use of different network communication resources, according to different application environments and local conditions, providing a richer network services for users, through flexible and efficient networking ways.

*-Intelligent information processing technology*

In the Internet of Things, in order to sense an event, it requires the deployment of many types of different sensing devices to monitor different attributes of the event, and then determine whether the incident occurred, through the integration of sensing data. The key technology is how to transform the physical sensing data into logic data that is easy to understand by man and machine. Intelligent information processing technology integrates intelligent computation, data mining, optimized algorithm, machine learning, and so on.

5.2.1. Service and applications

It is almost impossible to envisage all potential IoT applications, due to the rapid development of technology, and the diverse needs of potential users. Table 2 summarizes the current services and applications of IoT being developed in Korea.

Table 2

*Service and applications of IoT*

| Services | Descriptions |
|---|---|
| *Smart Cities* | Songdo, 40 miles south of Seoul in South Korea, the first of its kind fully equipped and wired ubiquitous, or smart city, is nearing completion. Nearly everything in this digital metropolis of smart homes is planned to be wired, connected, and turned into a constant stream of data that would be monitored and analyzed by an array of computers, with little, or no human intervention. Songdo as a smart city will be an exemplar model for other smart city in the world. |
| *Smart Energy & the Smart Grid* | There is increasing public awareness about the changing paradigm of our policy in energy supply, consumption and infrastructure. For several reasons, our future energy supply should no longer be based on fossil resources. Neither is nuclear energy a future-proof option. In consequence, future energy supply needs to be based largely on various renewable resources. |

| | |
|---|---|
| *Smart Transportation & Mobility* | The connection of vehicles to the Internet gives rise to a wealth of new possibilities and applications, which bring new functionalities to the individuals, and/or the making of transport easier and safer. In this context the concept of the Internet of Vehicles (IoV) connected with the concept of the Internet of Energy (IoE) represent future trends for smart transportation and mobility applications. |
| *Smart Home, Buildings & Infrastructure* | The rise of Wi-Fi's role in home automation has primarily come about due to the networked nature of deployed electronics, where electronic devices have started becoming part of the home IP network, and due the increasing rate of adoption of mobile computing devices. |
| *Smart Factory & Manufacturing* | The role of the Internet of Things is becoming more prominent in enabling access to devices and machines, which in manufacturing systems, were hidden in well-designed silos. This evolution will allow the IT to penetrate further into digitized manufacturing systems. |
| *Smart Health* | The market for health monitoring devices is currently characterized by application-specific solutions that are mutually non-interoperable, and are made up of diverse architectures. While individual products are designed to cost targets, the long-term goal of achieving lower technology costs across current and future sectors will inevitably be very challenging, unless a more coherent approach is used. |
| *Food & Water Tracking and Security* | Food and fresh water are the most important natural resources in the world. Organic food produced without the addition of certain chemical substances, and according to strict rules, or food produced in certain geographical areas will be particularly valued. Similarly, fresh water from mountain springs is already highly valued. |

5.2. Social and cultural issues

A few of the socio-technical issues for the IoT include standard, security and privacy. The lack of standard protocols to enable communication between sensors is resulting in siloed devices. Also, security of the data collected is a huge concern. While we might not be concerned about the security of temperature data from supermarket freezers, there are concerns about storing personal medical data. Additionally, there are privacy concerns on the type and amount

of information that is gathered about individuals that they might not even be aware of. Edward Snowden disclosed that National Security Agency has illegally collected massive data using advanced IoT technologies. In response to these rising concerns, IoT projects should bridge multiple cultures, addressing various social issues and problems. It is important to provide a framework for action. To be an effective IoT, it should (1) be accessible as a public good; (2) be sustainable; (3) provide interoperability; (4) facilitate collaboration; and (5) support experimentation. So far, there seems to be not enough efforts on social issues regarding Korean IoT projects. As it is in the early stage of development, primary forces have been focused on building technological infrastructure and technical equipment of the IoT. There are tendencies in Korea that view the impact of the IoT on society and culture as merely a side benefit of efforts aimed at practicing scientists (Shin & Jung, 2012). It is noted that Korea appears to overestimate the near-term effects of technology, and to underestimate its long-term consequences.

