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# The New Era of Smart Cities, From the Perspective of the Internet of Things

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## 1 INTRODUCTION

It is difficult to find the proper meaning of "smart" from the perspective of information and communication technology (ICT).This term is trendy in the global market, and is considered anything that is new and intelligent. The term "smart" has lots of synonyms, including acute, clever, astute, perspicacious, and so forth. However, when smart is associated with devices, it means efficient and knowledgeable. The word "smart" refers to thoughts that offer intelligent insights, but nowadays it has been adopted in developing cities with smart tools. With the application of smart technology, an overall growth has been seen in population, economy, and the efficiency of city life.

Similar to "smart," it is tough to find a unique definition for the term "city." It depends on the experience and considerations of individuals to specify a meaning and identify the properties that a locality should satisfy to become a city. In general, a city is a well-thought-out urban area where the population density depends upon the geographical region or countries to which it belongs. As per the UN world urbanization report, it is expected that around 67% of the world's population will be in urban areas in 2050. When the populations exceed 1.5 million, the cities will be considered megacities.

There are some global or international cities that influence and invite peoples from outside the nation, or even from all over the world. Most of the time, these cities compete with each other for resources [2]. An alternative analytic explanation says that the "city is an urban community falling under a specific administrative boundary" [3, 4].

Apart from their size and importance, cities can also be classified as new and existing, based on their urban growth and establishment. New cities come into existence to satisfy economic growth of the country. Some researchers suggested that a city is a complex system that includes physical (building, bridges, etc.) and social (people, institutions, etc.) components for society's development [5]. Some researchers described the physical component as a hard component, and the social component as a soft component of development [2, 6].

If we want to find the meaning of "smart city," then we can say that it is the combination of "smart" and "city." It can be represented as an urban area that uses smart systems to make day-to-day life easier. Here, smartness of the city defines the capability to combine all its resources, to successfully and flawlessly attain the goals, and achieve the purposes that have been set before [4]. However, if somebody looks for a perfect definition for smart city, he or she will fail to find it, and instead, will find many substitutes that result in an uncertain meaning.

## 2 EVOLUTION OF THE SMART CITY

The phrase "smart city" was coined in the early 1990s to illustrate the use of technology and innovation in urban development [1]. More precisely, it can be stated that in the 1990s, researchers examined cities and their ongoing IT
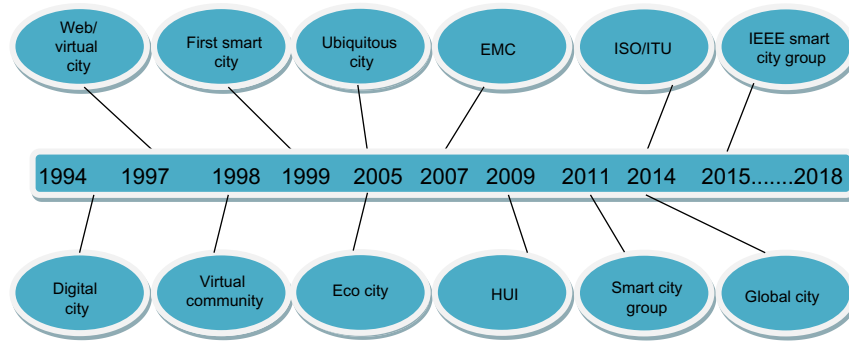
FIG. 1    Smart city evolution timeline.

projects from different viewpoints, and using slightly different terms, described IT and communication-based project initiation in urban spaces (Fig. 1).

The smart city evolved into a digital city in 1994 in Amsterdam. In 1997, it was claimed that there were 2000 virtual urban areas in the world [7]. These virtual cities introduced a local ICT network, which permitted the growth of local cyber-based (virtual) communities. These virtual urban areas were treated as electronic and web-based representations of the real urban areas, and were housed with the help of the world wide web (WWW).

Virtual cities were treated as the first effort to make use of the Internet to support native democracy, and allowed urban promotion, Internet-based municipal operation, and social development within cities. However, a deficiency of citizen feedback was documented.

