Road Safety and Vulnerable Road Users
Internet of People Insights

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Abstract: Researchers have been setting their focus on improving the quality of life of the human being, especially at large urban centres. However, problems like crowding, traffic accidents or crime are still to be unscrambled. Indeed, one may use the amazing technological evolution the world is experiencing to mitigate such problems, focusing the Internet of Things in the creation of truly Smart Cities. Hence, this work intends to study and analyse relevant areas of intervention in Smart Cities, with special focus on the efforts being made to enhance the safety of those more vulnerable at the road, known as Vulnerable Road Users. Undeniably, one's review shows that insufficient focus is being given to the use of the Internet of People to address this challenge, renouncing the possibility of access information such as position, pace, and physical and emotional conditions of the user. It becomes now imperative to shift the paradigm and proceed towards the Internet of People.

1 INTRODUCTION

Contrary to what one may think, Smart Cities stand for a theme that has been in the human mind for decades. Currently, the human kind takes advantage of the tremendous technological evolution the world is experiencing to improve either their quality of life or habitat in order to make the world a safer place. Coupling this with the typical challenges of large urban centres, one comes to the Smart Cities soul. There is no definitive characterization for this approach, but a broad range of very similar ones. One example is the definition of Harrison (Harrison et al., 2010) who state that "*Smarter City continues the long-standing practice of improving the operational efficiency and quality of life of a city by building on advances in IT*". It is not the intention of this work to clarify which is the most accurate designation. Instead, the focus is on a literature review in order to analyse and understand some of the major areas of intervention in Smart Cities, allowing us to lead our attention towards Road Safety and, specifically, to the Vulnerable Road Users (VRU) problem. On how are researchers currently addressing this major issue and on how we may combine things, such as vehicles or bicycles, and people in a global and pervasive network, with focus on reducing the vulnerability of such road users. The prevention of injuries in VRU must be seen as crucial as it will allow people to be safer and roads would no longer be so dangerous. Nevertheless, the authors of this work have their own opinion when the subject is the classification of a Smart City, i.e., assumed as the *ability to reason upon the knowledge acquired through data gathered by sensorization, with focus on improving the quality of life at urban centres, considering sustainability and safety principles*. Here, sustainability it is to be understood in terms of social, economic and environmental matters.

Internet of Things (IoT) also lacks a unique meaning. This term was first used in 1999, by Kevin Ashton (Madakam et al., 2015), where he claimed that in the twenty-first century "*because of the Internet of Things, computers can sense things for themselves*" (Gabbai, 2015). With this in mind, an acceptable delineation may be the one of Madakam (Madakam et al., 2015), where IoT is presented as "*An open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment*".

It is also necessary to clarify the bibliographic search strategy followed to find relevant documents. In this study, several databases were used, such as

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IEEE Xplore, Scopus and Web of Science. Some of the searched keywords were “Smart Cities” AND “Internet of Things”; “Internet of People”; “Vulnerable Road Users”. The employed keywords were used to search essay titles, focusing mainly on recent assets. Finally, a more attentive search on the subjects under analysis was carried out.

This paper is organized into four sections, namely: a former one that introduces the problem, motivation, and the bibliographic search strategy. The next one presents an analysis on the main areas of intervention in Smart Cities. The third focuses on Road Safety, particularly the VRU problematic. Solutions to enhance VRU’s safety are also mentioned. Finally, in the last section, conclusions are presented and future work is outlined.

2 SMART CITIES AND THE INTERNET OF THINGS

2.1 An Introduction

One should bear in mind that Smart Cities is a theme that encompasses different fields from different areas such as computer science, civil engineering, mechanics and electronics, among others. Therefore, the way to address Smart Cities will focus on a multitude of aspects and will demand huge efforts. On the other hand, once the IoT links objects to the Internet, enabling data and insights never available before, it was a question of common sense to take it into consideration in the present work. Objects such as clothes, food packing or shoes will be equipped with some level of Internet-addressable features, offering context awareness and communication facilities. Indeed, it is expected that by 2020 seven trillion devices will be used by seven billion people (Skouby & Lynggaard, 2014). On the other hand, not only home automation components are driven us toward “Smart Homes”, but other personal IoT devices like wearable fitness and health monitoring ones are transforming the way healthcare services are delivered to the citizens (Rose et al., 2015).