### 5.3. Government

The Korean government has taken a highly proactive role in promoting the IoT. Several technological initiatives of the IoT have been launched by the Korean government. Ambitious technology-driven programs have already led to a number of remarkable R&D and technology demonstrations. The government has laid the foundation for a technological approach towards complete IoT systems and networks. In parallel, a number of operators have developed a comprehensive strategy towards IoT development. Their IoT visions tend to be more in line with the original vision of the IoT developing as the next generation of the ubiquitous computing environment. They focus more on increasing technological capacity, through developing new systems or system components, and less on the applications and social services over infrastructure. The country envisions their government taking an active role in driving domestic manufacturers to set early IoT standards.

The government is sponsoring active research activities through ETRI, which is conducting cooperative research with universities, IT service operators, and domestic manufacturers. This cooperative activity is led by ETRI, with contributions from many participating organizations, and collaborative work via international partnerships. Goals of Korea’s R&D activities on the IoT are to take global leadership in ubiquitous computing, and to establish the world’s first Broadband Convergence Network-based infrastructure that can

converge wired, wireless and broadcasting systems. In order to support such research activities, and establish the vision and strategies of the IoT, the Korean IoT Vision Committee and IoT Forum were organized in January 2010 and October 2011, respectively. The government plans to invest money equal to $58.4 million over the next three years into both advancing the information infrastructure, and starting work on the IoT at the same time.

### 5.4. Industry

The IoT is becoming a major accelerator for innovation in all industries. The IT Industry has been actively working with the government in the area of technologies and equipment. Participating industrial leaders include Samsung, LG, Korea Telecom, and SK Telecom, which all regard IoT as an opportunity to develop new markets, particularly killer applications. These industries have received governmental support, or a subsidy to develop new technologies for the IoT. Industry is a good partner to the government to develop new technologies for a cash-cow.

## 6. Discussion: Socio-technical challenges surrounding the IoT in Korea

The advent of the IoT will bring a number of transformations to the smart environment, and drastic changes of regulation and policy, as well as improvement of service innovations into a future smart world (Gubbi et al., 2103). From a socio-technical perspective, a legitimate question is how to design the IoT, rather than what IoT to build. In other words, what matters more is the design process itself, more than the final status of the IoT, because it keeps evolving. Thus, the relevant question is, how to make the concept of the IoT relevant to their ongoing context, where the technology is used and developed? This question is very much related to socio-technical inquiries. One of the key questions may be, “Is it ready for the IoT?” or, “Is it reasonable to prepare the IoT, when the previous projects of NII are not even in full use yet?”

Although the development of the IoT is very actively carried on in Korea, there are significant obstacles ahead of the development of the IoT. A question is how Korean IoT get there from here, and where do they go from here? Such issues involve who is to pay for the huge transformations, and how? How do we effectively make the case for attention to the IoT, among the other competing demands for a limited budget? How can the budget be expanded, especially when there are strong public criticisms on the previous failures of IT projects? These series of questions are related to an existing common tendency in Korea to speak of building the IoT, as if

infrastructures can be built strictly from plan, in a highly conscious, carefully controlled, and fully directed sort of way (Jackson et al., 2005). A historic review of the Korean information infrastructure weighs heavily against this common tendency (Shin & Jung, 2012) and the legacy remains in the IoT. Also, the current IoT is being developed rapidly, without appropriate consideration of the profound security challenges involved, and the regulatory changes that might be necessary. In particular, as the IoT spreads widely, cyber attacks are likely to become an increasingly physical threat.

The development of the complex software and hardware system that will constitute the IoT is a cutting edge activity that will require substantive design, development, deployment, and evolution. At its core, the challenge of the IoT is to enable diverse and disparate components, services, and technologies to work together. Moreover, these pieces are operated and supported by users across multiple groups. The operation and management of a large-scale core IoT facility will require highly coordinated activities. These challenges are currently occurring for their ongoing IT projects, and at the same time, will be happening for the IoT, as well. The IoT is about new technologies, and is only in its adolescence. Many of the visions of the Korean IoT are largely a self-serving, hope-filled prediction. Possible challenges have been neglected by the government, who has its own ideas about the IoT.

