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ICT SUPPORT FOR SMART CITIES

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Abstract— **The concept of Smart City is the answer of the academia and important companies to the urbanization problem. This solution needs a strong technological support and this is ICT. It ensures continuous monitoring of the state of the city, in all the directions, for an efficient consumption of the resources, for modern health and education, for comfortable living conditions, for fluent transportation, care for the environment and for social and government problems. The present paper analyses and gives an overview of the ICT support for the Smart Cities concept.**

Keywords— **Smart city, Haar Wavelet, DWT, PSNR**

I. INTRODUCTION

The concept of Smart City is the answer of the academia and important companies to the urbanization problem. 2007 was the first year when the number of population living in cities was equal with the number of population living in rural areas. According to [1], 60% of the population will live in cities until 2030. Such a population density rises some problems: pollution, resource usage, living conditions, transportation etc.

Although some solution, more or less efficient, were found for each of the mentioned problems (and others too), the idea of a holistic solution seems to be the most promising one. This solution needs a strong technological support and this is ICT. ICT offers all the necessary tools and methods for continuous monitoring of the state of the city, in all the directions, for an efficient consumption of the resources, for modern health and education, for comfortable living conditions, for fluent transportation, care for the environment and for social and government problems.

There are other variants of the name Smart City too, [2]. In a *digital city* the accent is put on the technological aspect, more exactly on the physical level and digital networks. In the *virtual city* the accent is put on the upper levels such as cloud computing and cyberspace. Another concept is the *information city* in which the accent is put on collecting, processing, analyzing and structuring massive data and delivering it to people. The U-city (*ubiquitous city*) is based on the ubiquitous computer, which, at its turn, is based on chips and sensors embedded in almost all the city elements offering to people "any services, anywhere and anytime through any device". In the *intelligent city* the technological support creates not only information but knowledge, used for transforming significantly the life of the citizens.

The present paper analyses and gives an overview of the ICT support for the Smart Cities concept.

The rest of the paper is organized as follows. The next section defines the concept of smart city, the third section presents the ICT support and the last section outlines conclusions.

II. THE SMART CITY CONCEPT

There is no a widely accepted definition for the Smart City concept. [2] and [3] present part of definitions, found in the literature:

- A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens;
- A city that monitors and integrates conditions of all its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens;
- A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure, to leverage the collective intelligence of the city;
- A city striving to make itself "smarter" (more efficient, sustainable, equitable and livable):
- A city combining ICT and Web 2.0 technology with other organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability;
- The use of Smart Computing technologies to make the critical infrastructure components and services of a city-which include city administration, education, healthcare,

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public safety, real estate, transportation and utilities-more intelligent, interconnected and efficient.

In a way or other most of the definitions emphasize the role and position of the ICT. These technologies are the support for ensuring the development of the city, the increase of the quality of all services offered to the people, from the efficient use of the resources to the social and governmental aspects.

From our point of view, a smart city is a city in which the information and telecommunication technologies (ICT) offer the physical and functional support, in an integrated WAY, FOR INCREASING THE QUALITY OF PEOPLE, IN TERMS OF resources and costs efficiency, security, green environment, living conditions, social aspects and open participation to the city government.

III. THE ICT SUPPORT

There are two ways of representing smart cities, from a structural point of view. In the first one, there are layers, with a vertical hierarchy, not necessarily linear, it can be recursive also. In the second one, a smart city is represented as a group of characteristics, or services with horizontal position. Part of the representations from the first type and the involvement of the ICT will be presented next.

In [4], the model is made by 5 layers. From bottom to top they are: Natural environment (including topography, flora and fauna and resources), Infrastructure (including land use, roads, buildings and utilities), Resources (including water, oil, air and minerals), Services (including energy, water, transport and services) and Social systems (including people, commerce, culture and policy). The ICT is useful in infrastructure, resources, services and, partially, through social networks, e-commerce, in social systems.

A city model is presented in [5]. The city was divided into 3 service sectors which can be optimized by introduction of ICT solutions. The first sector is made by Infrastructure services, meaning: energy and electricity, water, buildings, transport and infrastructure, waste and data and telecommunications. The next sector consists in Community services which are: healthcare, education, recreation and commerce, travel and transport, security and safety and living environment. The last sector refers to Non-community services, that is: finance, workplaces and persuasive information.

In [6], the Smart City is modelled through 4 layers. The first one is made by the Infrastructure and comprises sensors, networks and storage possibilities. Here ICT is strongly present. On top of it, there is the E-governance layer which includes legislation, rules and policies. Here ICT is useful only for disseminating and finding information. On top, there is the Services layer, meaning energy management, healthcare, water and waste management. ICT solutions are very suitable for optimizing the functioning of this layer. The last layer is the one with Stakeholders, containing citizens, government, officials, operators. ICT solutions are necessary only for disseminating and finding information.