Over time some attempts have been made to set new paradigms such as the Internet of People (IoP) (Boavida et al., 2016; Miranda et al., 2015) or the Internet of Everything (IoE) (Kyriazopoulou, 2015). As per the authors, IoE has the major goal of extend IoT to exactly “everything”. As for IoP, it may be seen as an attempt to bring IoT closer to people (Miranda et al., 2015). IoP is a paradigm where the literature is practically non-existent. It is only now that it is beginning to receive well-deserved attention and its focus is on enabling people to be an active part of a global system, a global network of things and people, enabling the creation of people centric IoT (Boavida et al., 2016). Our approach to the VRU problem will focus on the IoP and consists in getting people to this global network of physical things known as the IoT.

An essential point when discussing these topics refers to the problem of knowledge representation and reasoning, and how to deal with the respective data. It is important to guarantee that information systems are able to extract knowledge from such data in order to reason. Recent studies have shown the huge potential of Logic Programming based approaches to reason upon unknown, defective or even self-contradictory data or knowledge, which is truly mandatory within the Smart Cities context (Fernandes et al., 2015; Neves et al., 2015).

2.2 Areas of Intervention

Internet of Things is the new trend in the development of Smart Cities and recommendations about its use have been published in the literature. Its association with sensor networks and cloud computing strengthens its acceptance (Figure 1) (Kyriazopoulou, 2015), as it is exposed beneath:

Smart Homes (Domotics) - inside smart homes all devices and appliances are aware of the existence of others, are capable of communicate among them and have an independent existence. Once this area of intervention deals with the technological enrichment of the living environments, smart homes may be able to react to changes in the environment and to take into account the preferences of the households and their individualities (Skouby & Lynggaard, 2014);

Smart Healthcare - smart healthcare is one of the major topics of concern in Smart Cities. Smart systems in this area comprise clinical care, remote monitoring, early intervention and diagnosis, prevention and emergency responses, where smart devices may be used by people to control diseases (Mehrotra & Dhande, 2015). Furthermore, it comprises interoperability along different health services and institutions;

Smart Energy - echo-friendly Smart Cities are required to use and produce green energy, reduce consumption, promote recycling, and decrease carbon footprint. Such goals may be achieved either by promoting user-awareness or practices that may be inherited from disciplines as Ambient Assisted Living or Ambient Intelligence (Silva et al., 2013).

Indeed, intelligent automated living assistance systems represent a promising approach for the extension of a self-governing and self-conducted life of physically or mentally challenged or elderly people thereby, enhancing their quality of life and reducing the need for manual social/medical care (Gomes et al., 2010; Silva & Analide, 2016);

Sustainability - it is a subject of concern for the assurance of steadiness, viability and system's use. A common definition to sustainability is on subject of equilibrium on the social, economic, and environmental issues. Assessing sustainability, and sharing those results with the community of citizens, is significant in the creation of user awareness (Silva et al., 2013);

Public Safety - a controversial topic rests in the use of IoT devices on the benefit of law enforcement and public safety (Rose et al., 2015). Public safety agencies could gather and analyse data for weather, traffic, security breaches, hazardous materials or disasters and provide actionable information to the citizens (Harmon et al., 2015). However, it should be taken into account that this topic may raise legal, security, privacy or ethical questions;

Citizen Sensor - the number of wearable devices is increasing exponentially, i.e., outfits used on our daily routine and that bring everyone "online". In fact, tools such as smart watches, clothing or wristbands represent printed electronics and sensing capabilities, making it a formidable potential that enables the citizen sensor and then the IoP. The citizen as a sensor would assist the gathering of a huge amount of data (Cano et al., 2015; Miranda et al., 2015), allowing people to be an active, reactive and proactive element in the IoP;

e-Government and e-Education - e-Government business is based on statutes and laws, providing citizens and firms access to government data and services. It rests on information access, public accessibility, quality of service and social awareness (Scholl et al., 2009). e-Education focus on improving learning outcomes by allowing full access to education, using smart applications and analytics to support teaching (Harmon et al., 2015);