This is about socio-technical design challenges, and is the reason that the IoT has been dubbed as a marketing label, to promote a particular vision of future Internet evolution. Unfortunately, most of the stakeholders involved in the IoT development pursue the plan with their own beliefs and interests. They should remember that in information infrastructure development history, many technology visions have been derailed, or diverted by the unexpected (Shin, 2010). In the case of the IoT, these unexpected obstacles appear to be more compelling, and more immediately relevant to our society, than other cases. The efforts should be given to build new communities of users and technologies, and attention should be focused on using the IoT effectively in society, and at the user level. It seems that with the advent of the IoT, Korea is expecting some form of drastic revolution. Korean officials regard the IoT as a way of leapfrogging to a next-generation smart environment. The Korean government seems to be more proactive than industry. They are taking a big leap, which they have planned for the IoT. At this stage, it’s still too early, and just what IoT is to promise, concerning the speed and services, is still unknown.

Just like the NII development, the advent of the IoT environment will likely occur incrementally, rather than in the form of a drastic revolution. The aim of the IoT movement should not be to revolutionize the provision of IT infrastructure and support, by consolidating it in the hands of a central IT. Regardless of technologies taken by industry, the evolution of the IoT will be much slower than expected, because of the immature socio-technical environment. The ambiguous vision and plan reveal a series of socio-technical challenges for various stakeholders to overcome, in the development of the IoT. Although there are wide ranges of predictions in the IoT, what seems less likely to happen is a smooth linear transition to a homogenous and universal pathway to development. The IoT is not a one-way initiative or one-off event by government, but rather a massive interaction, and participation of numerous parties. The IoT will be a platform for a user-oriented network, in which communities create value from multiple, individual contributions, so the future environment is one that will depend not only on large supercomputing centers and government, but on the changing practices of multiple arrays of individuals, all of whose developing practices are at work in designing new environments (Yan et al., 2008).

It is in the long-term interests of the Korean government to remain up-to-date with emerging trends in the IT field, even if that may involve difficult choices about how best to earn their past investments. And it is in the interests of Korean users and society to have access to an affordable and equitable information infrastructure, in order for society to remain competitive, and for citizens to enjoy full participation in the next generation of smart society. The situation is perhaps still changing too rapidly for specific policy recommendations to be possible, but clearly promoting research, facilitating the standards-setting process, and allocating resources are all areas in which policy-makers can exert some influence over the future direction of the industry, and the market.

## 7. Practical suggestions for the Korean IoT

In the IoT, people are not only the end-users, but are integral parts of the systems. It is therefore important to improve human interaction with such IoT systems. Barriers involved in linking humans and technological systems through an IoT raises a number of specific challenges, including human behavior recognition, modeling and representation; human interaction with the IoT technologies; and IoT system safety, security and privacy. Realizing the challenges and

opportunities of the Korean IoT, this study draws a model for IoT development. This model can be specifically applied to the Korean context, and, at the same time, it also can serve as a generic prototype for a universally applicable model. A new IoT architecture is required to support various fields and issues that maximize the benefits of IoT. As Gubbi et al. (2103) define, the IoT denotes the layer of information, expertise, standards, policies, tools, and services that are shared broadly across communities of inquiry, but developed for specific scholarly purposes. This study proposes a model that comprises 4 layers: (1) Network technology (network); (2) application technology (middleware); (3) user community (uses and services); and (4) governance (policy and regulation). All the components in the four layers are equally important to the whole system and process.

With the IoT architecture in place, this study proposes practical suggestions to the government for future IoT projects. The first recommendation affirms a continuity of investment in the core IT infrastructure that is the foundation for an advanced IoT – and, importantly, in designing the future IoT, technological functions and rationales need to be translated through a contextual aboriginal language (Shin, 2010). A contextual perspective should be taken heavily into account, in all the stages of development. Policy makers can seriously consider adopting a context-aware design in future IoT design (Shin & Jung, 2012). Lack of *in situ* and contextualized understandings in the planning and design of computing, can lead to intrusive technology, and an over-emphasis on infrastructure. In the long haul, governments will need to put more effort into leveraging social forces, and integrating such forces in technological arrangements, when implementing the IoT as a strategy toward advanced development.

