Application of IoT for a Smart City

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Abstract – The concept of Smart cities is widely emerging now days. A smart city can be defined as internet of networking the physical devices vehicles-smart devices which are embedded with electronics, software sensors, actuators and network connectivity that enables the objects to collect and exchange data. The ability of human and computers to learn and interact from the things which include sensors, services and other internet connected objects are provided by internet of things (IoT). Smart cities can work as a tool for controlling the rapid urbanization and various problems caused by the ever increasing urban population. The implementations of the smart technologies can increase the value of the city. Smart city concept introduces new practices and services that highly impacts policy making and planning. The understanding of IoT systems will make us to know the cyber world with one physical world and will fundamentally change and make powerful human interaction with the world.

In this paper an outline for the understanding of smart cities through the internet of things is presented. The outline includes completely the information of urban system, from the sensory level and networking support arrangement through data management and cloud-based integration of respective systems and services.

Index Terms—Information management, Internet of Things (IoT), network architecture, smart cities.

I. INTRODUCTION

A smart city is a area that is efficient, sustainable & liveable. Around 80% of the world's population will reside in cities and surrounding regions by 2030. So, cities need to be smart, if only to endure as platforms that enable economic, social, and environmental welfare. Smartness of a city is driven and enabled technically by the evolving Internet of Things (IoT) .The design Smart devices, Smart phones, Smart cars, Smart homes, Smart cities and smart world have been emerging for many years. Achieving these goals has been investigated by many different and frequently displaces research communities.

Five such prominent research communities are: Internet of Things (IoT), mobile computing (MC), pervasive computing (PC), wireless sensor networks (WSNs), and most recently, cyber-physical systems (CPS) With urbanization breaking the Wall, it is of top importance to understand the demand for increase the efficiency of city organization. Currently, few municipalities have systems for live monitoring and understand of urban process parameters. The commonly working approach is data collection, offline analysis and action followed by system adjustments and reiteration of the whole process. Data collection exercises are often costly and tricky to reproduce. There is thus an increased demand on municipalities to include smart technologies that collect the essential data and analyze them for action. A large-scale IoT infrastructure can aid this process by counting data processing. With superior sensing and computation capabilities, data is collected and evaluated in real time to take out the information, which is further converted to practical data. This will improve the decision making of city organization and citizens to turn the city smart.

The paper describes smart cities especially from the point of view of city councils. Then the details of the IoT infrastructure for a smart city, and particularly the design of network architecture are presented. Current trends and future thoughts of smart city improvement are also discussed.

II. LITERATURE REVIEW

A smart city utilizes ICTs in a way that addresses quality of life by handling urban living challenges taken in by more efficient utilization of restricted resources. The leading municipalities, in terms of services and quality of life, have provided professional services to their citizens by the forward thinking and use of technology in monitoring various environmental parameters. Most of these systems consist of sensor, data storage device, and computer at a base location where data is analyzed specially. From the technical perspective, the development of social networking in the past shows the usage of ICT at an individual's level. Large-scale implementations at system level have made some progress in recent years. A complete system with sensing, storage, analytics, and interpretation is incorporated.

The incorporated system must have core capabilities of plug-and-play sensing, secure data aggregation, quality of service (QoS), and re-configurability. With an urban sensing system, the ability to estimate the impact of the previous performance is readily available as the sensing cycle repeats. A unifying information management platform delivers a competence across application domains essential to the city. As large volumes of data collection and analysis are already performing different levels within city councils using manual and semi-automated methods, it is mostly in separation.