After the introduction of the virtual city, the virtual community came into existence in 1998 [8]. The virtual community enables communication between individuals through shared norms. This virtual community network had a narrow scope of digitalization, because it was associated with a community. People outside the community had no direct access to the community network.

The facts discussed herein show that virtual and digital cities intended to form communities using ICT to socialize residents, to digitalize local government policy, and to make use of virtual space to remove the barrier of public space. By this perspective, the Internet, in collaboration with the city system and the WWW, was used to build up city websites that present substitute smart services, including information rescue, and official and general communication. These two smart city approaches pretend the metropolitan spaces are either a connected communities, or two/three dimensional virtual spaces.

In 1999, the first smart city concept was considered in Dubai [9]. Another well-known digital city system was Kyoto [10], which was developed in 1998, and resulted in 2D and 3D spaces, where inhabitant communications were collected with sensors, and their behavior was animated.

The digital city model became identical to an information city, which was understood as a metropolitan location where the ICT is the key driver to deliver innovative online services [11]. The idea of an information city later evolved into the ubiquitous city, where data is available through implanted urban communications [12]. The intelligent city focuses on the city performance, which depends on innovation in the following areas (i) intelligence, creativity, and originality; (ii) communal intelligence; and (iii) artificial intelligence [11].

The preceding smart city types evolved progressively into a more complicated environment, which was able to present more services and enable scientific embeddedness. Anttiroiko et al. [13] explain scientific embeddedness as the capability of technology to embed itself into social systems in order to attain a smart service delivery. The level of embeddedness ranges from simple information delivery to intelligent system implementation, then from implementations to systems that deal with social and human concerns, and to ecological systems that deal with sustainability [13]. In comparison, the city ecosystems are generally defined as communities of interacting organisms and their environments, and are typically described as complex networks formed because of resource interdependencies [14].

An ecosystem can be seen as "an interdependent social system of actors, organizations, material infrastructures, and symbolic resources" [15]. In this respect, ecosystems, like other kinds of systems, are comprised of elements, interconnections, and a function/purpose; but are special types of systems, in that their elements are intelligent, autonomous, adaptive agents that often form communities, and also because of the way they adapt to elements being added or removed. According to this definition, four critical elements exist in ecosystems: (1) interaction/engagement; (2) balance; (3) loosely coupled actors with shared goals; and, (4) self-organization [14].

Today, almost all cities claim to be more or less smart with an underlying self-congratulatory tendency [16], obviously with regard to a different level of technology embedded, or due to the existing intelligent capacity that a city holds.

The era of the smart city deals with huge storage and processing issues. To get such storage, processing, and data availability, the smart architecture needs the help of cloud computing. Researchers have proposed different methods to distribute the work load of a cloud milieu [17]. Researchers also suggested some smart methods [18] that help build the smart city.

## 2.1 Components of a Smart City

The smart city has a collection of smart components. These components help to solve the problems in an intelligent way, and also provide facilities to its users to build a smart society. Fig. 2 shows how the components are interrelated, and the impact of data and communications in building the smart city. Following are the smart components:

- *Smart Infrastructure*: This includes the use of sensors and smart grid technologies to facilitate smart infrastructure, such as water and energy networks, streets, buildings, and so forth.
- *Smart Transportation (or Smart Mobility)*: This includes transportation networks with improved, embedded real time monitoring and control systems.
- *Smart Environment*: This component provides a smart innovation and ICT to incorporate natural resource protection and supervision, such as a waste product management system, sensor based pollution control, and so on.
- *Smart Services*: Smart services utilize the technology and ICT for health, education, tourism, safety, and so forth.
- *Smart Governance*: This component introduces smart government in the urban space, associated with technology for service delivery and resource utilization with respect to government policy.
- *Smart People*: This component deals with creativity and innovation introduced by individuals in the society.
- *Smart Living*: This refers to the advancements that improve lifestyles and quality of life in the urban area.
- *Smart Economy*: This is the technology and innovation that escalate business growth, employment, and urban growth.

