Smart Cities Based on Internet of Things (IoT) -A Review

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Abstract- *The requirement and effectiveness of making cities smarter, about the potential market size, about trials and tests. Increasing population density in urban centers demands suitable provision of services and infrastructure to meet the needs of city inhabitants, surrounding residents, workers and visitors. The utilization of information and communications technologies (ICT) to achieve this objective presents an opportunity for the development of smart cities, where city management and citizens are given access to a wealth of real time information about the urban environment upon which to base decisions, actions and future planning. This paper presents a framework for the realization of smart cities through the Internet of Things (IoT). The framework encompasses the complete urban information system, from the sensory level and networking support structure through to data management and Cloud based integration of respective systems and services, and forms a transformational part of the existing cyber-physical system. This IoT vision for a smart city is applied to a noise mapping case study to illustrate a new method for existing operations that can be adapted for the enhancement and delivery of important city services.*

Keywords: *Internet of Things (IoT), RFID, ICT, HAN, WAN, WSN, ZigBee.*

I. INTRODUCTION

It is estimated that 70% of the world's population, over 6 billion people, will live in cities and nearby regions by 2050. The rapid increase of the population density inside urban environments, infrastructures and services has been needed to supply the requirements of the citizens. So, cities need to be smart, if only to survive as platforms that allow economic, social and environmental safety. Smart city is the one that uses information and communications technologies (ICT) to make the city services and monitoring more aware, interactive and competent[1]. Smartness of a city is driven and enabled technologically by the growing Internet of Things (IoT) [2]- a radical evolution of the current Internet into a global network of inter-connected objects that not only gathers information from the environments (sensing) and interacts with the physical world, but also uses existing Internet standards to provide services for information transfer, analytics, and applications [3].

The Internet of Things (IoT) is a new model that is fast gaining ground in the result of modern wireless telecommunications. The basic idea of this concept is the ubiquitous presence around us of a variety of things or objects – such as Radio-Frequency Identification (RFID) tags, sensors, actuators, mobile phones, etc. – which, through distinctive addressing schemes, are able to relate with each other and cooperate with their neighbors to reach common goals powered by the adaptation of a variety of facilitating devices such as embedded sensor and actuator nodes, the IoT has stepped out of its beginning and is on the edge of revolutionizing current fixed and mobile networking infrastructures into a fully integrated future Internet. Wireless sensor networks (WSN), as the sensing-actuation support of the IoT, effortlessly integrates into urban infrastructure forming a digital skin over it. The information generated will be shared across diverse platforms and applications to develop a common operating picture (COP) of the city.

With urbanization violate the 50% obstacle; it is of utmost importance to understand the demand for service profiles to increase the efficiency of city management. Currently, few municipalities have plan for live monitoring, and gathering of urban process parameters. The commonly employed strategy is: data collection; offline analysis; action; followed by system adjustments and repetition of the whole process. Data collection exercises are often costly and difficult to imitate. There is thus an increased demand on municipalities to incorporate smart technologies that collect the required data and analyze them for action, all in real time. With advanced sensing and computation abilities, data are assembled and evaluated in real time to extract the information, which is further transformed to usable knowledge. This will improve the decision-making of city management and citizens to turn the city smart.

II. MOTIVATION

The smart city is becoming smarter than in the past as a consequence of the current expansion of digital technologies. Smart cities consist of various kinds of electronic equipment applied by some applications, such as cameras in a monitoring system, sensors in a transportation system, and so on.

Furthermore, utilization of individual mobile equipment can be spread. As mentioned, a smart city employs information and communications technologies (ICT) in a way that addresses quality of life by undertaking urban living challenges encompassed by more efficient utilization of limited resources (space, mobility, energy, etc.). World leading municipalities, in terms of services and quality of life, have provided efficient 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 station where experts analyze the data. From the technological perspective, the evolution of social networking in the past decade clearly shows the usability of ICT at an individual's level. Large-scale implementations at system level have made some progress in recent years. A fully integrated system of systems containing sensing, storage, analytics, and interpretation is required. The integrated system must have core capabilities of plug-and-play sensing, secure data aggregation, Quality of Service, and re-configurability. With an urban sensing system of systems in place, the ability to evaluate the impact of the preceding actions is readily available as the sensing cycle repeats.