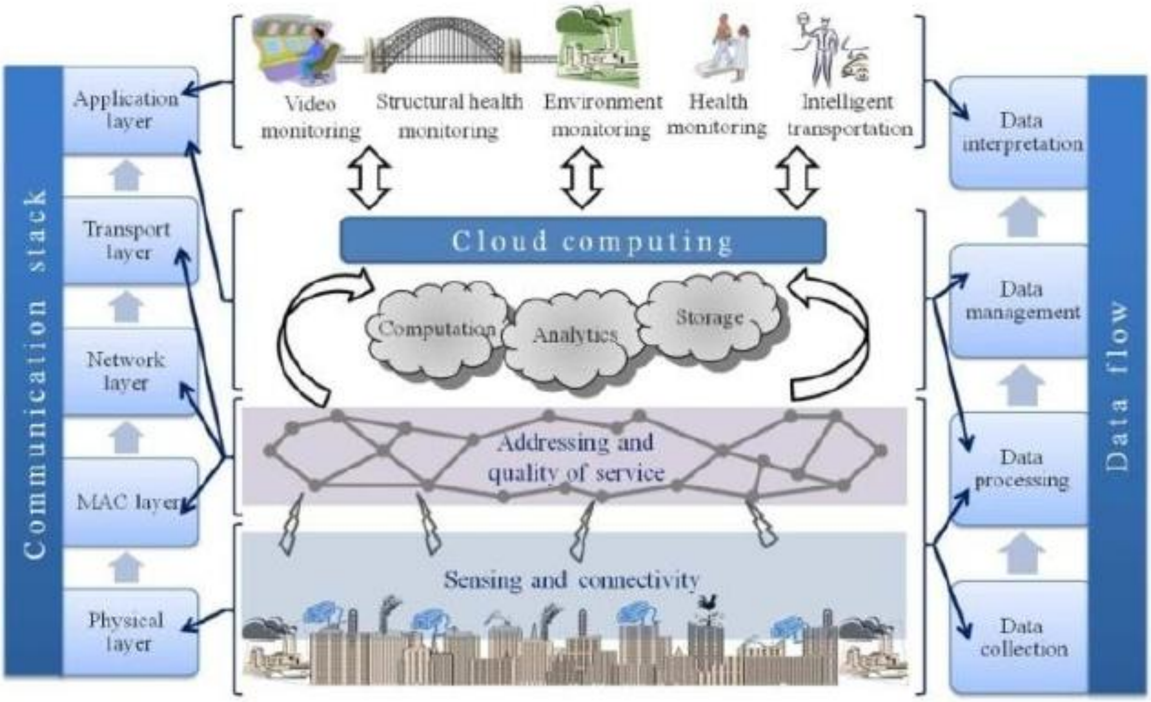

Fig. 1. IoT infrastructure from three different domains.

As with any large group it is to be expected that large portions of these data remain put out of place in the time scales over which they are collected and the capacity for them to be integrated. An urban information outline enabled by IoT provides a means for consolidating these tasks and sharing of data between various service providers in the city.

The applications within the urban environment that can benefit from a smart city IoT capability can be grouped according to contact areas. This includes the effect on health, mobility, productivity, pollution, and critical community services. Several projects are already in progress within the City of Melbourne that utilizes sensor technologies to collect application-specific information. These include public parking monitoring, microclimate monitoring, access and mobility. A number of specific application domains have also been recognized that could utilize smart city IoT infrastructure to service operations in health services, strategic planning, sustainability, tourism and city safety.

III. IOT INFRASTRUCTURE FOR SMART CITY

In this section, the building blocks of smart city IoT Infrastructure is presented. As the key technological enabler. IoT is introduced from three different domains: network-centric IoT, Cloud-centric IoT, and data-centric IoT, corresponding to communications, management, and computation requirements of smart city development and deployment (see Fig. 1)

A. Network-Centric IoT

The vision of IoT can be interpreted in two ways: 1) Internet based and 2) Object based. The Internet-based architecture will involve Internet services as the main focus while data are contributed by the objects. In the object-based architecture [4], the smart objects will take the centre stage. In either case, networking is the fundamental issue. The proposed networking modules and their relationship with communication stack are shown in Fig. 1.

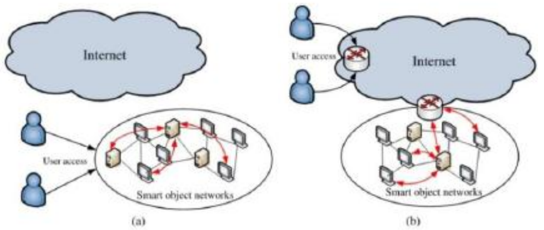

Fig. 2. Connectivity model. (a) Autonomous smart object networks. (b) Ubiquitous smart object networks.

Connectivity Model: Technically, the success of the Internet is partially due to the adoption of TCP/IP architecture. Meanwhile, it is interesting to note the transition of network architecture design for WSNs, which are considered as a subset of smart object networks since they share many of the properties such as low-power operation, the large scale of the networks, and resource constraints. Initially, the WSN community rejected the IP architecture with the assumption that it would not meet the challenges of WSN systems [7]. After several years, however, the community started to lean toward layered network architecture because of the benefits of modularity and separation of concerns [8], [9]. Many IP-based sensor networks have emerged now because of the interoperability with existing systems and the well-engineered architecture adhering to the end-to-end design principle [10].