Water, Waste and Disaster Management - a Smart City should be capable of manage its own resources and so it is of the highest importance to reduce the waste of water and, at the same time, improve its quality (Mehrotra & Dhande, 2015). Waste management is still a primary issue in many modern cities, i.e., first-hand solutions may result in significant savings, and economical and ecological advantages (Zanella et al., 2014);

Figure 1: Relevant areas of intervention in Smart Cities, such as Smart Homes, Healthcare, Sustainability, Public Safety, Water Management and Vulnerable Road Users.

Vulnerable Road Users - the importance of this area of intervention is clear when the objective is to help saving lives by preventing accidents. For example, it is extremely dangerous to cross roads in cities, even in the crosswalk. In a Smart City, having people dying and getting injured at the road does not make sense. Therefore it receives a greater importance in the next section, where a thorough revision of the current state of the art is performed.

3 ROAD SAFETY AND VULNERABLE ROAD USERS

Road safety has become a major concern not only for car manufacturers, but also for governments. Indeed, it is a very comprehensive topic, ranging from measuring traffic congestion to increasing the safety of motorcyclists or pedestrians. In Smart Cities, communication among people, vehicles and the city in itself will be a constant (Barba et al., 2012). Undeniably, focusing on IoT, where Vehicular Ad Hoc Networks (i.e., VANETs) are created by applying the principles of Mobile Ad Hoc Networks (i.e., MANETs), one may improve not only road safety but also drivers quality of life. VANET is a technology which uses cars as nodes of a mobile, highly dynamic, network (Khekare & Sakhare, 2013), allowing vehicles to easily communicate among them and with fixed infrastructures. Barba (Barba et al., 2012) propose a Smart City framework for VANETs that includes intelligent traffic lights established at crossroads, therefore transmitting warning messages and traffic statistics. However, it was made a set of assumptions that are hardly true, such as that all vehicles have devices like global positioning systems and driver

wizards, plus full map information including the position of the intelligent traffic lights. However, this work may have value or significance with regard to message propagation, i.e., there is authors that have been using VANETs and Intelligent Transportation Systems to achieve objectives such as improving road flow performance; create comfortable driving; distribute, in real time, up-to-date road information; and, last but not least, to improve road safety. With focus on vehicular communications, several authors have studied possible forms of communications between vehicles, pedestrians and infrastructures (i.e., V2X). Vehicle-to-Vehicle (i.e., V2V) communications are a form of bi-directional communication between vehicles. The exchanged information may be used to calculate traffic conditions, to avoid vehicle collisions or to propagate rescue messages (Anaya et al., 2015). Vehicle-to-Infrastructure (i.e., V2I) communications are a form of interaction between a vehicle and an infrastructure, usually built on roads or streets. V2I may be used, for example, by a vehicle to identify its position or to collect information, especially on traffic and road conditions (Anaya et al., 2014; Milanes et al., 2012). Other forms of vehicular communication are emerging, mainly directed towards pedestrians. These forms may be defined as P2V (Pedestrian-to-Vehicle) and are shifting the focus of vehicles to pedestrians (Cho, 2014; Liu et al., 2010). This form of communication would allow the exchange of messages between people and vehicles in both directions, allowing the enhancement of VRU protection.

