Technological Infrastructure for Building a Smart Ecosystem

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Abstract. *In most countries, the building of infrastructure is a centralized activity, government-led actions that have as their objectives sequential problem solving – such as the construction of a water supply system or sewerage network. Smart infrastructure solutions should also be added as components to anticipate global and medium-term phenomena. The city infrastructure must resist the pressures given by the increasingly rapid technological evolution - for example, electricity grids must take into account the growing number of users installing their own electric panels - a phenomenon that, on the long run, leads to consumption reduction, as well as climate change, which, due to the increasing temperature differences between seasons and the increasingly abundant rainfall, tend to cause heavy damage to the electricity transmission infrastructure. Smart cities need to isolate their infrastructure from these events. They may need to build new networks or adjust the old ones in such a way as to meet the new challenges. Within some of the most prestigious research centers, scientists formulated the most comprehensive definition of the concept, namely: Smart Infrastructure is the result of combining physical and digital infrastructure elements to provide valuable information to help make decisions faster and at lower costs. In this article, we will focus on the latest technological elements that are meant to improve the lives of citizens of a smart city.*

Keywords: *Smart cities; Internet of Things; IoT; smart infrastructure.*

Introduction

'Smart cities' is a relatively new concept used to describe the use of technologies along with data and information as the means to solve cities' challenges (Pavlovskaya & Kononova, 2018). Many cities are aiming to become smart; in other words, their goals might be to improve transport – both public and private, energy use, health, and air quality or to drive economic growth.

The British Standards Institute (BSI) defines smart cities as 'the effective integration of physical, digital and human systems in the built environment to deliver sustainable, prosperous and inclusive future for its citizens' (BSI, 2014). As we can see this definition is more likely to be citizen-oriented.

Cisco, on the other hand, has a more technical approach, defining the term as those cities that adopt 'scalable solutions that take advantage of information and communications technology (ICT) to increase efficiencies, reduce costs, and enhance the quality of life' (Falconer & Mitchell, 2012).

We found a large number of smart city definitions; some having a larger perspective while others focus on technology and data or on citizens. However, the term 'smart city' is rather broad and nonetheless ambiguous, with no agreed definition or consensus among scholars and researchers on how cities should tackle the challenges.

What most definitions do have in common is that they take into consideration the use of ICT as the main component in solving cities' problems: economic, social or even environmental issues – ICT being here related mostly to the smart technologies that can vary from expensive hardware solutions such as city control centers, smart grids and lately autonomous vehicles, all the way down to much lower cost solutions such as smartphone apps, online platforms for collecting citizens' ideas and low-cost environmental sensors (Vrabie & Dumitrascu, 2018). Knowledge transfer could occur from business partners (Pînzaru, Zbuchea, & Vițelar, 2018) or nonprofit ones (Zbuchea & Romanelli, 2018).

In order for the strategies built to shift to the 'smart' concept, the cities need to develop their infrastructure. They might need to build new infrastructure or to adjust the existing ones. Royal Academy of Engineering came up with a very good definition of smart infrastructure: 'Smart infrastructure responds intelligently to changes in its environment, including user demands and other infrastructure, to achieve an improved performance' (Royal Academy of Engineering, 2012).

Smart infrastructure investments bring social and economic benefits like more efficient services, digital convergence, and integrated workflows and greater resilience. However, all of this might be very expensive. For example, the city of Songdo in South Korea is a smart city built from zero with what might be called a state-of-the-art smart infrastructure (ultra-fast Wi-Fi, environmental sensors as well as for the energy use, an intelligent transport network and a waste disposal system where all household waste is sucked directly from individual kitchens through a vast underground network of tunnels to waste processing centers. But this project costs went up to more than $40 billion (World Finance, 2014) – that' if we are to compare, but less than a fifth of Romania's GDP in 2017 (World Bank, 2018).

The research question for this study is: 'What might be the most important smart infrastructure that should be taken into consideration on building up, or transforming into, a smart city?' and by answering it we aim to find the connection between one of the newest concepts: IoT and the Smart Cities.

