

## The development of smart cities in China

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### Abstract

Since IBM brought the concept of “Smarter planet” in China in 2009, smart cities construction has become a new trend of urban development. By 2013, there were 193 approved pilot projects of smart cities in China. Smart city has been viewed as a key strategy to promote industrialization, informatization, and urbanization. The rapid development of smart cities in China is largely attributed to the cooperation between IT companies and the government. This paper will study how smart cities have been developed in China. It will pay particular attention to the roles and relationships of various actors (including the government, market and society) in the development of smart city, which further divided into four layers, that is, sensor layer, network layer, platform layer and application layer. This article will finally summarize Chinese experiences on the development of smart cities and giving the visions of future development.

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## 1. Introduction

As urbanization accelerates, large numbers of people have been flocking to the city. With the rapid expansion of urban population, the development of cities is restrained by the environmental pollution and the shortage of resource, such as land, space, energy and clean water (Ji et al. 2011). It is difficult to solve all these problems using the traditional techniques and management methods. The developed countries begin to study how to use innovative information technology, knowledge and intelligence technology to re-examine a series of key problems in the development of modern city, such as nature of the city, urban functions, adjustment of the urban structure, and city image (Zhang 2011). It is urgent for China to learn the experience from other countries and find its own development way, to look for the new methods for planning, precise management and predictive.

Although the global financial crisis, also known as the 2008 financial crisis, is regarded as the worst financial crisis since the Great Depression of the 1930s, it stimulated the development of new technologies and innovations. In response to the financial crisis, IBM transferred its business from hardware to software and consulting services in order to achieving higher profit margins, and proposed the ideas of “Smarter planet” in 2008. In 2009, IBM saw the commercial opportunities in China, holding 22 times of smart city forums and communicating with more than 200 mayors and nearly 2000 city officials (Zhang & Du 2011). Then, the term ‘smart city’ has been widely accepted in China, and many cities, such as Nanjing, Shenyang, Chengdu, and Kunshan, have made strategic cooperation with IBM (Zhang & Du 2011). In 2012, the Ministry of Housing and Urban-Rural Development (MOHURD) formally issued “Notice of Carrying out the National Smart City Pilot”, “National Interim Measures for Smart City Pilot” and approved 90 pilot projects of smart cities. By 2013, there were 193 approved pilot projects of smart cities in China. Smart city has been viewed as a significant strategy to accelerating the industrialization, informatization, urbanization and agricultural modernization (National Development and Reform Commission 2014). In addition, smart city strategy is regarded as a powerful catalyst to utilize modern science and technology - such as Internet of things, cloud computing, big data, spatial geographic information - in urban planning, construction, management, and operation. The goal is to integrate various information resources, and improve urban management and service level, as well as promote the industry transformation (National Development and Reform Commission 2014).

The definition of ‘smart city’ is varied within the literature, but can broadly be divided into two levels. On the one hand, ‘smart city’ refers to intelligent and sustainable urban development, whose origin can be traced back

to the Smart Growth(Harrison & Donnelly 2011). To deal with the climate changes and social problems, both the governments and planners from all around the world have been aware of the importance of 'smart growth', and devised plans for existing and emerging cities to become both smarter and greener(Lee et al. 2013). And ICT make it possible to solve the emerging problems of urban system in sustainable way (Neirotti et al. 2014). Some institutional agencies, such as Barcelona City Hall and Amsterdam City Hall define a smart city as uses 'innovative technology' in order to create a sustainable greener city(Bakici et al. 2013; All et al. 2011).