At the road, there are people more vulnerable than others to injuries and accidents. Those are known as Vulnerable Road Users. Such users are defined as "*non-motorized road users, such as pedestrians and cyclists as well as motorcyclists*" (European Parliament, 2010). Their vulnerability may arise from several directions, namely: lack of external protection; age; physical and mobility impairments; or visual and/or hearing disabilities. It should also be emphasized that road traffic injuries are the world eighth leading cause of death (Guayante et al., 2014). Some different approaches have been studied on how to minimize the vulnerability of the VRU. Most of these studies are theoretical. Cho (Cho, 2014) proposes a P2V communication system focusing on conflict zones, such as the single unsigned road and intersection areas. Its main focus is children and the elderly. Although they claim to use a type of P2V communication, real communication happens between vehicles and infrastructures, and then between infrastructures and the pedestrians. There is no direct communication between people and things. More examples of theoretical studies may be found in the work of Carels (Carels et al., 2011), who propose the combination of new wireless technologies with existing collision prevention systems, showing and explaining several use cases such as "Right Turning Vehicle" or "Street Crossing". It also addresses important trade-offs for information exchange between vehicles and VRUs, namely: low latency, low energy consumption, high position accuracy and high reliability of warnings. Besides these trade-offs, there is one that should not be forgotten, i.e., cost. A hypothetical solution for the VRU problem will only be implemented in the real world if it is economically viable. There are, however, interesting examples of studies that have, in some way, implemented or simulated their work. A thought-provoking work is done by Anaya (Anaya et al., 2015). They feature a new advanced driver assistance system to prevent accidents involving motorcyclists and cyclists. They have developed a VRU detection system where vehicles and motorcyclists have their own communication unit. On the other hand, cyclists, whose bikes have reduced communication capabilities, are equipped with an on-board sensor known as iBeacon. An iBeacon is a new bluetooth-based sensor with low-cost, low-power transmitters. It notifies bluetooth devices of one's presence. However, they focused on keeping the non-vulnerable driver informed about the presence and location of the VRU by having a unidirectional information flow (Anaya et al., 2015). The same authors have studied the accuracy and performance of several technologies such as GPS and Wi-Fi. Such studies are important since the VRU (and the vehicle) needs to be informed of a possible collision before it happens, leaving no time for latency or bad connections between systems (Anaya et al., 2014). Other studies focused on the benefits that smartphones could bring to the VRU. One example is the study performed by Liebner (Liebner et al., 2013). These authors evaluated accuracy and transmission latencies for smartphone-to-car communications, being able to show that the performance of the smartphone's GPS is heavily affected if the smartphone is, for example, in the breast pocket of a jacket. Another different approach to this problematic may be seen in the work of Guayante (Guayante et al., 2014). Their approach is to make use of sensors to detect users and their movement, and then send alerts to vehicles nearby. This model is based on the VANETs' approach and it is not considering the VRU as an active and

proactive part of the system. Moreover, it showed important drawbacks such as the inability to detect a VRU that was moving at high-speed like running.

As discussed earlier, several approaches have been studied to improve VRU security and while some focus on drivers others center on the city's vehicles or infrastructure. Solutions that make use of cameras and sensor fusion techniques to discover VRU at the road are defining the VRU as a passive actor. In fact, this may be seen as the main conclusion of our literature review; clearly, the main emphasis is on vehicles and drivers, foregoing relevant information about the VRU. This is a gap that we intend to solve with the IoP. Some studies were already undertaken to look at P2V communication, relying in servers. There is no direct communication between VRU and things. In addition, such studies are mainly limited to smartphones and are considering people as "flat things". Our approach to the VRU problem is to get people to this global network of physical things known as the IoT, always taking into account the characteristics of the VRU, together with his physical and emotional state, allowing, for example, the creation of awareness for an unpredictable behaviour. Therefore, within the IoP, the citizen sensor is of the utmost importance as it focuses on empowering citizens with sensing capabilities. Thus, we would be in the presence of a global network composed of physical devices and people, being able to understand each other; be aware of the presence of others; and be able to act and react upon changes in the environment. As soon as the human being becomes an active part of the IoP, some concerns will always be raised regarding one's privacy and the management of one's data. Such concerns are already being addressed in the literature as, for example, in the work of Wu (Wu et al., 2010), who focused on ensuring reliability, security and privacy in V2V Communications.