A unifying information management platform delivers a capability across application domains critical to the city. Whilst large volumes of data collection and interpretation are already performing at different levels within city councils using manual and semi-automated methods, it is mostly in isolation. As with any large organization, it is inevitable that large portions of these data remain disjoint in the time scales over which they are collected and the capacity for them to be integrated. An urban information framework enabled by IoT provides a means for consolidating these tasks and sharing 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 impact areas. This includes the effect on: citizens (health and wellbeing); transport (mobility, productivity, pollution); and services (critical community services). Several projects are already underway within the City of Melbourne that utilizes sensor technologies to collect application specific data. These include: public parking monitoring; micro climate monitoring; access and mobility (pedestrian, cyclists, car sand goods vehicles). A number of specific application domains have also been identified that could utilize smart city IoT infrastructure to service operations in Health Services (noise, air and water quality); Strategic Planning (mobility); Sustainability (energy usage); Tourism(visitor services, tourist activity); Business and International (city usage, access); and City Safety.

III. IoT TECHNOLOGIES FOR SMART CITIES

The IoT is a broadband network which employs standard communication protocols [11, 12], whereas the Internet would be its merging point. The major idea of the IoT is the widespread existence of objects which are able to be measured and inferred, as well as it is able to modify the situation.

Accordingly, IoT is empowered by the growth of several things and communication equipment. Things in the IoT involve smart equipment such as mobile phones and other facilities including foodstuff, appliances and milestones [13, 14] that can collaborate to accomplish a joint objective. The main characteristic of the IoT is its effect on consumers´ life [9]. In the concept of IoT, since the cabling cost for millions of sensors is expensive, the communication between sensors should be wireless.

Low-power standard communication is suitable for interconnection among many devices. According to location and distance coverage, some networks are introduced as follows:

1. Home Area Networks (HAN) which use short-range standards like, ZigBee, Dash7, and Wi-Fi. All monitoring and control components in a home are connected by the HAN.
2. Wide Area Networks (WAN), provide communication between customers and distribution utilities which require much wider coverage than HAN and for implementation needs fiber cable or broadband wireless like 3G and LTE.
3. Field Area Networks, which are used for connection between customers and substations [8].

In IoT, two tasks, including sensing and processing the data, are performed, but they are not unified from a wireless sensor network (WSN) viewpoint. The unified solutions are Speakthing and iOBridge. Speakthing is an analytics IoT platform for gathering, visualizing and analyzing the live data in the cloud and you are able to analyze the data by MATLAB coding. In contrast, iOBridge has its own hardware modules that are connected to the cloud which can be accessed by web interfaces and collected data can be aggregated to other web services. It is noteworthy that cloud is very important in smart cities for data storage and processing. The IoT-related technology is explained in this section.

A. Radio-Frequency Identification (RFID)

RFID including readers and tags has a vital task in the framework of the IoT. Employing the technologies on each related thing, accomplishing their automatic identification and dedicating the single digital identity to any of the things will be possible, to include the network associated with the digital information and services [15]. RFID provides some applications in smart grids, including tracking and localization of objects, healthcare applications, parking lots and asset management. Each tag can be as a sensor because they have not only data which is written manually but also capture data like environmental information.

B. Near Field Communication (NFC)

Near Field Communication (NFC) is used for bidirectional short distance communication, especially in smart-phones. This range usually involves a centimeter range. The application of NFC in smartphones enables us to use it in smart cities, as well. One of its applications includes using smartphones with NFC as a wallet which enables us to use smartphones as our personal cards such as bank card, identification card, public transportation card, access control cards. Moreover, since NFC is bi-directional, it can be used to share data between devices, multimedia, and documents [8]. By placing NFC at a strategic position at the house and providing an interface with the central controller, it is possible to change the status of objects by checking the location for example switch on the Wi-Fi when the user comes home.

C. Low Rate Wireless Personal Area Network (LWPAN)

LWPAN is amongst short-range radio technology that covers large distances of up to 10–15 km. The energy consumption of this technology is extremely low and battery lifetime is about 10 years [6].

According to the IEEE 802.15.4 standard, it provides low cost and low-rate communication for sensor networks. It has the lowest two layers of protocols including physical and medium access level, besides upper layers protocols including 6LoWPAN and ZigBee [16].

1) ZigBee

In the sensor nodes, ZigBee is applied as a low-power and low-cost wireless communication technology [8]. It is based on the IEEE 802.15.4 standard and is suitable for creating wireless personal area networks (WPAN) such as home automation, medical device collection and other low-power, low-bandwidth. Some of its applications include wireless light switches, electrical meters, and traffic management systems. ZigBee is suitable for limited ranges, coverage of city region and supporting billions of devices. With the ZigBee-based network, a mechanism for transmission of IPv6 packets is specified. To apply ZigBee, additional equipment usually is required involving a coordinator, router and ZigBee end-devices.