The preceding components are interconnected to provide smart services to people of the city. Apart from that, smart government systems help to successfully execute smart city missions.
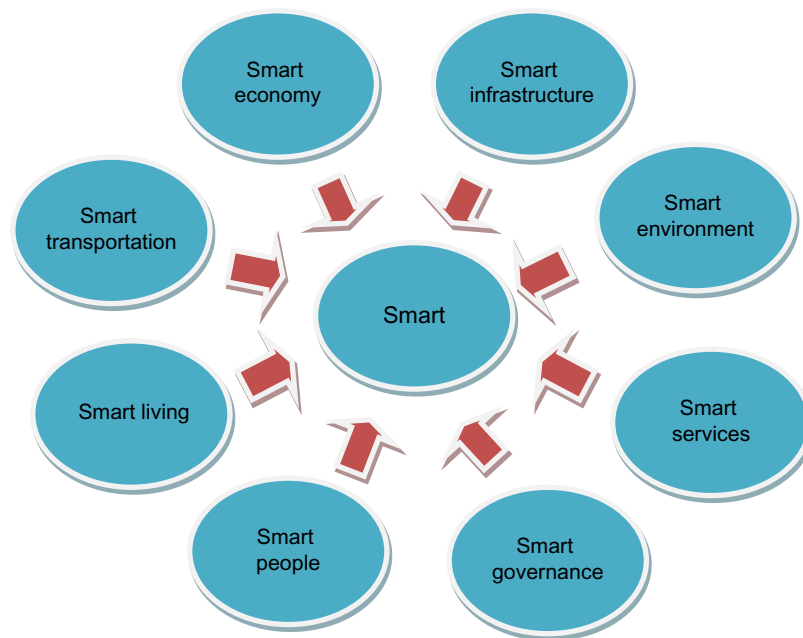


FIG. 2    Components of a smart city.

## 3 SMART CITY AN URBAN DEVELOPMENT

The World Foundation for Smart Communities encouraged the use of information technology in smart cities to meet the challenges in a global economy. However, the recent attention in smart cities can be recognized to the strong concern for sustainability and rise of new Internet technologies, such as mobile technologies, the semantic web, cloud computing, and the Internet of Things (IoT) for improving real world user interfaces.

The theory of smart cities has been seen from the viewpoint of technologies and components that have some specific properties within the digital and intelligent cities literature. It focuses on the most recent developments in mobile and persistent computing, and agent technologies, as they become embedded into the physical spaces of cities. The emphasis on smart embedded devices represents a distinctive characteristic of smart cities compared with intelligent cities, which create territorial innovation systems combining knowledge-intensive activities, institutions for cooperation and learning, and web-based applications of collective intelligence. The most critical challenge of the smart city environment is to address the troubles and improvement priority of cities within a global and innovation-led world. The first task that cities must address in becoming smart is to create a rich environment of broadband networks that support digital applications.

This includes: (1) the development of broadband infrastructure combining cable, optical fiber, and wireless networks, offering high connectivity and bandwidth to citizens and organizations located in the city, (2) the enrichment of the physical space and infrastructures of cities with embedded systems, smart devices, sensors, and actuators, offering real-time data management, alerts, and information processing, and (3) the creation of applications enabling data collection and processing, web-based collaboration, and actualization of the collective intelligence of citizens.

The latest developments in cloud computing and the emerging the Internet of Things, open data, semantic web, and future media technologies have much to offer. These technologies can assure economies of scale in infrastructure, standardization of applications, and turn-key solutions for software as a service, which dramatically decrease the development costs while accelerating the learning curve for operating smart cities.

