

The Construction of Smart City Based on SoS

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Abstract - Because of its promotion in social development, Information Communication Technology (ICT) is drawing attention globally. As a result, the development of Smart City in our country is coming to the forefront. Correctly understanding the essence of Smart City is crucial for its development. In this paper, the concept of Smart City is first discussed. Then the essence of Smart City from the point of view of System of Systems (SoS) is discussed. With this basis, some problems with Smart City planning are brought forward, and the roles and status of the related parties (stakeholders) are proposed. The goal of this paper is to understand the essence and role of Smart City, to allow it to bring tangible benefits for the urban society and economy.

Index Terms - ICT, Smart City, system of systems.

I. Information Communication Technology and Smart City

Smart City has become a hot topic of government and ICT industry. Clearly, it is inseparable from the development of application of ICT and its increasingly obvious role in promoting social and economy development. At present, countries around the world have attached great importance to the development of ICT. Many established national policies and proposed their own plan or project, both in terms of infrastructure construction and in the overall application of ICT. With the popularization and development of ICT, how to make use of these resources more efficient to serve the economic and social development has become a concern for all countries.

Since ancient times, all human activities are inseparable from the support of information. Since the emergence of ICT, changes have taken place in support of both greater quality and quantity of information. ICT greatly extend the people's capability to manipulate information. Manipulation includes the following several aspects:

- *Collection and input.* ICT will greatly heighten people's ability to collect and input information. With the development of sensor and sensor network, much of information that used to require manual collection can be collected automatically. With the development of Artificial Intelligence (AI) like the image processing and natural language identification technology, some kinds of information collecting technologies came true, such as facial recognition, moving target recognition and tracing, etc.

- *Manipulation.* Manipulation is the extension of information collection and input, bringing together data and information from various sources. Information of a higher level can be acquired through manipulation with historical data and stored information. With the development of hardware and

software technology (such as the large scale integrated circuit, distributed processing technology, etc.), computing power has increased rapidly, allowing very complex information processing to be widely used. For example, image processing algorithms in the digital camera is only possible through the rapid increase of computing capability of microprocessors.

- *Transmission and communication.* The development Communication technology makes the spread and communication of information commonplace, with increased ability (efficiency, capacity, etc.). Today, the ubiquitous nature of networking not only greatly facilitates the communication people to people, people to computer, but also allows the communication things to computer or things to things to be widely implemented.

- *Storage.* With The development of data storage technology, human accumulation of information accelerated dramatically. It has been estimated that the worldwide capacity of stored data on electronic devices, by the end of 2011, is 1.8 zettabytes, doubling roughly every two years[1]. There is no doubt that large amounts of information are contained in these data. For instance, a compressed 10-megapixel color photo takes about 4.3M bytes of storage space. The first hard disk 350 RAMAC's capacity is 5 M bytes, which was invented by IBM in 1956 [2], weighs a ton, nearly 4000 times of the hard disk today. The volume of today's hard disk is 600000 times of 350 RAMAC's. Without the development of storage technology, we can hardly store image information generally, allowing easy retrieval.

The development of ICT brings new opportunity for the progress of the society. It has greatly increased the human ability to process information, greatly contributing to the development of society. With the rapid development of ICT today, if we want it to bring greater contribution for the social progress and development, we must consider the ICT role at a higher level and put forward higher requirements. People put forward development target with the support of ICT from the perspective of a whole society and a whole country. Most famous of which include America's Smart Planet Plan, Japan's I - Japan [3], south Korea's u - Chesapeake, u - City [4]. These projects have a common characteristic. That is, under the premise of the opening and integrating existing ICT infrastructure and information resources, let ICT provide better services for social development. This includes the improving people's livelihood, developing new economic growth point, strengthening the industrial advantage, and enhancing the competitiveness of the country. We also put the

new generation information technology industry in our strategic plan for the emerging industries[5].

In this situation, The Smart City construction has become a natural thing.

Smart City's function is to fully consider the application of the new generation of ICT at many factors in the urban development, and to make it become the strong point and strong driving force for the development of the city. To achieve this, the status of ICT in urban development and the characteristics of it as a support for urban activities must be seriously considered.

II. Development of the Smart City

People has different understandings of the Smart City, for example, the definition in references [6], [7], [8]. Overall, the Smart City is applying new generation ICT technology to city activities, achieving a certain level or stage of city state.