Additionally, the IoT draws attention to another significant challenge, that of user acceptance. Governments have to be more involved in the micro-managing level of activities, to form social culture for the smart society. Per Freeman's argument (2007), the design process must constructively involve the technical, legal, policy, and usage communities. Given the previous IT history and legacy of their NII experiences, what matters in Korea is how well people use information properly, instead of whether one can go online or not. The success of bringing society into a smart ecology depends as much on people's attitudes and motivations towards the IoT. While the government can do just so much to promote IT, people have to embrace such events and moves, to want to make IT and information knowledge a part of their lives. People have to willingly allow the permeation of such ideologies to the core of their

private domains, to have the IT ideology in the crux of their daily lives, affecting the manner in which they do things, and in how they think. This question is related to build new kinds of critical socio-technical literacies.

Finally, the development of the IoT can be seen from a long-term perspective. The Korean government has shown its tendency to hurry up in the development of an information infrastructure (Shin & Jung, 2012). Since infrastructure is a social and technical construct, it is embedded in other structures, social arrangements, and of course, existing technologies. Infrastructure becomes an installed base, on which other things are built. Infrastructures are evolving over time, constraining and being constrained in a reflexive way, by the intricacy of the technologies, social relationships, and cultures. Because it is extensive and expensive, infrastructure tends to be *built incrementally*, neither all at once, nor everywhere at once (Star & Ruhleder, 1996). Therefore, infrastructure reaches beyond a single event, or a particular site of practice; and therefore, it takes time to stabilize. In this perspective, two key characteristics of the IoT can be proposed: maturity and complexity. The IoT as a system should reach a mature stage of development. It must grow and mature, at a level and time when impacts are stronger, more pervasive, and more divisive. The IoT should also have a combination of the culture and intricacies of related parts of which the IoT is comprised, and the scope of the IoT, in terms of the diversity of the users' characteristics. These characteristics take significant time to attain, because the IoT is something more specific than fundamental technology itself, but it is something more general than a tool or a resource developed for a particular project, a range of projects, or, even more broadly, for a particular discipline. This point is not to favor one component over another, that technical solutions are better than social ones, or vice versa, but rather to highlight their interchangeability. In other words, the boundaries between the social and technological are blurred and fluid, and can often shift, or be shifted, in either direction (Yan et al., 2008).

In all, Korea must have a broader contextual perspective, and consider all aspects of the IoT ecology, and the diverse stakeholders that are part of the scene, in order to ensure that future tools, technologies, and policies adequately meet the needs of all users and other stakeholders, and help to evolve and sustain the IoT itself. The IoT is actually a part of wider, socio-technical systems, comprising humans, human activity, spaces, artifacts, tools and technologies. As the IoT expands, it can draw on a growing domain of technologies, institutions, and strategies, for

coordinating and enabling infrastructure and controls. Optimizing these tools to support research and innovation requires a better understanding of the human and social forces surrounding the processes of science and technology. It requires a socio-technical, empirically grounded perspective on how tensions between enablement and control are addressed, and mitigated in practice. This may help Korea rethink and redefine laws and policies inherited from their previous development of infrastructure. In order to develop and implement the IoT as a socio-technical ensemble, the following suggestions are proposed:

- The government should support a meaningful IoT literacy program and awareness-raising, to empower self-regulation, and enhance individual interaction with the IoT.
- The government should support and promote knowledge sharing, research and social projects, constant debate and policy articulation, especially on security, privacy and ethics in IoT environments.
- Social demands should not be identified and addressed solely by the market. The boundary between the social and the economic has to blur, and society has to be reshaped into a more participatory arena.
- Users have to be empowered to utilize the IoT technologies to turn the physical environment into a socio-technical environment, where policies are shaped around them. Designers working with the IoT should be thinking from a human-centered perspective. The IoT is developed for human needs to provide the technology, framework and facilities to improve life and its meaningful experience.

## 8. Future research issues

The findings of this study have implications for both practice and academia. For governments, it provides practical guidelines, such as insights into information strategies and market structuring at a national level. It is too early to make a prediction regarding IoT roads and paths, but this study shows the potentials of new infrastructure, as well as a number of challenges that will come along with the technology. The findings imply the current Korean model of the IoT can be a viable and sustainable model for a new smart environment, but a supply side is not always equivalent to the demand side. In terms of policy, the findings imply that a series of legislative changes should be made, to define the future IoT infrastructure more clearly. In the future IoT, a growing variety of services will be provided on top of the basic connections. If

regulation is to be applied in the future, it should work along the lines of natural technological and social trends, and not at regulatory purposes towards them.

