Integration is the Key to Urban Evolution: Technical Challenges for the Smart City and the Internet of Thins

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According to the statistics and estimates of the United Nations, half of the world's current population resides in cities. In addition, there will be 91 cities with populations of over 5 million by 2025, and 36 of them will be megacities with populations of over 10 million. This signifies that cities shall play an increasingly important role in human civilization. However, as populations continue to concentrate in cities, more challenges shall arise in areas such as transportation, energy, housing, disaster prevention, pollution prevention, and various life-support systems and the issue for effectively improving "use efficiency" would need to be addressed.

Challenges brought forth by concentrated population and issues in the efficiency of the supply of various life support systems (including software and hardware) have made the design of a smarter city a point of concern. In the last five years, several cities in Europe, the Americas, East Asia, and even the Middle East have come forward with diversified and colorful designs for a "smart city."

One question that must be asked of the development is: What exactly is the essence of smart cities and how do we observe them? If we wish to enhance the efficiency in the use of various life-support systems, what other technological barriers remain to be solved?

Smart City as an Open Innovation Lab/Space

Rather than referring to the smart city as an industry, we should instead refer to it as an Open Innovation Lab/Space for the fulfillment of numerous new technologies. This would broaden our imagination for smart cities and free it from the existing industrial scope and definition. The key to the perceived success of a smart city lies not in how complicated its technological applications are, but in whether it could create a sustainable business model or even an economic ecosystem.

Evaluations of smart city designs around the world has shown that they all have two basic traits in general: (1) A "problem-solving" concept of the smart city and how it provides a solution to the problems and conditions in cities, (2) The technologies incorporated in the smart city have high "applicability" and therefore the main issue has become how to integrate technologies from different sectors.

Optimized Technology Integration is the Key to Urban Evolution

If we observe the technologies involved in smart cities, we can classify them into eight technological applications and roughly five layers: the "power supply layer," "equipment layer," "communication layer," "processing layer," and "application layer." At the present stage of development, each layer has its own challenges to overcome (please refer to Table 1.)

By distinguishing the technical layers in the smart city, it is clear that extremely complex issues are involved. Different technical deployments would be necessary in accordance with different demands. For instance, video transmission is required in applications for police administration and transportation, and the communication layer would be more reliant on wired optic fiber transmission. Wireless transmission would run into issues related to high costs. Perhaps we could look at

the smart city this way: the main issues are not the maturity of technologies but how the operator "identifies issues" and how to come up with the optimal integration tests between different technologies.

The Smart City Market Gives Birth to A New Form of Innovation Industry

As described above, the smart city is regarded as an Open Innovation Lab/Space. From the perspective of industrial innovation, the space can bring forth two clear types of innovation industry:

(1) Innovation Industry for System Solutions

The key in establishing a system, in addition to the maturity of the technologies, involves the integration of various technologies such as: IoT equipment, wireless communication, and network structure etc. They would form a new type of industry in the experiment of smart cities in the future. This industry would encompass software and hardware as well as the export and expansion of solutions for different demands; as the system is exported, it would also advance the development of the semiconductor and IC industries.

(2) Innovative Application Services from the Extension of Data

Data analysis and applications are also another important innovative industry brought about by the smart city, and they include data storage, database management, digitalized currency, innovative financial services etc. They would form a "comprehensive urban big data industry" through the experiment of smart cities in the future. Analysis of urban data could provide smart governance for public administrations as well as provide various data convergence, analyses, and identification of new business opportunities to facilitate the advancement of innovative commercial services.

In conclusion, the smart city is expected to bring forth public and industrial benefits. However, we could also conclude that: "Integration" is the keyword to the successful development of the smart city. Its challenges include taking into consideration and integrating multiple technology items in different stages of development as well as the core issue of how to identify and analyze urban issues in order to provide adaptive total solutions. Faced with such issues, we must rely on expertise of information engineering as well as the expertise in urban planning, spatial design, and social sciences in order to succeed in building a safe and efficient city.

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Table 1. Technical Layers and Challenges for the Smart City and IoT.

Technical Layer		Technical Challenge
Layer	Technology Application	
Applications Layer	Central Coordination	Central coordination and procedures are the operational backbone of the "smart operations center" and the construction of its control room will be the key to the success of its operations, such as optimizing Internet access capabilities and network structure to achieve the best information service management.
	Analysis and Application	Analysis and application reply on the quality of the data. If there is insufficient data, it would be difficult to conduct an analysis; if there is excessive data, the performance of the current network structure and servers would need to be improved because they have yet to be sufficient to handle large quantities of data analysis and processing. In addition, the data access calculation (price calculation) model has also become one of the important challenges we now face.
Processing Layer	Data Munging and Fusing	City governance involves multiple types of data refinement and recomposition. The main challenges involve the acquisition of data from different authorities (public and private) and how to coordinate the recomposition of the form, version, and semantics of the data to facilitate recomposition.
	Data Storage	As the collected data rises in volume, the main challenges (involving the design of the data center) for stable data access, tracking, and storage would be expanding Internet capacity and preventing bandwidth overload; in addition,

		data would become an important asset and the storage (security) of data as well as information security would become issues that must be resolved.
	Edge Computing	Fog computing employs a distributed structure that is closer to the margins of the Internet, and an important challenge is to establish transmission lines between different facilities. In addition, from the perspective of city governance, the marginal data should also be transmitted to the center for analysis, but there remain issues on data recomposition and transformation.
Communications Layer	Connecting Communication	The mobility (speed and range) of different movable objects in the city differs greatly (people, cars etc.) and it affects data transmission rates (Mbps) and choices; wired communication involves issues related to higher deployment costs (such as fiber optics and broadband cables), while wireless communication involves issues related to the diminishing performance in the quality of communications with the scope and the environment.
Equipment Layer	Sensor and Network Topologies	Large-scale deployment has become possible with lower related production costs for sensors, but sensors for city use are different from those for indoor use because they are exposed to the climate and humidity of the environment. The lifespan of sensors and equipment would be shorter than those placed indoors; in addition, if the topology of the deployment of a network of sensors is in a star or mesh form, it would require adjustments in accordance with different applications to reach optimal deployment.
Power Supply Layer	Battery and Power Supply	The collection and understanding of city information rely on the deployment of various sensors and equipment. However, the operations of related equipment can be divided into two choices in terms of power supply. The first involves transmitting power to existing equipment (such as street lights, signal lights etc.) and the second involves power supplies from batteries; however, the former involves an increased demand to the power supply from the equipment, and the existing transformers were not designed to handle such loads. In the latter scenario where power is provided by batteries, there would be the issue of how to extend the life of batteries.