According to IBM's point of view, the city consists of six core systems, which are related to the city's main function as different types of networks, infrastructure and the environment: Organization (people), business / government, transportation, communications, water, and energy. These systems are not fragmented, but connected in a collaborative manner. The city itself is a macroscopic system composed by these systems [6]. In the Smart City, ICT not only support these activities directly, but is also an important link of collaboration and convergence. These systems make full use of ICT in collaboration and convergence, improving the level of the intelligent of the city.

The main point of the Smart City is to use intelligent ICT services to promote urban development. The progress of intelligence is the result of the expansion of information processing, these extensions include:

- *Scope*: The larger the amount of data acquired and processed, the more information available, the better support for higher level of intelligence.
- *Range*: More diversification of information and connection of data result in more information associated. More high-level information can be obtained, achieving higher level of intelligent.
- *Time*: Making use of historical data and information not only allow current information to be used more effectively, but can also predict the future, greatly improving the degree of intelligent of information services.

No matter the angle, to improve the degree of intelligence, it is necessary to obtain and store a large amount of data. The data is processed to extract useful information, to support intelligent automation services

In order to access a broad range of information, we must break the barriers of individual owners of information and data. Open integration is the basic conditions of a Smart City. To accomplish this, first, we need to change mindset and establish a mindset of for one, one for all in the field of information. Second, we need to establish the appropriate mechanism or mode, so that all the stakeholders in this city can both provide information services to the Smart City and get the

information support from the Smart City, and achieve their own development through these activities.

Like the complex composition of the city itself, the Smart City relies on ICT facilities and services throughout every corner to achieve its function. Thus, the Smart City is a project for the whole city, not just a business of the government, a technical departments, or one company. It takes the power of the entire city to build a Smart City

III. The Smart City And SoS

It is generally accepted that a system is a collection of elements that pool their resources and capabilities together. The system offers more functionality and performance than a simple sum of the constituent elements. From this perspective, combined with the above description, the Smart City should be a system. However, this system is not an ordinary information system (such as enterprise management information system). The relationship between the elements or parts is different from the general information systems. For example, it is different from enterprise management information system in the following aspects:

- An enterprise information system is owned by the enterprise. Even though its elements can have clear owners, the overall system of Smart City does not have a sole owner.
- All the elements of an enterprise information system serve the overall objective. The elements of the Smart City do not necessarily obey that rule. Some elements may even contradict the overall objective of the Smart City, but can be used in the activities of the Smart City regardless.
- A traditional enterprise information system and the elements are controllable and manageable. The parts of the Smart City system are autonomous, and overall unmanageable and uncontrollable. These elements can only be ruled and impacted from a higher level.
- Stakeholders may have different requests to the enterprise information system, but their goal is a unified, the enterprise's interests. Different stakeholders of the Smart City have different demands, the demands of these stakeholders are not consistent. Collectively, however, they are the goals pursuit by the Smart City.

Above all, if the Smart City is seen as a system, the system consists of many autonomous elements. In the system theory, this kind of system is called the System of Systems. A traditional enterprise information system is a Monolithic System. Today, information systems are open, many information communication systems having such a nature. The Internet is a prime example.

The SoS has five common characteristics[9][10]:

- *Operational Independence of Constituents*
- *Managerial Independence of Constituents*
- *Geographical Distribution of Constituents*
- *Evolutionary Development*
- *Emergent Behavior*

Emergent Behavior is the system behavior has the following properties:

- *Not observed in the past*

- *Cooperative association occurred*
- *Macroscopic*
- *Dynamic process or evolution generated*
- *Can be observed or perceived*

Reference [11] points out that the elements of the SoS are autonomous, determining its characteristics as mentioned above. Thus, the Smart City can be classified a system of systems.

The current research on SoS reveal its many characteristics, theories and methods. The application of these theories and methods achieves system objectives in the SoS environment, and there can be many valuable features. In order to better achieve the goal of Smart City, we must plan and construct it based on the characteristics of SoS.

IV. The Principles of Smart City Construction From the Point of View of SoS

Smart City has the characteristics of SoS. In general, the planning and construction of the Smart City is a metaphysical work. Many cities have attached great importance to the overall plan or “top-level design”, which indicated that they have realized that. From the point of view of SoS, the overall planning and construction of the Smart City needs to establish some principles and ideals.