On the other hand ,the notion of a 'smart city' refers to urban environments with pervasive and ubiquitous computing and digitally instrumented devices (Kitchin 2013). In this level, 'smart city' can be divided into four layers, that is, sensor layer, network layer, platform layer and application layer(Xu 2012). Here, availability and quality of the ICT infrastructure is deemed to be of basic element for a smart city, and the technology is seen as the central importance. However, Hollands (2008) pointed out the embedding of ICT in urban infrastructure is not enough to make a city smart, and the term 'smart city' refers more broadly to the development of a knowledge economy within a city-region(Kourtit et al. 2012). In this vision, policies and governance which can be enhanced by ICT are also included. Smart city is an organic connection among technological, human, and institutional components(Nam & Pardo 2011). It can be divided into six main areas: smart living, smart governance, smart economy, smart environment, smart people and smart mobility(Giffinger et al. 2007)

In China, smart cities are more focused on the technological issues, and pay less attention on the innovation, creativity and entrepreneurship, enacted by smart people. Many researchers suggested that smart city was an upgrade version of digital city. Li (2012) pointed out that smart cities is the integration of digital city and various technologies, such as the Internet of things and cloud computing(Li et al. 2012). Those technologies make it possible to communicate between things and things, people and things, even people and society, realizing more intelligent urban governance(Liu et al. 2013).

In practical, construction of smart city means the construction of 4 layers-sensor layer, network layer, platform layer and application layer. While a majority of discussions present definition, vision, and characteristics of smart city, little research has tackled actors in developing smart cities (who really makes cities smart). Understanding actor's motivation and role can help to analyze existing problems and potential risks, and find out new solutions to guide further smart city's construction.

## 2. A conceptual framework

Each of the layers has their main stakeholders which presents different mode of funding and operating in developing smart cities (Figure 1).

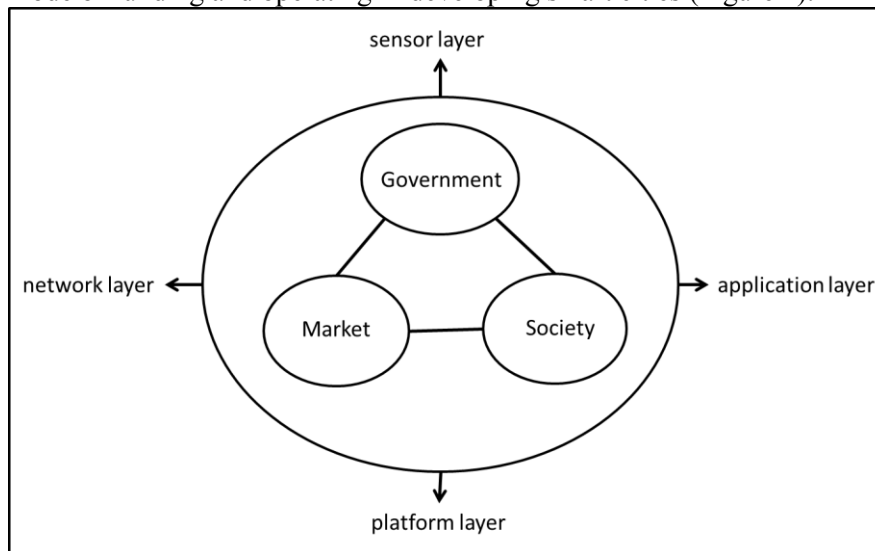


Figure 1. A conceptual framework on actors of each layers.

### 2.1 Four layers: sensor layer, network layer, platform layer and application layer

National Development and Reform Commission of China defines smart city as “new idea and new mode of promoting smart city planning, construction, management and service, using the Internet of things, cloud computing, big data, and spatial geographic information integration, etc.” From this definition, it can be speculated that the government more focus on the technological issues in developing the smart cities. In this level, where the technology is seen as the central importance, ‘smart city’ can be divided into four layers, that is, sensor layer, network layer, platform layer and application layer (Figure 2). The combinations of sensing, network and information processing platform enable objects to interact with the each other(Chen 2013).