Internet of Things

The Internet of Things concept (known in the literature as IoT) is not as new as one might think. It first appeared in 1999 when Kevin Ashton – the British who created the RFID (Radio Frequency Identification) systems standards, used it to describe a system in which the Internet connects to the physical world through sensors (Asthon, 2009), these having the role of collecting data for sending them over networks to servers. Since back then he described how the devices connected to the Internet will change our lives, which nowadays is already far from being science-fiction. We see everywhere around us either cars connected to the Internet (via GPS terminals installed onboard), industrial or agricultural equipment remotely coordinated through the Internet, drones, even refrigerators and washing machines (the smart mobile phones, present in everyone's pocket, are the best proof of the development of this IT industry segment) (Nemțanu & Pînzaru, 2017).

Today, the total number of connected equipment reached 20.35 billion, with the prospect of reaching 75.44 billion in 2025 (Statistic portal, 2019).

The main components of an IoT system are the following (UK RS online, 2017):

- Data collection equipment – some examples here would be: sensors, mobile phones, etc.;
- Communication networks with the role of connecting the equipment mentioned above – such as Wi-Fi, 4G, Bluetooth, etc.;
- Servers and other computational systems that use these data – such as storage, analysis devices or dedicated software applications.

When all three of these components are found in the same system with the role to deliver services (and sometimes products), then we can really talk about the added value created with the aim of developing citizens, the public and the private environment (Jezdović et al, 2018). A short example would be the smart devices that monitor the evolution/involution of chronic disease in a patient by transmitting real-time data to doctors who may intervene if the situation requires so.

IoT applications and systems are organically developed – based on needs, but the impact they have on us depends on the degree of acceptance of new technologies by citizens, the public and the private sector (Vrabie, 2016).

The greatest risks that can arise from the extensive use of IoT come from the data security and cyber-attacks area. However, the laws of the economy must be understood, namely that the most trustworthy products and services will continue to be procured by the beneficiaries – demand and supply are strongly connected. The Statistic Portal tells us that the IoT market has exceeded a trillion-dollar at the end of 2018, forecasting evolution of up to 1.7 trillion dollars at the end of 2019 (Statistic portal, 2019).

A strong relationship between the smart city and IoT, as technological infrastructure, is helping the whole ecosystem to provide a proper development framework.

‘Sensored’ City

More and more cities in the world are experiencing a new dimension of sensor networks. Many are involved in pilot projects with the purpose of monitoring various activities in urban life, such as the level of noise or air pollution, parking management, health monitoring applications for persons suffering from chronic illnesses, etc. Thingful is a search engine within this new dimension of the digital world. It contains indexes with the geographical positioning of all the fixed equipment connected in the world – a simple typing of a city’s name can indicate on the map where different sensors are placed and what function they fulfill (Thingful, 2019).

Thingful’s goal is not just to provide a map of existing public or private equipment, but also to provide developers with solutions for smart cities to use these devices – of course, with the consent of the owners (Thingful, 2019).

Figure 1. *World of IoT in London, UK (left) and Bucharest, Romania (right)*
(Thingful, (2019) http://www.thingful.net/)

London has developed together with six partners, including Future Cities Catapult and Intel Collaborative Research Institute, the project ‘Sensing London’. Five living labs were built around the metropolis to collect data (obviously through sensors) about humidity, air quality, traffic, and pedestrian activity. Subsequent analyzes directly help enrich the knowledge of how British capital residents use the infrastructure. At the same time, indirectly, these data are used as inputs in the health, environment and life comfort systems due to the statistical analyses that can be carried out and thus the impact that a particular phenomenon can have in the area of interest researched can be predicted. From this point to developing new solutions (such as an application that would help asthmatic patients to travel through the city) or to developing new business models that allow the expansion of green spaces without major financial investment or even the justification for the development of new technological infrastructures is just one step (Future Cities Catapult, 2017).

The Christchurch city of New Zealand has developed, through a nonprofit organization, a similar project called Sensing City Trust. The actors involved want to better understand how data gathered through sensors can help mayors to develop better public policies. After a devastating earthquake in 2011, a network of digital sensors was developed and installed as part of the city`s physical infrastructure in order to gather information on air quality. In addition, 150 people registered in the public health system were recruited as chronic respiratory patients who were given a ‘smart inhaler’ which records where and when they are using medication to relieve symptoms. The data is then automatically transmitted via the smartphones the individuals own, to a secured database, overlapping those that come from the sensors we mentioned and which were collected shortly before, and thus offered to decision-makers for them to be able to develop the most effective public health policies. Supplementary to the initial purpose of the project, the information produced by the analyzes help doctors to improve their understanding of chronic lung diseases, thus managing to bring real benefits to patients by the fact that they can get treatment before reaching the hospital – in the event of an intervention, medical crews already know the condition of the patient, his/her needs and implicitly their response time is being reduced (Sensing City, 2017).