The second task consists of initiating large-scale participatory innovation processes for the creation of applications that will run and improve every sector of activity, city cluster, and infrastructure. All city economic activities and utilities can be seen as innovation ecosystems in which citizens and organizations participate in the development, supply, and consumption of goods and services. Fig. 3 presents three application areas of smart cities in the fields of economy, infrastructure, and governance.
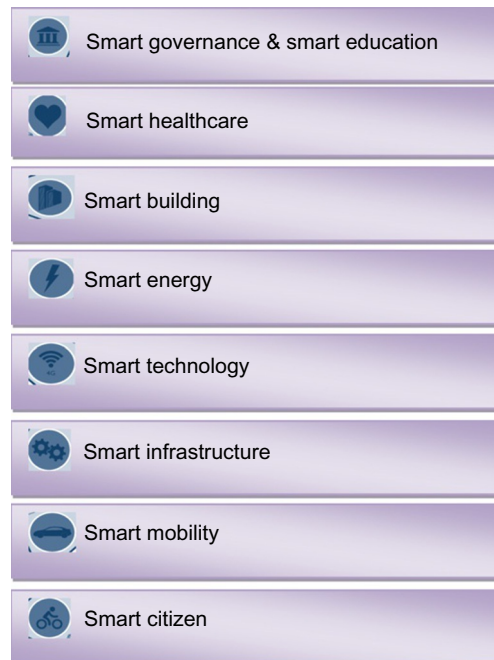


FIG. 3  Application areas of smart cities.

# 4 SMART CITY ARCHITECTURE

The term "architecture" describes several technological aspects, which range from information structure to technology delivery, or, ICT. However, the most familiar use for the term concerns the formulation of physical structures such as systems or buildings. In this respect, architecture concerns a definition of the structure, relationships, views, assumptions, and rationale of a system.

Following up on the preceding definition, an ICT system also has an architecture, which offers the following features:

- It is used to define a single "system."
- It describes the functional aspects of the system.
- It concentrates on describing the structure of the system.
- It describes both the intra-system and inter-system relationships.
- It defines guidelines, policies, and principles that govern the system's design, development, and evolution over time.

The smart city architecture definition consists of the following components:

- Smart city meta-architecture
- Smart city multilayer communication architecture
- Smart city modular architecture

The smart city multi-tier, meta-architecture consists of the following Fig. 4 layers:

*Layer 1—Natural Environment*: This includes all the environmental features where the city is located.
*Layer 2—Hard Infrastructure (Non ICT-based)*: This includes all the urban facilities (e.g., buildings, roads, bridges, energy-water-waste-heat utilities, etc.).
*Layer 3—Hard Infrastructure (ICT-based)*: This concerns all hardware with which smart services are being produced and delivered to the end-users (e.g., datacenters, telecommunication networks, IoT, sensors, etc.).
*Layer 4—Smart Services*: These are the smart services that are being offered via both the hard and soft infrastructure (e.g., smart safety, intelligent transportation, smart government, smart water management, etc.).
*Layer 5—Soft Infrastructure*: This includes individuals and groups of people living in the city, business processes, software applications and data with which the smart services are executed and being realized.

The communications view of the architecture is also multi-tiered, and consists of the following Fig. 5 layers:

- *Sensing Layer*: This layer consists of the terminal node and capillary network. Terminals (sensors, transducers, actuators, cameras, RFID readers, barcode symbols, GPS trackers, etc.) sense the physical world. They provide the superior "environment-detecting" ability and intelligence for monitoring and controlling the physical infrastructure within the city. The capillary network (including SCADA, sensor networks, HART, WPAN, video surveillance, RFID, GPS-related networks, etc.) connects various terminals to network layers, providing ubiquitous and omnipotent information and data.
- *Network Layer*: indicates facilities that are being provided by telecommunication operators, as well as other metropolitan networks provided by city stakeholders and/or enterprise private communication networks. It is the
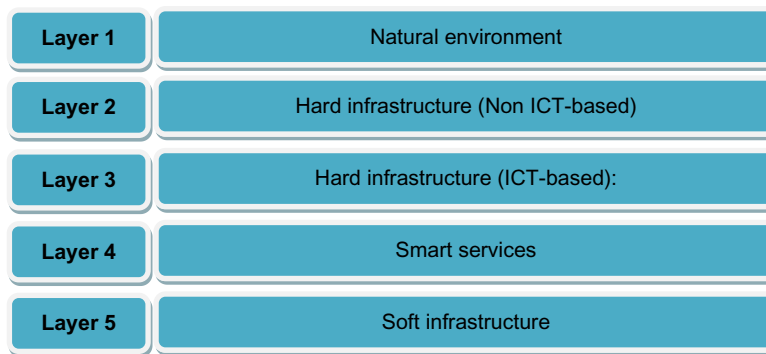