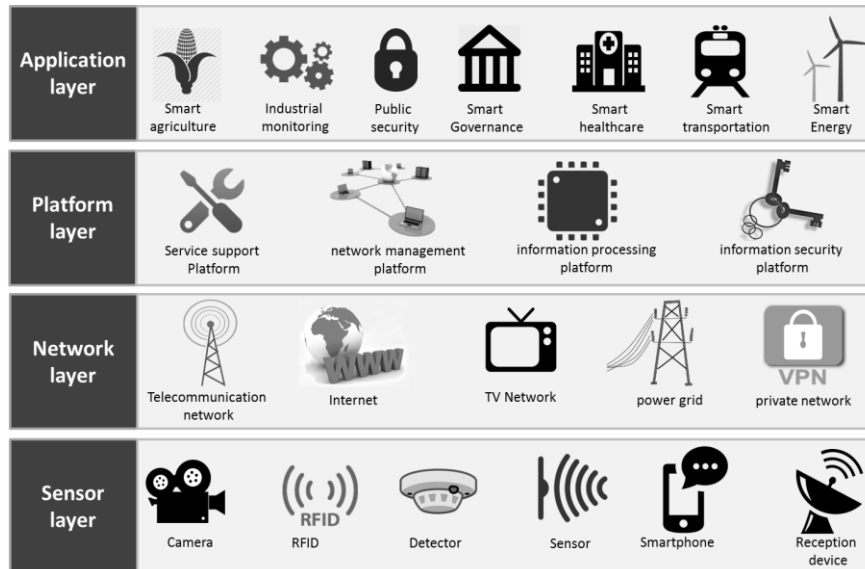


Figure 2. Four layers of smart city

#### •Sensor layer

The first step of enabling smart services is to collect contextual information with object sensing and information gathering layer(Chen 2013). Sensors can monitor themselves in real time and act on their own intelligently(Hancke et al. 2013). They can be used to monitor public infrastructures and human's physiological activities, collecting data and sending to a central information system with network layer, where intelligent decisions can be made by this data(Hancke et al. 2013; Chen 2013). Sensor layer consists of wireless sensor nodes, such as RFID tags, RFID Readers, cameras, GPS, Qr code tags and readers, which usually set up in a network, also known as a wireless sensor network (WSN)(Xu 2012; Hancke et al. 2013).

#### •Network layer

Network layer is the path for information exchange and transfer, including access network (AN) and transmission network(Xu 2012). Transmission network consist of public and private network, including typical telecommunication network (fixed-line and mobile), TV network, Internet, broad band network, electric power communication network, private networks (VPNS). Access network include optical fiber access, wireless access, Ethernet access, satellite access and other kinds of access, accessing RFID network and at the bottom of the sensor networks.

#### •Platform layer

Platform layer is in charge of information processing and control. Although information processing can be performed on intelligent terminals such as smartphone, more complicated- big data based task is completed through cloud computing platform(Chen 2013). Platform layer has various functions, such as coordinating, management, computing, storage, analysis, mining, and providing public service for industry and users, including business support platform (middleware platform), network management platform (such as M2M management platform), information processing platform, information security platform, and service support platform(Xu 2012).

#### •Application layer

Application layer is a solution set which combine the Internet of things technology with industry professional technology, to realize widespread application intelligent service(Xu 2012). With application layer, a smart city can finally realize the integration of the information technology and industry technology, influencing deeply to the national economy and social development. Based on the very latest information collected from sensor layer, rapid responses can be given to physical phenomena. These create new services based on real time physical world data, improving infrastructure integrity (energy, transport, etc.), increasing efficiency of urban management (governance, monitor, public security, etc.), and addressing environmental degradation(Chen 2013).

### **2.2 Three key stakeholders: government, market and society**

#### • Government

The government and the market are two foremost stakeholders in the development of the smart cities. When IBM proposed the ideas of “Smarter planet” and “Smarter Cities” in 2008, China approved “Chinese economic stimulus plan” to invest 4 trillion RMB, which is equal to 561 billion Euro, in infrastructure and social welfare. Since then, all levels government and enterprises have seen the development opportunity, and got involved in the construction of smart cities\_(Wang 2013). Since 2010, China began to construct smart city, and by the end of 2012, there are more than 180 cities joined to smart cities construction, and the investment scale of infrastructure construction, such as communication network and data platform, have reached nearly 500 billion RMB(CCID Consulting 2013). Smart city is regarded as one of the most important measures to carry out the slogan of Central Committee of the Communist Party of China and the state council about innovation driven development, promoting the new urbanization, and building a well-off society in an all-round way. In addition, smart city

is viewed as coincide "Four Modernizations": industrialization, informatization, urbanization, and agricultural modernization.