Chicago, in the United States, has developed a matrix of equipment – Array of Things. This is an interactive network of modular sensors that collects real-time data from the environment, from the physical infrastructure of the city, as well as those that target the behavior of citizens. The goal is obviously to better understand the local urban environment and the impact it has on the lives of individuals living and working there – the most important elements for analyzes being those related to climate, air pollution, and noise pollution. The data thus collected are open, meaning that they are open to free use by residents, software developers, scientists or decision-makers. Citizens' behavior is detected through three different types of sensors: sound sensors, which collect data from the surrounding environment; infrared cameras oriented to car or pedestrian traffic areas and which are designed to record temperatures from the surface of fixed or in motion objects; and a wireless network that measures the number of nearby Bluetooth and Wi-Fi devices – it acts as a proxy for pedestrians in the area. Although questions can be raised that would concern the privacy area of citizens, the project guarantees that no personal or identification data are collected (Array of Things, 2017).

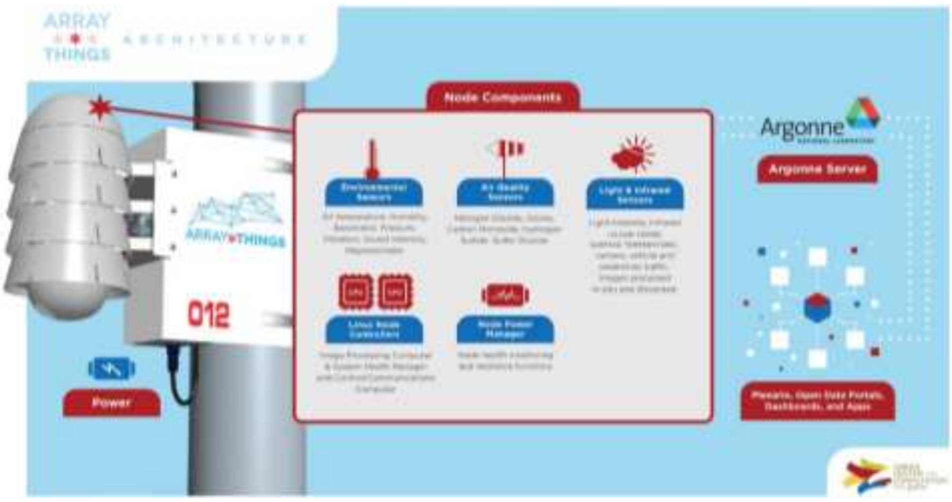

Figure 2. *The architecture of the Array of Things system*
(Array of Things, https://arrayofthings.github.io/)

In Sibiu, Romania, was developed, thanks to the collaboration of 'Lucian Blaga' University of Sibiu with the University College of Southeast Norway, Norway, the project 'A Mobile Platform for Environmental Monitoring' with the aim of producing an environmental map that provides all actors in the city's perimeter with information on air quality and noise pollution. The Faculty of Engineering within 'Lucian Blaga' University has developed hardware modules that can be placed on cars and which are meant to collect traffic data both when the car is in motion or in the parking areas when the car is parked. The collected data is transmitted via a GSM module combined with a GPS module implemented on the equipment to a server that has the role of storing them and providing them for analysis to the actors involved. Two prototypes of sensors were realized, the last of them (and the most advanced) being able to collect both data such as the CO2, NOx level as well as the amount of suspended solid particles. The project is still in the pilot phase, with only 16 cars equipped with such modules in the city, being completely functional, a number of approximately 100 units will be produced to be mounted on vehicles (Berntzen et al, 2016).