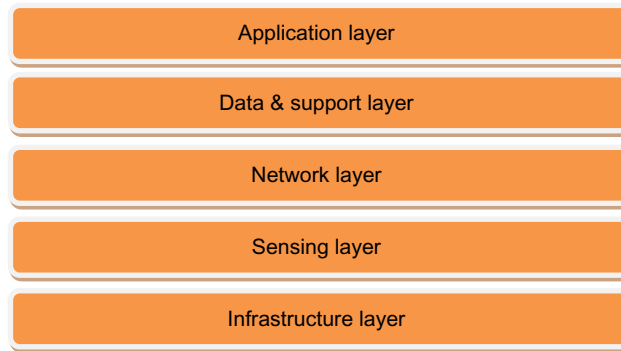**FIG. 4** Meta architecture of a smart city.

**FIG. 5**   Smart city multilayer communication architecture.

"Infobahn," the network layer data and support layer: The data and support layer makes the city "smarter," its main purpose is to ensure support capabilities of various city-level applications and services. The data and support layer contains data centers from industries, departments, and enterprises, as well as the municipal dynamic data center and data warehouse, among others, established for the realization of data processes and application support.

- *Application Layer*: The application layer includes various applications that enable smart city management and deliver smart services.
- *Operation, Administration, Maintenance and Provisioning, and Security (OAM & P & security) Framework*: This layer ensures operation, administration, maintenance and provisioning, and security function for the ICT systems.

The third type of architecture, also known as "modular architecture," consists of the following modules:

- *Smart City Networking Infrastructure and Communications Protocol*: This module addresses the necessary network infrastructure (telecommunications networks and IoT) to deploy smart services and enhance living inside the city.
- *Applications*: This concerns all the smart applications that are available inside the smart city ecosystem. These applications could be classified in the 6 smart city components (people, mobility, government, economy, environment, and living).
- *Business*: This refers to all business groups, which are available inside the smart city ecosystem, and use smart applications. This particular module deals with the following information management issues:
  - User information for consumer behavior recognition.
  - Business intelligence for statistical and feasibility studies.
- *Management*: This module contains all rules and procedures for managing a smart city. The primary elements of this module concern:
  - *Information management*: information collection and dissemination across the smart city.
  - *Process management*: ICT management from a business transaction perspective.
  - *People management*: human and workflow management in terms of a sequence of operations within the city, such as a single organization and visualization.
- *Data*: Data is crucial in smart cities, and can be either used or produced, while they can be stored centrally or in a distributed manner (locally). It is analyzed in the following components:
  - *People data*: This is individual information, which is produced by inhabitants and mostly preserved with privacy issues.
  - *Process data*: This is produced during smart service execution and routine transactions between machines and/ or people.
  - *Documents*: These are mainly used or produced by government applications, or within the business sectors. Documents can be also the basis of smart service controls (e.g., quality assurance, disaster recovery plans, etc.) and can be organized in digital repositories.
  - *Geospatial*: This data is used and stored by Geographical Information Systems (GIS).
  - *Business data*: This is created in the business module by smart economy applications.

# 5  IoT FOR SMART CITY

The Internet of Things (IoT) is the network of devices that are connected together and communicate with each other to perform certain tasks, without requiring human-to-human or human-to-computer interaction. The Internet of

Things is about installing sensors (RFID, IR, GPS, laser scanners, etc.) for everything, and connecting them to the Internet through specific protocols for information exchange and communications, in order to achieve intelligent recognition, location, tracking, monitoring, and management. With the technical support from IoT, a smart city needs to be instrumented, interconnected, and intelligent.

The Internet of Things examples extend from smart connected homes, to wearables, to healthcare. It is not wrong to suggest that IoT is now becoming part of every aspect of our lives. Not only are the Internet of Things applications enhancing the comforts of our lives, but also they are giving us more control by simplifying routine work life and personal tasks.