In [7] it is shown that a Smart City is made by 4 layers: sensor layer, network layer, platform layer and application layer. The first layer is necessary for collecting information and sending it to a central system where decisions are made. The second layer ensures access to networks and information exchange and transfer through public and private networks such as: telecommunication network, TV, Internet, energy network, optical fiber networks etc.. The platform layer is responsible with the information processing and control. Its functions are: management, computing, coordinating, analysis, storage, mining and providing public services for industry and users. The fourth layer offers application intelligent services, based on the others three layers. In this model, ICT is strongly necessary in all the layers.

Most of the specific literature shows that ICT is involved in at least 3 levels: the physical (or sensor) level, the network (or communication) level and the application (or service) level

A. The physical (sensor) level

One of the major problems which should be implemented in a city in order to become a smart one is the ubiquitous sensing for continuous monitoring of the status of different parts of the city. For that, smart sensors are needed. A smart sensor is made by a sensing block, a processing block, a communication block and power supply. In most cases the communication is RF based. They are connected forming a wireless sensor network (WSN).

The lifetime of a WSN highly depends on the sensors' energy. The main limitation in designing and developing a WSN is the energy problem. There are several solutions for this problem, [8]. The solutions were divided in solutions at the node (sensor) level and solutions at the network level. Further, the solutions at the node level are divided in energy saving solutions and energy replenishment solutions. The solutions at the network level are divided in different directions: MAC protocols, routing, in-network processing, data aggregation, set k-cover problem and network replenishment.

The energy saving solutions were structured in: sensing, processing and communicating. The energy replenishment solutions include battery recovery and energy harvesting.

Solutions for minimizing the sensing energy are: hierarchical sensing, adaptive sensing and model-based active sampling. Minimizing the processing energy can be made by: low power modes, dynamic frequency scaling, dynamic voltage scaling and system partitioning. Best modulation strategy and reducing the number of bits are solutions for reducing the communicating energy. The solutions for energy harvesting are grouped in: wind energy, thermal energy, solar energy, mechanical energy and radio frequency energy.

Today technology offers a lot of families of smart sensors. Examples are: Mica, Mica2, IMote, IMote2, Telos, TelosB Waspmode and Stargate. A short comparison is presented in [9].

B. The network (communication level)

The communication between sensors and with the upper levels is done through different networks and their associated protocols. They are suited to different types and conditions of the communications. Examples of networks are, [9], [10]:

ZigBee: is defined by the IEEE 802.15.4 standard and is used in low power, short range communications. ZigBee interfaces have low prices.

Bluetooth: is defined by the IEEE 802.15.1 standard and is used for creating PANs (Personal Area Network) in which sensors communicate with mobile devices, such a smartphone. The communication still is low power (higher than in ZigBee case) and short range (higher than in ZigBee case).

3G, 4G: they were designed for broadband connectivity, for high range and higher power communications. As a consequence they are suitable for mobile devices, e.g. smartphones, and not for sensors. Sensors can be connected to these networks through gates.

RFID (Radio Frequency Identification): is a technology for short range and low power communication. A RFID based communication is done between a RFID tag, passive or active, which contain data, and a RFID reader. When the RFID reader is near the RFID tag it induces an electromagnetic field providing power to passive RFID tags in order to read the data. A longer range communication can be obtained in case of active RFID tags. The communication is unidirectional.

NFC (Near Field Communication): is used in very short range communication (a few centimeters) for a bidirectional communication between mobile devices. NFC is integrated in smartphones enabling many applications which increases the smartness of living, such as: digital wallet, detecting the presence of people in houses, allowing changing of different features according to what is happening in a certain area.

IPv6: is a communication protocol for identifying the position of each entity connected to Internet. Each device connected to Internet has an IP address. These addresses were managed by the IPv4 protocol which allotted 32 bits for the address, generating $2^{32} \approx 4,3$ billion addresses. In the last period it became obvious that this is not enough so another protocol replaced IPv4, that is IPv6. The address is formed with 128 bits, their number increased to $\approx 3,4 \times 10^{38}$.

6LoWPAN: is a communication protocol using IPv6 over low power personal area network. IPv6 introduced overhead not compatible with the limited resources of low power devices. The problem was solved by the new protocol, which implemented a compression format for IPv6 and UDP headers over low power networks. A specific device, connected to the 6LoWPAN network, transparently converts IPv6 format into 6LoWPAN compressed format and the translation in the inverse direction at the other end of the communication route.

LoRaWAN (Long Range Wide Area Network): is a communication protocol for long range communication in wide area networks but with low bit rate among entities with scarce resources, e.g. smart sensors.

CoAP (Constrained Application Protocol): is a communication protocol for devices with limited resources connected to Internet. The protocol is suited for small, low power devices (smart sensors, switches, actuators and other similar devices) which need to be controlled or monitored remotely. CoAP and 6LoWPAN allow smart sensors to be connected to Internet by using proxies for HTTP to CoAP conversion. If smart sensors running CoAP are connected to Internet, sensing data can be retrieved by a web browser in the same way a HTTP agent is queried.