2) 6LoWPAN

The 6LoWPAN standard is specified to adapt IPv6 communication. Over the time, IPv4 which was the leading addressing technology supported by Internet hosts has been replaced by IPv6 due to the exhaustion of its address blocks and the inability to separately address billions of nodes which is a characteristic of IoT networks. IPv6 by providing 128-bit addresses solves the lack of enough nodes for IoT networks, but it creates another problem however, which is compatibility with constrained nodes. This problem is addressed by 6LoWPAN which is the compression format for IPv6 [18].

D. Wireless Sensor Networks (WSNs)

WSNs make diverse proper data available and might be applied in lots of uses like healthcare, as well as government and environmental services [13]. Moreover, WSNs can be aggregated with RFIDs to obtain several targets such as gaining data related to the position of people and objects, movement, temperatures, etc. A WSN consists of wireless sensor nodes which include a radio interface, an analog-to-digital converter (ADC), multiple sensors, memory and a power supply [8]. The different parts of a wireless sensor node are illustrated in Figure 1. According to the wireless sensor node framework, it includes various kinds of sensors which measure data in analog format which are converted to digital data through an ADC. Some procedures are processed on the data through a memory and microcontroller according to data requirements. Finally, data are transmitted by a radio interface. All of this equipment needs to be equipped with a power supply.

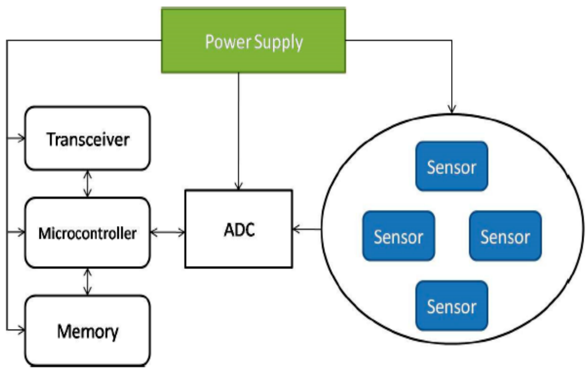

Figure 1.The architecture of a wireless sensor node.

A completed WSN is an extremely tiny low-power, low-cost sensor node which can be applied in any environment and works continuously for a few years. In reality, this topic WSN has not been realized. WSN has severe source constraints like reliance on battery life. With a large number of sensor nodes in smart cities, replacing or recharging their batteries is infeasible. Designing a protocol for sophisticated power management schemes like solar panels is essential for WSN power sources.

E. Dash7

Dash7 is a promising standard for WSNs used in long distance and low power sensing applications such as building automation and logistics. This protocol is for kilometer-distance range and operates at 433 MHz which not only has better penetration through walls than 2.4 GHz but is also appealing for HANs. It is worth noticing that Dash is very attractive in military application especially substation construction. Some of its applications are hazardous material monitoring, manufacturing and warehouse optimizations and smart meter development [18].

F.3G and Long Term Evolution (LTE)

3G and LTE are standards for wireless communication for mobile phones and data terminals. Regarding the development and expansion of wireless communication infrastructures, LTE and 3G are available everywhere, even in third world countries. This technology is for broadband connectivity and was not designed for short range uses. Hence, it is applied for WANs which require longer distance ranges. Nevertheless, there are some barriers to their implementation that should be addressed.
High data cost due to providing this service by the service providers, and inability to use them for communication among billion devices are some of the problems of these services.

G. Addressing

The Internet empowers a significant interconnection among persons, and similarly, the current tendency in the IoT creates an interconnection of things and stuff, for providing smart environments [10]. For this purpose, the ability of exclusively identifying devices and things is essential for desirable results of the IoT. The reason behind this is the fact that exclusively addressing the large-scale mixture of things is crucial to control them through the Internet. Besides the expressed exclusivity idea, reliability, scalability and strength indicate the main needs to establish an improved unique addressing structure [10].

H. Middleware

Due to several concerns regarding the heterogeneity of contributing objects, to the limited storage and process ability, along with to the huge different kinds of application, the middleware has a vital task in the interconnection of the things to the applications' layers. The main target of the middleware is to briefly aggregate the functionality and communication abilities of all included devices.

I. Smart Cities Platforms and Standards

The relationship between the physical and IT infrastructure constructs a novel machine-to-machine (M2M) communication for smart cities which along with new features of network drives smart cities' communication platforms. These platforms help to cover the communication requirements between heterogeneous access technologies and application suppliers. Moreover, these platforms help form the IoT with real world sensors and communication networks. One of these platforms which are being used widely is openMTC extracted from the latest ETSI standards for the smartM2M specification. The aim of the openMTC platform is to provide a compliant middleware platform for M2M applications and implementation of the smart city [19].