Figure 3. *Data collected through mobile traffic platforms in Sibiu [8]*
(Florea & Berntzen, 2017)

The risks associated with IoT & Sensors

Cybersecurity

As our cities are becoming more and more saturated with sensors, they are becoming smarter and smarter (Business Insider, 2016). However, we must also take into account citizens' degree of tolerance for the invasion of data collection equipment – as the number of equipment increases, the citizens feel more supervised (Vrabie, 2017).

The most common questions here are: (1) „Who produces and controls the equipment?", (2) „What do they measure?", and (3) „Who has access to the data?". All these questions are important and answers to them must be available to every citizen in a language that is as easy to understand as possible so that there is no confusion.

Other questions such as those related to the purpose of collecting data, the changes that will follow from these operations and the benefits of citizens, the public and the private sector are also important. Data storage management mechanisms (often software) are also commonly found in studies about IoT (Maślankowski, 2017).

Many cities consider elements of security (obviously not only digital) and intimacy as key to sustainable and harmonious development. The level of trust and acceptance of the new by citizens is crucial in developing smart solutions. However, there is little written information on how citizens see these things.

Dan Gârlașu, from Oracle Romania, warned IT users that in the future smart cities may be more vulnerable to hackers than smart computers and smartphones are today (Gârlașu, 2016).

With billions of interconnected devices all over the world, cybersecurity challenges are increasingly addressing also the IoT dimension of the digital world. Often the media poses on the front page of the newspaper titles that refer to hacking actions of different types of equipment. In the summer of 2015, the car producer Fiat recalled 1.4 million vehicles for software updates due to the risks of machine safety being affected (BBC, 2017). At the end of 2017, a clip posted on YouTube featured two hackers who stole a luxurious car by remotely cloning the door opening device and starting the vehicle. Shortly after the event, CNN tech has produced the „Watch thieves steal car by hacking keyless tech" material explaining each action of the hackers (CNN Tech, 2018).

Cesar Cerrudo, Chief Technology Officer of IOActive – one of the most prestigious digital security consultancy corporations, stated for The Independent in the UK that „a malicious hacker could use the information to manipulate traffic lights to cause jams and alter speed limits" (The Independent, 2017).

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This research area is particularly rich in topics. The European Union Agency for Network and Information Security (ENISA) launched in November 2017 some recommendations on IoT security in the context of critical information infrastructures (ENISA, 2017). Microsoft, Symantec, along with other leading companies in the cyber field regularly make reports on case studies accompanied by warnings and recommendations on this new dimension of the digital world: „Developing a City Strategy for Cyber Security" (Microsoft, 2014), „Transformational 'Smart Cities': Cyber Security and Resilience" (Symantec, 2017). Unfortunately, however, there is little information on how these recommendations are embedded in smart solutions implemented at the city level.

Cybersecurity efforts tend to be focused on the role of local leaders in the development of smart cities and the IT&C embedded systems, although it is known that the development of such cities is much more complex, involving many partners in this process and as many technologies.

Temporary inoperability

IoT enthusiasm is often tempered by the connectivity problems that the equipment is faced with. The wireless ecosystem, though easy to understand, is hard to imagine. Due to the very large number of IoT uses, we cannot find a single standard – both in wireless technologies and in electricity consumption (Texas Instruments, 2017). These two seemingly minor problems can cause major effects in the good functioning of an IoT system.

The technology of a smart city could be taken by surprise by the technological advances – new equipment is being developed, with new standards long before the old and already in motion ones are depreciated. Hence, many connectivity problems can arise between the equipment placed in the wireless ecosystem of IoT. For example, we can imagine a smart city in which automated cars (without a driver) navigate by themselves on the city's streets. What happens when they pass through an area in which the sensors of the traffic lights are no longer compatible with theirs? Another question that arises is what happens when, due to network noise, communication between the vehicle and the traffic light system is slow or temporarily interrupted? Obviously, these questions must first find an unequivocal answer in order to be able to talk about a successful implementation of such a system (Ghena et al., 2014). In Figure 4 we can see the complexity of such a system and, practically, due to a large number of devices that need to communicate in a very short time, the risks associated with a small data flow disruption.