• **Market**

Market also plays a crucial role in this process. More and more telecommunications operators, domestic and foreign IT companies have participated in smart city construction expand their turf. According to statistics, the three major telecommunications operators have signed smart city strategic cooperation agreement with the provinces and prefecture-level city government, and the cooperation agreement have reached more than 85 % (Guomai Internet Smart City research center 2013). The three major telecommunications operators have put forward their own smart city strategy, not only devote themselves to build communication networks, but also distribute layout cloud computing center all around the country, in order to expand the market share in the field of information services. Recently, the number of domestic and foreign IT companies who engage in the smart city business is increasing. China's smart city listed companies have reached 33, and listed companies related to the smart city, such as internet of things, cloud computing, big data, smart grid, intelligent medical and others have reached 229. In addition, the large foreign enterprises who enter the field of smart city in China have come to more than 30 (Guomai Internet Smart City research center 2013).

• **Society**

In addition to the government, many public sectors get involved in the development of smart city. Such public sectors include colleges and universities, hospital, police, etc. Those public sectors construct smart city in indirect way, which means, they often cooperate with government and market, purchasing their products and services to provide smart city services. For instance, China mobile cooperate with schools have launched education informatization project, which is a "three-in-one educational network" project, consisting of educational informatized equipment rooms and educational informatized application platform construction, a computer network, and a management network. In Jilin, their fiber-optics have been installed in 81 schools and the entire county Educational Bureau after almost a year since the project's inception, forming a video surveillance system (Mobile 2013).

### ***2.3 Funding and operation mode in developing smart cities***

Securing ICT infrastructures play a crucial role in emerging smart city services (ITU 2013). Thus, the governments pay much attention to the con-

struction of smart infrastructure. The investment in the smart infrastructure is the second largest part of total investment in the smart city construction, while the industrial parks occupy the largest proportion(Guo 2014).

In 2013, there are more than 250 cities which have proposed or under construction of the smart city, however, only nearly 80 cities have smart city development plan and real action(Guomai Internet Smart City research center 2013). A counselor of CCID Information Research Center which directly subordinate to the Ministry of Industry and Information Technology said smart city project requires a lot of investment, and financing is one of the biggest challenges when developing the smart city(Li 2015).Thus, it is important to understand the funding and operation mode in developing smart cities.

Funding and operation mode can be summarized as government fully and public-private partnerships (PPPs) (Jiu 2013). Public-private partnerships(PPPs) can be defined as co-operation and relationship between public and private actors, sharing the risk, costs, and benefits(Klijn & Teisman 2002), which can be further divided into government investment-private operate, government partly investment-private investment and operate, Build-operate-transfer (BOT), Build-transfer (BT) mode, Build-own-operate (BOO), and Build-transfer-operate (BTO) (Jiu 2013).

**Table 1:** Theoretical and empirical funding and operation mode in developing smart city

		government fully	PPPs				
			Gov't investment-private operate	BT	BOT	BTO	BOO
Actor features	Funding	Gov't agencies	Gov't agencies	private sector	private sector	private sector	Private sector
	Operation	Gov't agencies	private sector	Gov't agencies	private sector for specified period	private sector for specified period	private sector
	Ownership	Gov't agencies	Gov't agencies	Gov't agencies	Gov't agencies after specified period	Gov't agencies after construction	private sector

**• Government fully**

Government fully mode refers to governments fund, operate, and own the smart infrastructure by their own(Jiu 2013). However, they could out-source the design and construction to specialized company. This mode can be applied under the premise that the government has enough money. On



account of the simple investment structure, the operation cost is relatively low. However, the government is under the long-term high financial pressures with low operational efficiency and service level.