Based on the IP architecture, as shown in Fig. 2, connectivity models range from autonomous smart object networks, which are isolated from the Internet, to ubiquitous smart object net-works, which are part of the Internet. In between, there are numerous models available depending on different applications.

B. Cloud-Centric IoT

In order to integrate the ubiquitous urban sensing and the smart city applications, as well as to realize the full potential of Cloud computing, a combined framework with Cloud at the center is shown in Fig. 1. In this model, sensing service providers can join the network and offer their data using a storage Cloud; analytic tool developers can provide their software tools; and computational intelligence experts can provide their data mining and machine learning tools useful in converting information to knowledge. Cloud computing is able to offer these services as infrastructures, platforms, or software. Specifically, the data generated, tools used, and algorithms developed all disappear into the background, with focus given to various application domains of IoT. According to our vision for Cloud-centric IoT (as shown in Fig. 1), the Cloud integrates all facets of ubiquitous computing by providing scalable storage and computational resources to build new businesses. Moreover, the core objective of the Cloud to efficiently model cost based on supply and demand offers a unique opportunity to create an efficient IoT business model.

Table I: Comparison Of Characteristics Of Iot Network Architecture Classification

Network architecture	**Autonomous**	**Ubiquitous**	**Application-Layer overlay**	**Services oriented**
Design approach	Evolutionary	Evolutionary	Evolutionary	Clean-slate
Connectivity model	IP-compatible	IP	IP	IP-compatible
Network hierarchy	Yes	Yes	Yes	Yes
In-Network Processing	No	No	Yes	Yes
QoS Complexity	Low	High	Low	High
Progress in defining QoS	Intermediate	Intermediate	Advanced	Early Stage

C. Data-Centric IoT

It is not surprising that there will be a massive amount of data generated in a fully functioning IoT. Data-centric IoT emphasizes all aspects of data flow, including collection, processing, storage, and visualization.

Data Collection: Efficient heterogeneous sensing of the urban environment needs to simultaneously meet competing demands of multiple sensing paradigms. It also has implications on network traffic, data storage, and energy utilization. Importantly, this contains both fixed and mobile sensing infra-structures as well as continuous and random sampling. A generalized framework for data collection is required to effectively exploit spatial and temporal characteristics of the data, both in the sensing domain and associated transform domains.

Besides common sensing paradigms, such as RFID and WSN, participatory sensing is emerging as a novel sensing paradigm, where people, rather than deployed sensors, take the responsibility for collecting and sharing sensory data. It offers the possibility for low-cost timely sensing of the environment localized to the user, complementing data from a fixed infra-structure. A salient feature of participatory sensing is that people are not obliged but voluntary or incentivized to perform the sensing tasks. As such, it is difficult to guarantee the quality of data being contributed. In [11], we have defined a metric to evaluate the quality of data contributed through participatory sensing. At the same time, systems for ensuring privacy and trust are yet to be adequately addressed.

IV. DESIGN OF NETWORK ARCHITECTURE

By further focusing on the networking aspect of IoT, in this section, we will design and construct appropriate network architecture for different smart city applications as well as define their corresponding performance metrics.

In general, there are two main design approaches for network architecture: 1) an evolutionary approach and 2) a clean-slate approach. The evolutionary approach makes incremental changes to the current network architecture to reuse as many components as possible from existing networking solutions. From this perspective, an IoT could be viewed as an extended architecture evolved from the Internet. On the other hand, the clean-slate approach advocates a redesign of network without being con-strained by the current structure. It means, in order to cope with next-generation network challenges, new architecture and proto-cols will be developed according to disruptive design principles. Indeed, an ongoing debate about these two approaches has engaged in the networking research community over the past several years. Ultimately, individual researchers have their own styles, often a unique blend between them as the applications dictate.

In the following, we will present four most common network architectures in the smart city domain, that is, autonomous network architecture, ubiquitous network architecture, application-layer overlay network architecture, and service-oriented network architecture. They are all given in three parts devoted to architecture description, applications, and QoS requirements, respectively. Table I summarizes the characteristics of each network architecture in terms of different features, namely, design approach, connectivity model, network hierarchy, in-network processing, QoS complexity, and progress in defining QoS.