The recent hype about the future prospects of the IoT has forced companies to take the initiative of coming up with basic building blocks of the Internet of Things, that is, hardware, software, and support to enable developers to deploy applications that can connect anything within the scope of the Internet of Things. Following are the different application areas where the IoT works:

- Smart homes
- Connected cars
- Wearables
- Industrial Internet
- Smart cities
- IoT in agriculture
- Smart retail
- Energy engagement
- IoT in healthcare
- IoT in poultry and farming

## 6 CYBER SECURITY AND PRIVACY IN SMART CITIES

All together, the smart-city market is expected to exceed $1.7 trillion in the next 20 years. But the interconnectivity across the virtual and physical infrastructure that makes a smart city work also creates new and substantial cyber security risks. With each additional access point, sensitive data exposure vulnerabilities expand. Smart cities can be susceptible to numerous cyberattack techniques, such as remote execution and signal jamming, as well as traditional means, including malware, data manipulation, and DDoS. To overcome these risks, a critical infrastructure needs to be designed that involves all parties (from individual citizens to large public and private institutions).

Security is a global idea tied to safety (life, property, and rights) as an assurance that a person may go about their life without injury.

Cyber security is a subset of security that focuses on the computing systems, data exchange channels, and the information they process. Information security is interlaced with cyber security, with the focus being on information processed. Cyber security is a critical issue due to the increasing potential of cyberattacks and incidents against critical sectors in smart cities. When we think about cyberthreats in smart cities, we come across data and system threats. The data threats include personally identifiable information (PII) being put at risk, natural disasters, and malicious activities and DDoS attacks.

To overcome these cyber risks, we need to develop a clear structure for risk assessment and management. The following actions should be taken to help reduce cyber risk in a smart city:

- Use threat modeling to assess threats.
- Document and review risk acceptance and exceptions.
- Make risk assessment and management an ongoing process.
- Educate city leaders to understand and support the principles, and to manage priorities.
- Consider resilience.
- Leverage procurement processes to reflect priorities and risks.
- Establish minimum security baselines.
- Define clear responsibilities for supporting a security baseline.
- Establish a system for continuous security monitoring.
- Set expectations for sharing threat and vulnerability information.
- Create a cross-city mechanism for sharing.
- Run cyber drills to test game plans.
- Emphasize privacy and civil liberty protections in threat information sharing.

- Apply relevant national or international standards for information sharing.
- Create a Computer Emergency Response Team (CERT).
- Create clear ownership.
- Engage private sector and national resources.
- Enable consistent incident classification.
- Test incident response capabilities and processes.
- Develop public awareness campaigns.
- Cultivate employee development and workforce training programs.

## 7　FUTURE OF THE SMART CITY WITH RESPECT TO THE IoT

The Internet of Things (IoT) carries the potential to transform communities around the world into "smart cities," creating a new era of urban living. The benefits include increased safety, reduced traffic, lower levels of pollution, more efficient use of energy, and a better overall quality of life for future city dwellers.

Smart cities of the future will allow IoT systems to revolutionize the way we live and conduct business, with sensors attached to virtually every vehicle, device, or piece of equipment that a city uses on a daily basis. The possibilities are almost endless, as IoT produces invaluable data for a multitude of business intelligence systems, such as emergency services, crime prevention, parking management, and much, much more. And according to Smart America, city governments will invest more than $41 trillion over the next two decades to upgrade their infrastructures to benefit from the IoT. Here are some of the initiatives taking place in smart cities today:

- Smart roads to optimize and adapt to changing traffic patterns.
- Smart buildings to optimize energy, lighting, and resources.
- Smart lighting with adaptive street lights.
- Smart waste management to monitor and optimize collection.
- Smart grids to manage energy consumption with monitoring and allocation for dynamic conditions.

## 8　CONCLUSION

There are a lot of benefits of smart cities that can make citizens' daily lives more comfortable and convenient. The Smart Cities Mission is a bold new worldwide initiative to drive economic growth and improve the quality of life of people by enabling local development and harnessing technology as a means to create smart outcomes for citizens.

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