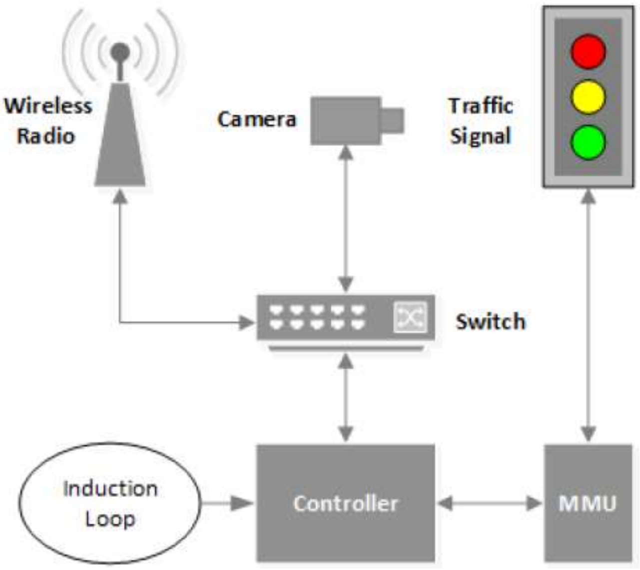

Figure 4. *A typical traffic intersection (Ghena et al., 2014)*

All Internet users experienced situations where web pages were loading slower or when mobile calls were disrupted apparently for no reason. These situations can create frustration, but humans understand and know they can appear. But when we talk about electronic equipment, they cannot understand, and the effects of their misunderstanding can produce less pleasant effects for citizens or the environment.

If in the case of the cybersecurity risks previously presented, the pressure was on the managers of a smart city, in the case of interoperability, the pressure tends to be put on the research environment, especially in the technological and academic areas. Only these can find viable solutions to such problems.

Conclusions

The dimension of IoT is not just a goal to be achieved – often mayors, hearing the concept but not understanding it in its depth, want to invest in IoT sensors and equipment for their cities – it is a remarkable symbiosis between society and technology. Many of those technologies that once represented the top ones are today viewed as part of everyone's life.

The parallel between IT and Internet innovations has led to a series of changes in the world economy such as the growth of the sector of products and services dedicated to the informational economy. As Thomas Lauren Friedman (a New York Times journalist) said in his book „The world is flat: A brief history of the twenty-first century", written in 2005, „the Internet has flattened the world, IT has first provoked and then increased the pace with which these changes have occurred, providing a platform for development" (Friedman, 2005).

Of all the challenges of the electronic world, IoT is the newest and probably the biggest – due to the explosive evolution of the number of Internet-connected equipment. It must be well known, understood and managed. There is a hidden component in people's Internet, also known as Deep Web or Dark Web, where unknown operations are made and of which only the actors directly involved have a clue. Many of these operations are illegal. Why wouldn't the Internet of Things risk to have its own dark side? To minimize this risk, proper education of all stakeholders is required, so that the responsibility for successful system management will be implicit.

References

Asthon, K., (2009). That ‚Internet of Things' Thing. *RFID Journal*. Retrieved from http://www.rfidjournal.com/articles/view?4986.

BBC News (2018), http://www.bbc.com/news/technology-33650491

Berntzen, L., Johannessen, M.R., & Florea, A. (2016). Smart Cities: Challenges and a Sensor-based Solution. *International Journal of Advanced Intelligent Systems,* 9, 579-588. Retrieved from http://www.iariajournals.org/intelligent_systems.

British Standards Institution (BSI) (2015), *Smart cities overview – Guide*, PD 8100:2015, published by BSI Standards Limited.

Business Insider (2016). How smart cities & IoT will change our communities. Ret4ieved from http://www.businessinsider.com/internet-of-things-smart-cities-2016-10.

ENISA (2017). *Baseline Security Recommendations for IoT*. Retrieved from https://www.enisa.europa.eu/publications/baseline-security-recommendations-for-iot, accessed on 10.12.2017.

Falconer, G., & Mitchell, S. (2012). Smart city framework. *Cisco Internet Business Solutions Group (IBSG),* 12(9), 2-10.

Florea, A., & Berntzen, L. (2017). Green IT solutions for smart city sustainability, paper presented at the Smart Cities Conference, 5th edition, December 8, 2017, SNSPA, Bucharest, Romania.

Friedman, T.L. (2005), *The World Is Flat: A Brief History of the Twenty-First Century*, New York, NY: Farrar, Straus and Giroux.