In addition to the practical venue, the theoretical contribution from this study can also be noted. A socio-technical framework has been normally applied in an organizational context, to give an implication for design issues. The framework has been rarely applied to societal or macro levels, for comprehensive analysis for emerging technologies. Only a little research has investigated interaction among the components of the theory. Much research using the socio-technical system theory investigates its components in a discrete way, and thus has somewhat neglected the integrated perspective, looking at the interactions by components themselves. This study applied a socio-technical framework to various levels of analysis, and drew an implication of human-centered design. In so doing, it clarified the interaction of the social and technological factors. The weakness of a socio-technical approach has often been indicated that the distinction between social and non-social artifact is often blurry, and, thus, the analyses of the interaction between technological artifacts and social entities are not always clear (Shin, 2008). This weakness can be a more challenging point, as well as opportunity, because people and technology can be viewed as two highly interconnected components in the IoT. For a better understanding of clear interaction, it would be worthwhile for future research to investigate the technological innovations of the IoT. Typical social science research using a socio-technical approach tends to analyze the technological change as black-box. Instead, future research can explain technological change, that is, how technological change occurs, and how a new technology is evolved. With these suggestions, future research will extend the integrated perspective of the socio-technical system perspective, looking at future IoT infrastructures. Future studies may draw on some examples from an empirical case study on the development and use, to illustrate the conceptualization of the IoT.

Korea is proud of being a global leader in linking their infrastructure to the Internet. The government has declared that it aims to lead the world in this new technology: Korean manufacturers are focusing aggressively on this new IoT, with a view not only of supplying a growing market, but also to laying down global standards. At the very least, Korea seems to have got off to a very impressive start, in what is likely to be a series of socio-technical challenges to come ahead. The IoT is, as yet, very immature, and a range of alternative scenarios are still

possible. As a result, all the analyses and forecasts are by definition open to criticism. The study is well aware that its findings are not the final conclusion on the topic.

## 9. Conclusion

Deployment of the IoT is not far from reality, and, unlike the previous NII initiatives, the IoT will, and should, exist for a long time. For the time being, however, the IoT remains more of an untested promise, than a reality. Creating the IoT is a grand challenge for all the stakeholders involved in Korea. Despite impressive technological advances, the IoT vision will not be easily realized. Many industry reports, as well as academic papers, discuss the prospectus of the IoT, and the specific visions enabled by technological infrastructure. What they have missed in their analyses is what the eventual benefits of the IoT development are, or what the eventual goal of the IoT is. The case of Korea is no exception to this *a priori* question. Various stakeholders related to IoT development in Korea are actively engaged in establishing a vision for the IoT, but clear vision of the IoT is still incomplete, or largely a supply-focused view. It remains the task of the stakeholders to take the IoT forward over time. The IoT development work is poised to move into the next stages: establishing criteria for the IoT. Only then will the clear picture be shown of what is and can rightly be called the IoT. By that time, stakeholders will face enormous challenges – far more than the technical – in human, socio, economic, and political battles with what it could replace. The IoT will support an increasing number and variety of users and usage scenarios, and will accelerate the evolution of an Internet culture (Yan et al., 2008).

For the upcoming IoT, Korea may need a series of socio-technical experiments that emphasize both the sociological, and the technological aspect of a development. As Star and Ruhleder (1996) suggest, infrastructure should be considered as artifacts emerging from practice directly connected to human activities and material structures. In this light, Korea probably needs an ethnographic perspective, when designing and deploying the IoT. For example, they may identify different narratives used by users to make sense of the IoT, explore how users will use the IoT, and investigate paradoxes in the upcoming IoT. These kinds of attempts are in line with socio-technical experiments, which can be of great benefit, in addressing core-identified challenges. The observations of this study reveal the implication on how to design with a combined technical and social view, how to structure design processes in multidisciplinary teams, and the translation challenge that addresses how to design for a context that is going to change

with the introduction of the new smart environment. How the IoT unfolds over the coming years will depend on the interaction of a number of socio-technical factors, under an uncertain future ubiquitous environment. These include the progress made in developing various technologies by industry, the emergence of a new culture in society, the creating of new user experience, and the adoption of new services by users. As socio-technical innovation develops in unpredictable ways, and such a socio-technical ecosystem evolves at different rates, an even more prudent approach is desirable in Korea, because what is most needed is not an Internet of Technologies, but an Internet of Humans.

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