• **Government investment-private operate**

The government is primarily responsible for the investment while the private sectors take charge in the construction and operation(Jiu 2013). In this mode, the government provides subsidies to private sectors, and user can enjoy free resources. The profit of private sectors mainly comes from the advertising business and value-added services. Cities, such as Shenzhen and Xi'an have adopted this mode in terms of digital urban management, wireless video surveillance, and real-time traffic information(Jiu 2013).

• **Build-transfer (BT)**

BT mode is a mode that the governments provide a franchise agreement which is a fixed time-fixed cost contract with private sectors, and the private sectors arrange financing, design, construction, and assume the risk within the contract period, then the government repurchase the projects in installment after the completion of the construction(Yin & Jiang 2011). During the period of construction, the government doesn't have the ownership of the projects, but support the project by giving a certain amount of property loans or loan guarantees.

• **Build-operate-transfer (BOT)**

In a BOT project, the private sectors fund, construct and operate the infrastructure and the projects will be transferred to the government after certain years(Yang & Meng 2002). On the one hand, BOT mode benefit from the market competition mechanism. As the main actors, the private sectors have the ownership of the projects during the concession period. On the other hand, the government could intervene through relevant agreements. Although it is the private sectors that are responsible for the implementation, the government controls the whole project from beginning to end. With the growing popularity of the BOT mode, various modes are derived, such as Build-own-operate (BOO), Build-own-operate-transfer (BOOT), Build-lease-transfer (BLT), and transfer-operate-transfer (TOT) (Jiu 2013).

• **Build-transfer-operate (BTO)**

The essential idea of BTO is that private sectors arranges the finance, builds it, transfer to the government, and operates it. This mode applicable to the high public welfare projects which are not appropriate for the private sectors to have the ownership of the projects. Thus, the ownership will be transferred to the government after been built. The typical cases of BTO mode is new facilities with the right to charge, such as water works, sewage treatment works(Jiu 2013).

• **Build-own-operate (BOO)**

BOO modes means that the private sectors arranges the finance, builds it, owns it, and operates it(Morris & Suratgar 1988). The biggest difference between BOT mode and BOO mode is the ownership. The ownership of project must be transferred to the government after the concession period in BOT mode while the private sectors own the project with no time limit. A survey shows that the understanding of the operation mode is changing: “ who build- who operate” is becoming the trend(Jiu 2013). In this model, the government may offer other financial incentives such as tax-exempt status.

### 3. Case study

#### 3.1 Public Section case 1: Ningbo

Ningbo, which is located in the east of Zhejiang province, is an important seaport city of China, the second largest city of Zhejiang province, economic center of Yangtze River Delta, and the national famous historical and cultural city. The municipality had a population of 7.6 million in 2012. In 2010, Ningbo issued “Decision of Ningbo municipal government on the smart city construction”, and one year later, released “Action of speeding up the creation of smart city in Ningbo (2011-2015)”, which includes 10 application system construction projects, 6 Smart industrial bases construction projects, 4 Smart infrastructure construction projects, 3 Information system construction projects, and 7 Organizational guarantee system construction projects (table 2).

Table 2: Smart city construction projects of Ningbo in 2011-2015

Source: Action of speeding up the creation of smart city in Ningbo (2011-2015)

project	Sub-Construction projects	implementation period	total investment of the “12th five-year plan”(million RMB)	investment in 2011(million RMB)
Application system	Smart logistics system, Smart manufacturing system, Smart trading system, Smart Energy application system, Smart public service system,	2011-2015	7478.50	1657.70