A. Autonomous Network Architecture

i. Architecture Description: Fig. 2(a) illustrates the connectivity model of autonomous networks. As suggested by the name, autonomous networks are not connected to the public networks, and there are several such use cases in reality. However, it does not necessarily mean that the Internet access is forbidden; it is in fact possible via gateway if required. While designing autonomous networks, though not mandatory, IP protocol suite is still commonly adopted due to its scalability and flexibility. What is more important, the large address space provided by IP is desired in most cases.

ii. Application—Automatic Parking Management: Automatic parking management, as a direct example, is a useful service city councils may provide to its citizens. By collecting the information regarding the parking bay occupancy wirelessly, the council can provide parking vacancy information to the users on a visualization platform like a smart-phone. It will also enable the council to apply fine in case of parking infringements. Due to the technological advances and relative simplicity of application, a few commercial systems are available based on this wireless technology. Most of the systems work autonomously in a three-tier mode where the lowest tier modes are attached to sensors, the middle tier contains forwarders, and the uppermost tier contains base stations connected to an Internet-enabled device. With developments in antenna engineering and availability of motes with long range, formation of star network will be made possible bypassing the intermediate forwarders.

iii. QoS: The QoS requirement in this case is indeed application-dependent. For the above automatic parking management, sensor coverage, reliability, and system responsiveness are the major concerns.

B. Ubiquitous Network Architecture

i. Architecture Description: For ubiquitous networks, the connectivity model is as shown in Fig. 2(b), where smart object networks are a part of the Internet. Through the Inter-net gateway, authorized users will have access to the information provided by smart object networks either directly fetching from the device or by means of intermediate servers. Usually, the servers act as the sinks in smart object networks to collect data from each object. Taking scalability and resource conservation into account, the user access through the servers is probably more preferable. Instead of abstracting as smart object networks as previously, we are now referring to the specific networks.

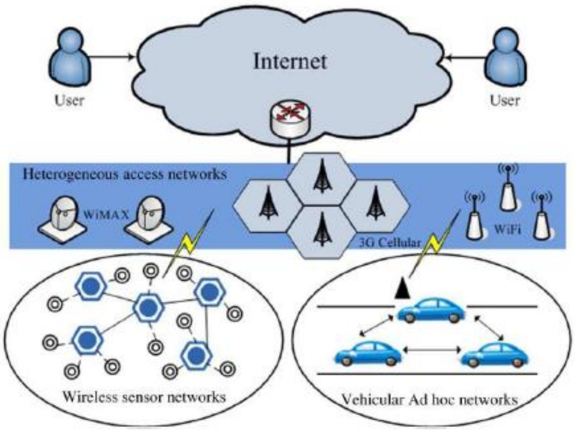

Fig.3. Ubiquitous network architecture

By taking a close look at the interface between the Internet and smart object networks, Fig. 3 captures a detailed view of ubiquitous network architecture. The feature of ubiquitous network architecture includes:

Multitier: The network architecture is hierarchical, comprising both wireless multi-access networks and wireless multi-hop networks. In particular, wireless multi-hop networks could be in the form of WSNs or vehicular ad-hoc networks, with respect to the applications in Sections IV-B2 and IV-B3.

Multi radio: It is not uncommon nowadays to have a number of radio access technologies available to connect to the Internet, either covering the same or complementing geo-graphical areas. These networks could be WLAN, Wi MAX, macro-cellular, femto-cellular, or even ad-hoc. The synergy and integration of different networks in multi-access and multi-operator environment introduces new opportunities for better communication channels and an enhanced quality of provided applications and services.

ii. Structural Health Monitoring: A typical application of

WSNs for smart cities are structural health monitoring. The city is full of stationary structures—some small, some huge, others new, most of them very old—such as buildings, dams, or bridges [6]. They are actually part of our life: bridges are used by humans and vehicles, and people are living and working in the buildings. The health of these large structures is clearly critical; any damage may cause life-threatening situations and serious financial loss. To monitor their health level, passive wireless sensors will be embedded within a concrete structure, and send a radio signal of suitable amplitude and phase characteristic periodically using the radio frequencies in the unlicensed Industrial Scientific and Medical (ISM) bands. The data collected at the sink are then used to detect any anomalies that could be a sign of abnormality for early warning or damage prevention.

iii. Traffic Congestion and Impact Monitoring: Urban traffic is the major contributor to traffic noise pollution and one of the major contributors to urban air quality pollution and greenhouse gas emissions. Traffic congestion directly imposes significant costs on economic and social activity in cities: congestion in Australia's metropolises cost the nation $9.5B in 2005, and is forecast to cost $20.4B in 2020. In addition, supply chain efficiencies and productivity, including "just-in-time" operations, are severely impacted by this congestion causing delays to freight vehicles and failures to meet delivery schedules.