The totality of devices connected to Internet and the needed networks and protocols received, in the last period, the name of Internet of Things. It is known also as the 6 A connectivity. The Internet of Things vision was first formulated in [11]: "From anytime, anyplace connectivity for anyone, we will now have connectivity for anything". Later the vision was added with: "…using any path/networking and any service."

C. The application (service) level

Several applications specific to smart cities will be described, [9], [12]:

Water distribution system: such a typical system consists of a water collecting point, storage facilities and a distribution solution. The distribution of the water has to be done efficiently and has to be regulated. It is also necessary to ensure the quality of the water in order to be safe for human consumption. An ICT based solution can be used for monitoring the content level in reservoir tanks, for leak detection and for monitoring the water quality at specific points.

Waste management: is an important problem especially in dense populated cities due to the costs and the problem of the storage of garbage. Significant savings, economical and ecological advantages can be obtained through ICT based solutions. An example is the use of smart waste containers, which contain sensors for detecting the level of the load and contribute to the optimization of the collector trucks route. These smart containers have to communicate with a central system which will determine the optimal routes for the collector trucks.

Health care: different solutions were developed. Wireless body area networks is a modern research field. A body area network consist in interconnected sensors placed inside or on a human body, making possible to monitor the physiological parameters remotely. Examples are: electrocardiography, respiration, skin temperature etc. The sensed data can be sent to a medical center to be viewed by a specialist and take decisions in real-time. Another problem optimized with ICT help is the decrease of the emergency response. The surveillance of single elder people is also a major concern. A monitoring system can ask help in case of an in-house accident fastening the emergency intervention.

Structural monitoring of buildings: sensors can be embedded in buildings in order to measure their structural health, the effects of vibrations, the extend of the deformations. This increases the possibility to avoid catastrophic accidents, such as bridge crash, prevents irreversible deterioration of buildings and gives trust to people living in these buildings or visiting it.

Prolongation of economic activities in certain buildings can take place until the moment when the ICT system allows this. It will be also possible to combine vibration and seismic readings in order to better study and understand the impact of light earthquakes on city buildings.

Smart lighting: this application can be implemented at different levels: at home level, at building for offices, halls and large size institutions level, at street level, at district level and at city level. Such a solution requires the possibility to sense the level of the ambient light and the presence of people and/or cars. It is also necessary to remotely command the on/off state of the light and its level of intensity. A smarter solution anticipates the need of light, taking into consideration the direction of movement of a person or a car and his/its speed.

Smart homes: a smart home has the role to optimize the utility consumptions while offering very good living conditions. This includes: energy management system, which senses the energy consumption for the domestic appliances and offers data about the level of consumption and what should be done to reduce it, smart lighting, in order to tailor the functioning time and intensity of the light according to the needs, optimization of the functioning of the HVAC systems, customization of the multimedia system functioning according to the habitant profile etc.

Environmental monitoring: this is absolutely necessary in order to keep under control and reduce one of the more important threat of people that is the pollution. The air quality has to be monitored by sensing parameters such as temperature, humidity, carbon dioxide level etc. especially in crowded areas but also in parks, streets etc. This can lead to establishing a pollution map which will help people to avoid certain areas, at certain moments of the day, in their everyday activities. This will help also people doing sport to choose the green routes. Furthermore another goal can be reached: to study the relationship between human behavior and weather in an attempt to better understand the dynamics of an urban system. Environmental monitoring helps also to control and reduce acoustic pollution. The idea is to reduce the noise level in city areas at specific time periods under a certain level. The environmental monitoring is an important tool for implementing the 20-20-20 Renewable Energy Directive of the European Union. This means a 20% reduction in greenhouse emissions, a 20% cut in energy consumption through improved energy efficiency and a 20% increase of the use of renewable energy by 2020 compared with 1990 levels.

Intelligent transportation system: due to the accelerated increase of the number of vehicles and to the much more slow development of the road infrastructure intelligent transportation systems are necessary for multiple reasons. First of all it is important to reduce the number of accidents and for that intelligent cars and intelligent roads are a significant solution. Cars will communicate each other, will avoid each other and the same with the roads. Secondly, it is at least of same importance to reduce the numbers and intensities of traffic congestions. This will reduce pollution, fuel consumption and will save time. For that, traffic must be monitored especially in intersections by using cameras, sensors for detecting the appearance of a car and sensors for measuring pollution and noise. The sensed information is of great importance for city authorities, to discipline traffic and send officers where and when needed, and citizens, to plan in advance the route to reach the destination

IV. CONCLUSIONS

This paper presented the role and the importance of ICT in developing smart cities. After delimitating the levels of a smart city, in a vertical model, the involvement of ICT was described. Three levels were approached: the physical (or sensor) level, the network (or communication) level and the application (or service) level.

No doubt the use of ICT for building smart cities is important. There are some disadvantages too: increase of the inequalities and promoting of digital divide. And a question remains open: how smart, how “genius” should be people living in smart cities in order to benefit of the advantages brought by the integration of smart technologies in the city?

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