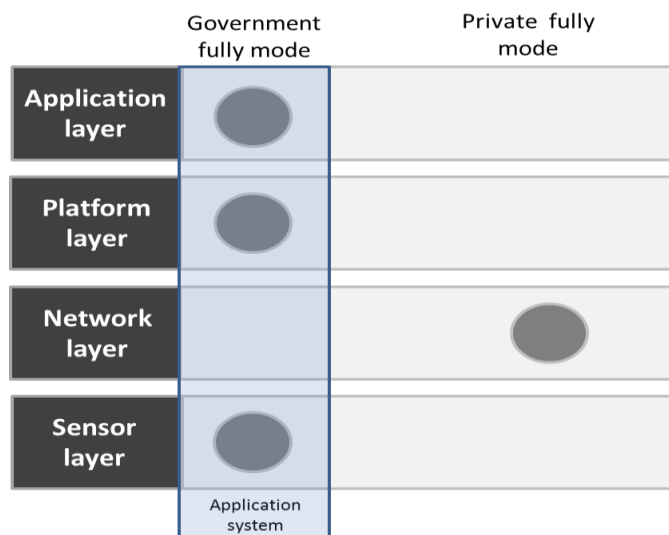
	Intelligence community management system, Intelligent transportation system, Smart health security system, Smart housing service system, Smart cultural service system			
Smart industrial bases	Network data base, Software industrial base construction project, Smart equipment and product development manufacturing base, Smart service demonstration base, Smart agricultural demonstration base, Smart corporate headquarters base	2011-2015	25346.10	1759.60
Smart infrastructure	Next-generation information network infrastructure, Information resource library project, Information Security project, Perception of urban infrastructure project	2011-2015	7320.10	1313.10
Information system	Universalness of smart city literacy project, Information service equalization, Internet access environment in public places	2011-2015	419.80	109.40
Organizational guarantee system	Organization and leadership system, Decision consulting and evaluation system,	2011-2015	138.00	34.00

	Financial investment and support system, Regulations and standards system, The introduction of personnel training mechanism, Cooperation and exchange mechanism between home and abroad, Pilot promoting mechanism			
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Those investments come from the public finance expenditure. As can be seen from the table 2, the investment of constructing smart industry during the “12th five-year plan” period occupy the largest part, which reach 25 billion RMB. The application system construction projects and smart infrastructure construction projects account for the second largest part, which together reach 14.8 billion RMB. The construction of application system can be divided into the construction of application layer, planform layer, and sensor layer. Each of the application includes these three parts. The construction of smart infrastructure includes the construction of network layer and platform layer. At this stage, Ningbo adopted the “Government fully mode”, and purchased related products and services. For example, in 2011, Ningbo Municipal People's Government united other 7 agencies, holding “1st Smart City Exposition Ningbo China”. The purchases of Ningbo during this expo were over 10 billion RMB.

After 1-2 years of practice, Ningbo began to attract private sectors in developing smart cities. According to the “2013 action plan of speeding up the creation of smart city in Ningbo”, the three big operators which include China Telecom, China Mobile, and China Unicom, have participated in developing smart cities. The funding comes from these operators and the total investments have reached 10 billion RMB. Those projects mainly focus on the construction of network layers, such as physical network backbone, optical fiber, WIFI, TD-LTE, and ITV.

Reviewing many other cities experience, they have something in common in their constructing mode, since many cities develop themselves abiding by “successful Pattern”. Thus, we can preliminary concluded that mode of funding and operation become ever more diverse. However, government fully mode still plays the dominant role.



**Figure 3.** funding and operation mode of Ningbo smart city

### 3.2 Private Section case 3: China Mobile

China Mobile Limited, as the leading mobile services provider in Mainland China, was incorporated in Hong Kong on 3 September 1997. China mobile is mainly engaged in mobile voice, data, IP telephone and multimedia services. Before all levels of government begin to construct smart city, China Mobile have launched various products and service which make city smart.

In 2006, the first smart mobile network, the world's largest softswitch tandem network, and the world's largest data service management platform (DSMP) was built by China Mobile. In addition, they provided many applications, such as Locating Ambulance, E-Hospital services, Campus Information Service, Grid Enabled Urban Management Information System, Police Information Service, Disaster Alert System. Most of them are provided through Short Messaging Service (SMS) and their advantages in network technology.