Future Cities Catapult, (2017) *Sensing London*. Retri3ved from http://futurecities.catapult.org.uk/project/sensing-london/.

Gărlașu, D., (2016). Cyber Security Update on Threats and Trends, paper presented at the Smart Cities Conference, 4th edition, December 2016, SNSPA, Bucharest, Romania. Retrieved from http://administratiepublica.eu/smartcitiesconference/2016/program.htm.

Ghena, B., Beyer, W., Hillaker, A., Pevarnek, J., & Halderman, J.A., (2014). Green Lights Forever: Analyzing the Security of Traffic Infrastructure. In *Proceedings of the 8th USENIX Workshop on Offensive Technologies (WOOT '14).*

Jezdović, I., Nedeljković, N., Živojinović, L., Radenković, B., & Labus, A. (2018). Smart city: A system for measuring noise pollution. *Smart Cities and Regional Development (SCRD) Journal,* 2(1), 79-85.

Maślankowski, J. (2017). Using sentiment analysis with Big Data tools to enrich knowledge on society in the city. *Smart Cities and Regional Development (SCRD) Journal*, [S.l.], 1(2), 37-46.
Microsoft Corporation, (2014) *Developing a City Strategy for Cyber Security. A seven-step guide for local governments*.
Nemțanu, F., & Pînzaru, F. (2017). Smart city management based on IoT. *Smart Cities and Regional Development (SCRD) Journal*, 1(1), 91-97.
Pavlovskaya, M., & Kononova, O. (2018). The Smart city vision: The internet-of-postal-things (iopt) approach. *Smart Cities and Regional Development (SCRD) Journal*, 2(1), 57-69.
Pînzaru, F., Zbuchea, A., & Vițelar, A. (2018, September). Knowledge Transfer from Business to Public Administration in Smart City Development. In *Proceedings of the 19th Conference in Knowledge Management* (Vol. 2, pp.700-707).
Royal Academy of Engineering, (2012) Smart infrastructure: the future, The Royal Academy of Engineering London.
Sensing City, http://sensingcity.org/
Statistic portal, (2019) *Internet of Things (IoT) connected devices installed base worldwide from 2015 to 2025 (in billions)*. Retrieved from https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/.
Symantec Official Blog (2017), *Transformational 'Smart Cities'*: Cyber Security and Resilience. Retrieved from https://www.symantec.com/connect/blogs/transformational-smart-cities-cyber-security-and-resilience.
Texas Instruments (2017), *Wireless connectivity for the, Internet of Things: One size does not fit all*
The Independent (2017). *Vulnerabilities in traffic light sensors could lead to crashes, researcher claims*. Retrieved from http://www.independent.co.uk/life-style/gadgets-and-tech/news/traffic-light-hack-could-lead-to-road-chaos-claims-expert-9309936.html.
Thingful, (2019) http://www.thingful.net/
UK RS online, Retrieved from https://uk.rs-online.com/web/generalDisplay.html?id=i/iot-internet-of-things.
Vrabie, C., & Dumitrascu, E. (2018). *Smart Cities. De la Idee la implementare sau despre cum tehnologia poate da stralucire mediului urban [Smart Cities. From the idea to implementation or how technology can shape the urban environment]*, Bucharest, RO: Universul Academic Publishing house & Universitara Publishing house.
Vrabie, C., (2016). *Elemente de e-guvernare [Elements of E-Government]*. Bucharest, RO: Pro Universitaria Publishing House.
Vrabie, C., (2017). *Your freedom starts where my privacy ends, Smart cities*, Bucharest, RO: Pro Universitaria Publishing House.
World Bank (2018), *Romania*. Retrieved from https://data.worldbank.org/country/romania.
World Finance (2014), *Could Songdo be the world's smartest city?*. Retrieved from https://www.worldfinance.com/inward-investment/could-songdo-be-the-worlds-smartest-city.
Zbuchea, A., & Romanelli, M. (2018). The Role of NGOs in Urban Development. In *Societal Impact of Knowledge and Design, Proceedings of the IFKAD*. Retrieved from https://www.researchgate.net/profile/Alexandra_Zbuchea/publication/328767592_The_role_of_NGOs_in_urban_development/links/5be189f24585150b2ba230c8/The-role-of-NGOs-in-urban-development.pdf.