As introduced earlier, the main standard for smart cities is IEEE 802.15 which is for wireless personal area networks. This standard consists of different parts including: 1—Bluetooth, 2—coexistence, 3—high rate WPAN, 4—low rate WPAN, 5—mesh networking, 6—body area networks,7—visible light communication, 8—peer aware communication, 9—key management protocol,10—layer 2 routing, 11—wireless next generation standing committee [18].

IV. IoT APPLICATIONS FOR SMART CITIES

The IoT uses the Internet to merge various heterogeneous things. Accordingly and for providing the ease of access, all existing things have to be linked to the Internet. The reason behind this is that smart cities include sensor networks and connection of intelligent appliances to the internet is essential to remotely monitor their treatment such as power usage monitoring to improve the electricity usage, light management, air conditioner management. To get this aim, sensors are able to be extended at various locations to gather and analyze data for utilization improvement [7]. Figure 2 illustrates the major utilizations of the IoT for a smart city.

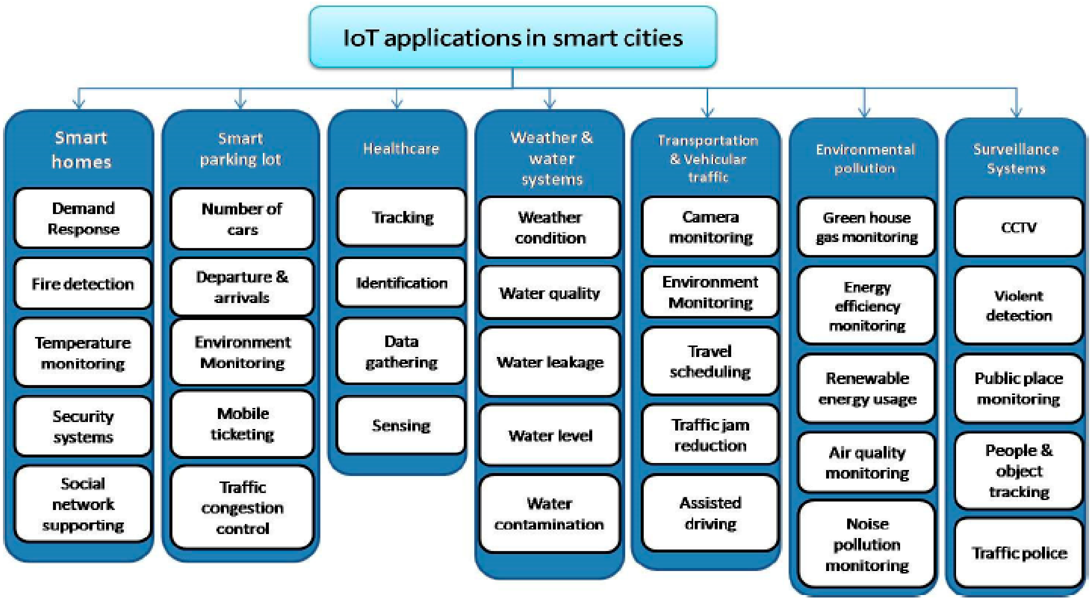

Figure 2.The main applications of the IoT

V. CURRENT TRENDS AND FUTURE THOUGHTS

Along fast urbanization, making the cities smart becomes imperative. It is fair to say, WSN is evolving into the Internet of Things. As a result, the WSN testbed activities of the last decade have provided precious information about the architecture, security, networking and data handling critical to large-scale IoT accomplishment. Most of these testbeds address targeted applications and their communication backbone and other resources are not shared [20].This clearly leads to high costs and complication, yet providing precious 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 enterprise 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 integrated CASAGRAS2, Internet of Things Architecture (IoT-A) and the IoT Initiative (IoT-I). A city-wide smart city testbed development is now complete in Spain (Santander) that is laying out a testbed 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 have initiated "Sensing China" project. Analogous activities are in progress in Japan, Korea, the USA, Australia and India, where various stakeholders are collaborating to advance the capabilities towards an IoT.

With these studies, the need for common communication, data storage and processing infrastructure is quite clear. Moreover, the simplicity of data sharing between various departments within the council can easily be facilitated using rising IoT.

The end goal of smart city IoT platform is to have plug- and-play smart objects that can be deployed in any atmosphere with an interoperable backbone allowing them to merge with other smart objects around them. In order to understand 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 play a vital 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 essential role in the success of this emerging technology.

VI. CONCLUSIONS

With rapid development in the emerging Internet of Things technology, we give in this paper 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 necessary services and quality of life for city populations. In this context, we identify the key IoT building blocks of smart cities, as well as provide the approaches and resolutions to meet the irrespective communications, computing and computation necessities. Furthermore, IoT enabled noise mapping work in association with the City of Melbourne is presented as a case study to highlight the practical usage and merit of our recommended framework. 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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