In 2007, they come up with Next Generation GSM (NG-GSM), with the concurrent developments in 2G and 3G technologies. They also developed various products and services, such as Machine to Machine Services (M2M), banking information service, municipal information service, building an information system to track meat production and food safety.

In 2008, they proposed "Wireless City" strategy, which plan and promote city-level initiatives using mobile telecommunications technology, such as

TD-SCDMA technology. It is a program under government leadership, including unified wireless broadband access for all citizens and wireless services in various fields.

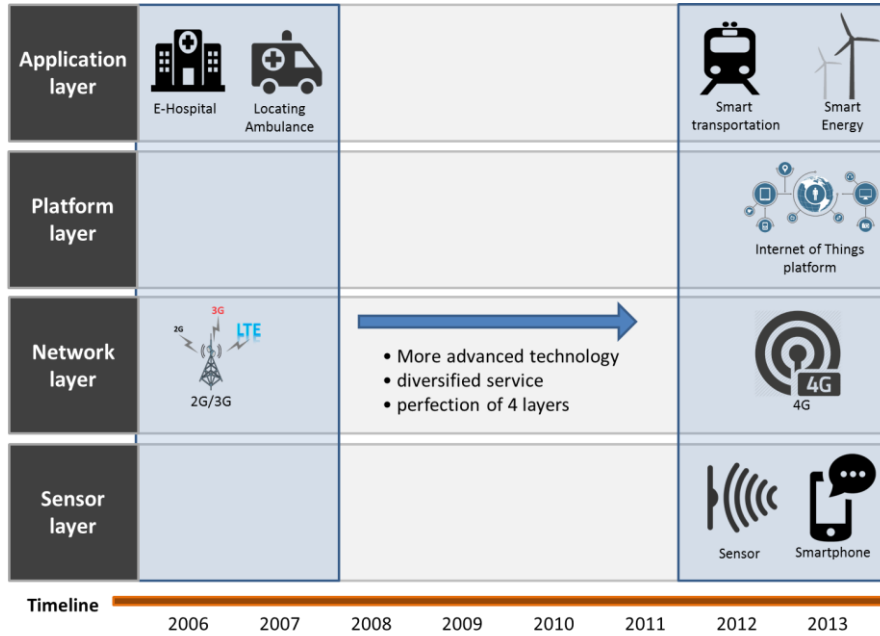
In 2009, China Mobile launched Mobile Market, which is a platform for industry chain collaboration and innovative business models. Mobile Market provides 3 Platforms, that is, consumer-oriented one-stop sales platform, developer-oriented one-stop service platform, and industrial chain-oriented one-stop support platform.

In 2010, China Mobile pushed forward the perfection of TD-SCDMA Long Term Evolution (TD-LTE) technology and made breakthrough in the research fields of cloud computing and the Internet of Things. They also established the “114 Strategy” for the development of the Internet of Things, and developed key technologies and standardized products, such as applications for energy and transportation sectors among others.

In 2011, China Mobile established a new model featuring “Smart Pipe + Open Platform + Featured Businesses + Integrated Interface”. Mobile Market (MM), which refer to the open platform achieved 1.58 million customers and over 630 million times of downloads cumulatively. They had completed the development of the “Internet of Things” applications in the agricultural, industrial and service sectors, and integrating “Wireless City” with public administration, public services, traffic control, healthcare, education, employment, finance and shopping and others.

In 2012, China Mobile achieved the many exceptional advances, such as TD-LTE development, IDC construction, Internet of Things platform construction, Call Center Construction, Logistics Center Construction.

In 2013, China Mobile successfully implemented TD-LTE trial and commercialization of 4G technology. Their 4G service became available in 16 cities in 2013. With the existing technologies, facilities and platform, such as IOT, cloud computing, they developed a growing variety of applications in 2013.