There are a variety of sensors available for measuring pollution levels and traffic delays and queuing, either stationary at fixed locations or mobile mounted in vehicles. Via vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, they are able to form ad-hoc vehicular networks, which allow online monitoring of travel times, origin-destination route choice behaviour, queue lengths and air pollutant and noise emissions, as well as predict possible accidents. Together with information gathered by the urban traffic control system, valid and relevant information on traffic conditions can also be presented to travellers.

iii. QoS: In such multi-access multi-hop wireless networks, providing QoS guarantees is unsurprisingly challenging and an emergent discipline. The shortage of a standardized end-to-end protocol for establishing QoS, the complexity of network dynamics, and the difference of QoS requirements to be achieved cause this hard situation. Specifically, structural health monitoring mainly requires reliable data delivery from each node to the sink. The QoS requirement of traffic congestion and impact monitoring is relatively stringent in terms of throughput and delay, due to the involvement of real-time data information.

C. Layer Overlay Network Architecture

i. Architecture Description: Similar to WSNs, the most common operation of IoT is to collect data from hundreds of thousands of nodes. Because of the multipoint-to-point nature of data flows, it is easily observed that traffic congestion occurs more likely near the sinks, which would not only degrade the QoS, but also increase energy consumption of these nodes.

Statistically, the spatio temporal data are correlated unless something unusual happens. Thus, in-network data processing, e.g., data aggregation, data fusion, or rule-based feature extraction, will greatly help reduce the amount of data transmissions and prolong system lifetime. The idea can be realized by forming an application-layer overlay network, consisting of selected nodes (e.g., cluster heads) running in-network data processing tasks.

ii. Compressive Sensing for Environmental Monitoring: The above architecture is readily applied to city-wide environmental monitoring application. By deploying large-scale environmental monitors, the data from these will be relevant to rapid urbanization and climate change adaptations, and enable continuous monitoring of the city environment for ensuring appropriate environmental health and safety standards. More specifically, parameters including hydrocarbons and oxides of nitrogen—the basic ingredients of photochemical smog, carbon dioxide, carbon monoxide, ammonia, and benzene will be monitored to reflect the air quality in the deployed area of interest. In addition, microclimate sensing will also be achieved through the deployment of temperature and humidity sensors. Overall, urban sensing is able to improve the quality of life and productivity for a more sustainable city.

iii. QoS: The data traffic for environmental monitoring is elastic in nature. It implies that bandwidth is the primary concern; delay and packet loss are tolerable to some extent.

D. Service-Oriented Network Architecture

i. Architecture Description: Heterogeneity is the most distinguished characteristic of the IoT, which often contains a variety of sub networks adopting different communication technologies. To enable communication between these sub-networks, traditionally, a complex gateway device needs to be installed in order to translate different network protocols. Because of the inherent complexity of the translation gateway and the lack of flexibility and scalability, it is clearly not an efficient solution. To remedy this situation, revolutionary network architecture, named IDRA (Information Driven Architecture), is developed.

The IDRA is based on a clean-slate design approach, with its conceptual presentation given in Fig. 4. The key idea is to implement different network functions (such as addressing, naming, synchronization, routing, etc.) as a standardized, technology-independent component called network service.