A. Unify overall goal and stakeholder interests

From the perspective of SoS, a Smart City is made up of numerous autonomous systems (some of which themselves are SoS). The wide range of applications uses the system services in the way of emergent behavior. Thus, the overall goals (such as planners prioritizing living convenience) and the targets of different stakeholders involved in the system (such as enterprise seeking profit, which is in conflict with overall goal) are not uniform, sometimes even contradictory. How this contradiction can be solved is a question the system planners must consider. Only by solving these contradictions is it possible for more people to participate and obtain benefits. Overall, planning and construction should be able to accommodate the different demands and expectations of the parties of the Smart City.

B. Fusion, openness, and change of mindset

A very important premise of Smart City is information consolidation and openness. A member of the city can simultaneously be a user of information service and a provider of information service. Participation of wide variety of information services is paramount to achieve the goal of the Smart City. It is impossible with the government or a minority of enterprise organizations alone. Under this premise, the success of Smart City relies on the change and adaptation of new mindsets of all participants. The fusion of Smart City is “inclusive” rather than the “integration”. Based the change in mindset, and under the rule of the policy and legal, all kinds of information service providers and users reach a unified target and overall interests of Smart City despite different local goals and interests.

C. Government guidance and coordination

SoS does not have a overall control, only with the interaction and game between the components. As the country makes laws in order to coordinate the interests of all society parties, Smart City needs the government to formulate policies, laws and regulations to coordinate the interests of all parties, which is the precondition of achieving Smart City goals. This is mainly achieved through policy or interest orientation. Various measures must be taken to solve various contradictions and conflicts within the Smart City, such as the contradiction of information sharing and privacy protection, or the conflicts between enterprise interests and social interests. Recently, the conflicts between OTT (Over The Top, such as Tencent's WeChat) service operators and traditional operators fully embodies this point [12]. In this case, the government's intervention and coordination are necessary. It has quite a few precedents in the international field, for example, the number portability in the United States is carried out under the impetus of the government regulation. Monopoly NBN Co. (new national broadband network company) established in Australia is the result of government industry regulation for coordinating the interests of all parties.

D. Focus on planning and top-level design

Another important role of the government is to organize all forces for Smart City planning. Through the previous discussions, we know such planning is a metaphysical abstraction work. The focus of which is on the city, rather than the IT system. It involves a wide range, an unfixed boundary and complex associations. In addition, the environment, demand, and technology change over time. SoS does not have a stable state, but has a relatively Stable Intermediate Forms [13, 14], so it is a system with long-term evolutions. Smart City is in accordance with this feature. In order to adapt to these situations, planning or abstract description become very important. Relatively to the analysis and design of specific implementation, metaphysical abstract description is able to grasp the overall condition, and has a universal applicability of time and space. In addition, due to the difficult for interdisciplinary researchers to understand all kinds of details in the field, abstract description is also the essential means to the communication between stakeholders in different areas. This is very important for systems like Smart City with an unprecedented scale (both vertical and horizontal).

E. Attach importance to the innovative space of Smart City

Due to the development of information and communication technologies, the penetration ability of its application is becoming stronger and stronger, spreading gradually from fields such as engineering, business management to people's daily life, humanities, and social science. The great inclusiveness (fusion) of the Smart City as the SoS brings broad space for innovation in all walks of life. A large amount of data and information, as well as the processing technology, will bring many traditional areas of city activities (such as traditional Chinese medicine, literature and art, etc.) new vitality and tremendous progress through system

innovation. It is very important to attach great importance to the Smart City inclusiveness and openness from the angle of innovation. Based on this, special attention should be paid to the innovation in the field of ICT technology penetration.

F. Technology, standards and pilots

The Smart City is a fusion of open environment not only for information resources, but also for technology. In general, it must be able to accommodate different technologies, different technical systems, and different technical standards. This is because:

1) Smart City with the characteristics of SoS is a long-running system, its life cycle is longer than most of the technical systems and the standards. When the technology system and standard changes, it should not affect the normal operation and the city.

2) Smart City need to integrate the information resources from different industries and different areas, and they each have different technical systems and standards. Overall, the Smart City must be equipped with compatibility and interoperability.

3) Smart City is an integral part of a larger information environment. The technology and the information environment systems involved are beyond the local control of Smart City. In order to achieve a wider range of interconnection and perception, and more integration of information service, Smart City must adapt to the environment, rather than create a system of its own.