**Figure 4.** Development tendency of China Mobile

At the beginning, China Mobile mainly focused on the construction of network layer, and provided applications basing on the advantages of its network coverage. In 2006, their business was limited in application layer and network layer, however, in 2013, all layers are included. Meanwhile, each of layers is developing with more advanced technology, providing more diversified services (Figure 4).

**3.3 Private Section case 3: Yanhua Smartech**

Shanghai Yanhua Smartech Group Co Ltd is a high-tech enterprise who is listed on the shenzhen stock exchange. Yanhua Smartech is a comprehensive service provider for the intelligent building and digital community, including office buildings, residential communities, factories and enterprises, education, scientific research, medical and health care, government agencies, hotels and municipal engineering. Yanhua Smartech has always been developing and expanding their business areas of smart city products.

At present, the business area of Yanhua Smartech covers everything from the top planning and design to all aspects of the smart city construction and operation, including: smart building, smart energy, smart transportation, smart community, smart hospital, data center, smart park, city one-card, and green city, etc. It is setting up smart city core product system to meet the need for smart city planning and construction. It includes three main

areas: (1) Smart city top platform (2) Smart city Internet of Things (IoT) products system; (3) Application service product system (table 3);

**Table 3.** smart city core product system of Yanhua Smartech

	Smart city top platform	IoT product system	application service product system			
			Smart building product system	Energy efficiency service product system	Smart transportation product system	Smart community products system
Application layer			Smart building	Smart energy	Smart transportation	Smart community
Platform layer	public information service support platform	IoT integrated management platform	Smart building control management platform	smart energy management control platform	intelligent traffic information service platform, the government regulatory platform	Smart community service platform
Sensor layer		Sensors, IoT middleware	Controller, actuator	collector, regional controller	electronic stop, interactive information screen, the data communication controller	wear type terminals, intelligent home terminal

- **"Smart city" funding and operation mode**

Since the "twelfth five-year" plan of China, Yanhua Smartech takes the lead in exploring the new mode of cooperation with local government, has formed several local smart city services and operating companies, including Wuhan smart city, Hainan smart city, Zunyi smart city, Gui'an smart city. Specifically, Yanhua Smartech cooperates with local State-owned Assets Supervision and Administration Commission (SASAC) funded companies, setting up new companies through joint venture.

#### 4. Visions and conclusion

The case studies analyzed the developing tendency of smart city from two dimensions- the government and the market. The experience of other local governments and other enterprises follow the same pattern in China.

- Telecommunication services providers continue to benefit from their advantages in the network and expand their business in other areas. They are not only keep on extending their network coverage and improving their network quality, but also exploring new technologies to build new network layer. Meanwhile, with cooperation with other companies, they are expanding their business areas and constructing sensor layer and platform



layer using cloud computing technology and IOT. In addition, with open platform provided by them, more and more application developer can join the smart city construction.

- Other companies, such as Yanhua Smartech, E-Hualu, and Huawei, expand their business in other areas basing on their original advantages. Some of them are the facilities providers while others are technology providers. They were focused on the one limited areas or layers then began to extend their business areas to two or more layers. Meanwhile, the connection and cooperation between different enterprises is increasing.

- The construction of 3 basic layers, which are sensor layer, network layer, and platform layer, will provide the platform for the developers to build the application layer, attracting more social capital and private sectors into the construction of smart city. In future, there will be more bottom-up development.

- At present, government fully mode still plays the dominant role, mainly purchasing smart city products and services from private sectors. However, mode of funding and operation is becoming ever more diverse. For instant, in 2014, Dongguan city cooperate with E-Hualu, signing “Letter of intent for construction of intelligence center of Dongcheng district”, constructing smart city with of BOT mode or BT mode(Beijing E-Hualu Information Technology Co. 2014). More and more private sectors are focusing operation of smart city. In recent years, the local governments play a key role in developing smart city and this phenomenon will last few years. However, in future, the construction of smart city will become more market-oriented and the government will more focus on the standardization, law making, planning and comprehensive arrangement, and there will be more PPP in developing smart cities.

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