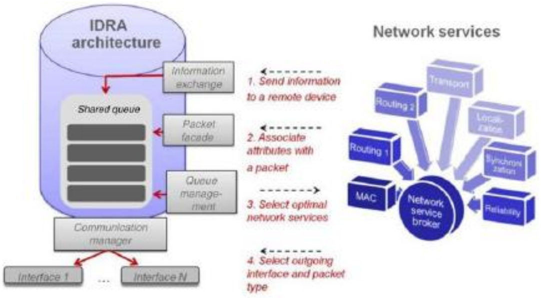

Fig. 4. Service-oriented network architecture

Net-work service can also be used to build either a full network protocol (e.g., transport protocol) or a simple operation (e.g., MAC for controlling the timing and sending the packets). In this case, different communication technologies are simply different services that will be understood by the communication manager. Regarding information exchange, a special packet is created and maintained by IDRA, whose metadata is associated with different network services required. For simplicity, IDRA uses a single system-wide queue for storing and processing all the packets. In summary, the major advantages of IDRA include: 1) IDRA enables direct communication between sub networks even with different communication technologies, without the need of translation gateways and 2) IDRA supports backward compatibility with IP architecture.

ii. Combined Noise Mapping and Video Monitoring: One immediate IDRA application for smart cities is combined noise mapping and video monitoring.

The well-known implications on health, well-being, and quality of life associated with noise pollution provide a significant challenge to city councils in managing noise and its effects. A reliable system for measuring noise and responding to noise issues is the strong motivation in development of acoustic sensor network within a municipality. Video sensor network, on the other aspect, integrates image processing, computer vision and networking to perform dynamic scene analysis. Detecting the cause of noise helps the council to take action and reduce noise in urban environment. With the coexistence of acoustic sensor network and video sensor network, they can be further combined together to empower noise-activated video monitoring for obtaining a fine-grain real-time COP. This will offer the city council an unprecedented practical opportunity to understand dynamic noise pollution profile, assess its impact on health and well-being and better plan for noise reduction and desirable urban sound space.

iii. QoS: Both audio and video data are categorized as inelastic traffic, which are generally delay sensitive and have strict QoS requirements. Unlike elastic traffic, they have an intrinsic band-width threshold because the data generation rate is independent of network congestion. The degradation in bandwidth may cause serious packet drop and severe performance degradation. To ensure the QoS of inelastic traffic, rate control and admission control is hence necessary to guarantee that they will receive sufficient bandwidth, at least greater than the threshold.

V. CURRENT TRENDS AND FUTURE THOUGHTS

Along rapid urbanization, making the cities smart becomes imperative. It is fair to say, WSN is evolving into the IoT. As a result, the WSN test bed activities of the last decade have provided valuable information about the architecture, security, networking, and data handling critical to large-scale IoT implementation. Most of these test beds address targeted applications and their communication backbone and other resources are not shared. This obviously leads to high costs and complexity, nevertheless providing valuable information about large-scale deployments.

More recently, IoT activities are gathering momentum around the world. Europe is becoming the contact point of IoT research with the establishment of Internet of Things European Research Cluster (IERC), which is a cluster of European Commission 7th Framework Program (EU-FP7) funded IoT projects. Key projects have included CASAGRAS2, Internet of Things Architecture (IoT-A) and the IoT Initiative (IoT-I). A city-wide smart city test bed development is now complete in Spain (Santander) that is laying out a test bed for research and service provision. China has established an IoT Center in Shanghai to study technologies and industry standards. A group of 60 telecom operators (key drivers of the technology) have initiated “Sensing China” project. Similar activities are underway in Japan, Korea, USA, Australia, and India, where various stakeholders are collaborating to advance the capabilities toward an IoT.

The end goal of smart city IoT platform is to have plug-and-play smart objects that can be deployed in any environment with an interoperable backbone allowing them to blend with other smart objects around them. In order to realize this goal, there are many technological hurdles including architecture, energy efficiency, security and privacy, QoS, Cloud computing, data analytics, and GIS-based interpretation. Standardization of frequency bands and protocols plays an important role in accomplishing this goal. Several projects and activities detailed above are addressing these critical challenges in the next decade, a clearer picture regarding the usefulness of IoT in making the city smart will emerge. Due to the scale of activities, participation of large companies and the Government will play a pivotal role in the success of this emerging technology.

VI. CONCLUSION

With rapid development in the emerging IoT technology, a comprehensive blueprint of developing a smart city using IoT, which is actually motivated and strongly demanded from city councils as they seek to ensure the provision of essential services and quality of life for city inhabitants, is presented. In this context, we identify the key IoT building blocks of smart cities, as well as provide the approaches and resolutions to meet their respective communications, computing, and computation requirements. Finally, in order to push the development forward, the proper business model of smart city is believed to be equally important as technological advancement.

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