4) Under the market economy environment, the market has a great influence on technical systems and standards. As a result, the uncertainty of technical systems and standards also increases. This is also out of the Smart City's control.

Smart City, overall, is a SoS itself. It is also in the domestic and international information environment. In general, each element of the SoS is using the rendering behavior formed by the other parts working together, no control relations between them, only the game and influence relationships. Thus, the work Smart City should do is to choose, rather than to formulate the technical systems and standards in this aspect, and it's a challenging job to include existing and future technologies and technical standards on the basis of the abstract description, to achieve a state of "formlessness beats form".

Of course, Smart City should eventually make sure that the implementation will be achieved. The implementation is not the Smart City itself, but the elements of it. Some elements are still SoS themselves (such as intelligent traffic), ultimately realizing a single system. The decomposition and implementation to validate the overall concept of the Smart City should be part of the pilot of the Smart City, to see if it could help to achieve its overall goals. If Smart City focuses on the implementation of a single system, it is no doubt putting the cart before the horse.

V. Conclusion

From a global perspective, China's ICT development is only at a medium level [15], Of course, this corresponds to our

economic development. Today, the rational development of ICT will bring huge boost to social and economic development. The development of China's information superhighway has proved this point. The usual practice is to promote the development of the information infrastructure (such as the U.S. information superhighway, the national broadband plan), then constitute the policy planning (such as the Smart Planet of American, i-Japan, etc.). Subsequently, promote the fusion and openness of infrastructure and information resources, coupled with the development of information resources and ICT (such as the big data and cloud computing, etc.), to promote their applications. Smart City is undoubtedly the important development strategy under this situation.

The ICT application in Smart City is different from the traditional ICT application. Its construction and management is an integral part of the city construction and management. It is not a single system, but a complex SoS with the complex relationships and interests. Precisely because of this, it brings opportunity and space for the innovation and development of the whole society. From the planning point of view, the efforts in mindset, policies, laws and regulations, organizations, and systems are more important than the works in technology and local technical standards, which we should already have a full understanding.

References

- [1] People's Daily Online: <http://finance.people.com.cn/n/2012/1224/c1004-19988145.html>
- [2] F. Liu, and J. Pan, "Explore the mysteries of the hard disk," *electronics world*, 2002(7):25-27.
- [3] The Smart Japan: "I-Japan" strategy, China Smart City Net, July 14, 2012: <http://www.cnsn.com.cn/news/show-htm-itemid-1041.html>
- [4] L. Wang, and L. Chu, "Digital City" in Korea, *Shanghai Informatization*, 2007(2): 83-87.
- [5] Notice of the State Council on the issuance of the "12th Five-Year" national strategic emerging industry development plan, July 9, 2012, The Net of China Government: http://www.gov.cn/jzwgk/2012-07/20/content_2187770.htm
- [6] IBM, www-31.ibm.com
- [7] J. Tang, and L. Tong, and X. Deng, "Smart Nanjing: The New Model of Urban Development," Nanjing Normal University Press, March 2011.
- [8] M. Zhu, "Version Path to Smart City and learn," *New Economy Weekly*, 2011(4):81-85.
- [9] Sage, A.P., and C.D. Cuppan. "On the Systems Engineering and Management of Systems of Systems and Federations of Systems," *Information, Knowledge, Systems Management*, Vol. 2, No. 4, 2001, pp. 325-345.
- [10] Maier, M.W., "Architecting Principles for System of Systems," *Systems Engineering*, Vol. 1, No. 4, 1998, pp. 267-284
- [11] FISHER D A. An Emergent Perspective on Interoperation in Systems of System. CMU/SEI-2006-TR-003 ESC-TR-2006-003, March 2006.
- [12] G. Liu, "The Australian NBN Act focus on economic growth and social services," *World Telecom*, 2011(4):24-28.
- [13] Kevlin Henney. Stable intermediate forms: A foundation pattern for derisking the process of change. In *Proceedings of the Ninth European Conference on Pattern Languages of Programs*, 2004.
- [14] H.A. Simon, *The Sciences of the Artificial*, MIT Press, 1996. ISBN 0-262-19374-4
- [15] ITU Report : Measuring the Information Society 2012, ITU Official Net : <http://www.itu.int/ITU-D/ict/publications/idi/index.html>