4 CONCLUSIONS

Smart Cities and IoT should be seen as relevant topics for the present, not as forward-looking topics. This work analysed relevant areas of intervention in Smart Cities, showing that further studies are needed to achieve effectiveness and efficiency in many of them. One of the many points that still require extensive studies is focused on Road Safety, namely on how to improve VRU's security. Injury prevention in such users should be seen as crucial as it would save lives. It has become clear that, currently, the VRU itself is being insufficiently focused and, therefore, the use of IoP to deal with this problem. The VRU is part of the problem and obviously should be part of the solution. We must seize the citizen as a sensor and as an active and participatory element and, therefore, enable the IoP. Communication should go to, and come from, the VRU. In the context of the VRU problematic, the IoP would allow a system to have direct information about the VRU and share such information with cars, road side infrastructures and other people. Just by focusing on VRUs, it would be possible to exchange information such as one's position, pace, direction, physical condition, age and disability, among others. We will not forget important questions when handling VRU-relevant information such as ensuring reliability, security and privacy of information through the use of reputation models or automated auditing.

Once we focus on the IoP, new possibilities to address this problem will emerge and everyone would benefit if they could be deeply understood and then finally implemented. Having completed this literature review we are now focused on designing and conceiving an architecture, a framework, that will lead us to the implementation of an IoP solution for the VRU problem. Therefore, the nodes of this global and open network will be pedestrians, cyclists and drivers along with "things", all in constant communication to enhance VRU's security. Last but not least, the VRU will be led towards the IoP, with the creation and adoption of software and devices that will help ensure his safety.

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REFERENCES

Anaya, J. et al., 2014. Vehicle to pedestrian communications for protection of vulnerable road users. In IEEE Intelligent Vehicles Symposium Proceedings. pp. 1037–1042.

Anaya, J. J. et al., 2015. Vulnerable Road Users Detection Using V2X Communications. In IEEE 18th International Conference on Intelligent Transportation Systems. pp. 107–112.

Barba, C. T. et al., 2012. Smart city for VANETs using warning messages, traffic statistics and intelligent traffic lights. In Intelligent Vehicles Symposium (IV). pp. 902–907.

Boavida, F. et al., 2016. People-Centric Internet of Things-Challenges, Approach, and Enabling Technologies. In P. Novais et al., eds. Intelligent Distributed Computing IX. Guimaraes: Springer International Publishing, pp. 463–474.

Cano, J., Jimenez, C. & Zoughbi, S., 2015. A smart city model based on citizen-sensors. In IEEE First International Smart Cities Conference (ISC2). pp. 1–2.

Carels, D. et al., 2011. Architecture for vulnerable road user collision prevention system (VRU-CPS), based on local communication. In 18th World congress on Intelligent Transport Systems: Keeping the economy moving. Orlando, p. 10 pages.

Cho, W., 2014. Safety enhancement service for vulnerable users using P2V communications. In International Conference on Connected Vehicles and Expo (ICCVE). pp. 1002–1003.

European Parliament, C. of the E.U., 2010. DIRECTIVE 2010/40/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. Official Journal of the European Union, 8, pp.296–308.

Fernandes, B. et al., 2015. Handling Default Data under a Case-based Reasoning Approach. In Proceedings of the International Conference on Agents and Artificial Intelligence. Lisbon, pp. 294–304.

Gabbai, A., 2015. Kevin Ashton Describes “the Internet of Things.” SMITHSONIAN MAGAZINE. Available at: http://www.smithsonianmag.com/innovation/kevin-ashton-describes-the-internet-of-things-180953749/?no-ist [Accessed February 17, 2016].

Gomes, P. et al., 2010. Patient Monitoring under an Ambient Intelligence Setting. In J. C. Augusto et al., eds. Ambient Intelligence and Future Trends-International Symposium on Ambient Intelligence (ISAmI 2010). Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 185–188. Available at: http://dx.doi.org/10.1007/978-3-642-13268-1_22.

Guayante, F., Diaz-Ramirez, A. & Mejia-Alvarez, P., 2014. Detection of Vulnerable Road Users in Smart Cities. In Eighth International Conference on Next Generation Mobile Apps, Services and Technologies. pp. 307–312.

Harmon, R., Castro-Leon, E. & Bhide, S., 2015. Smart cities and the Internet of Things. In International Conference on Management of Engineering and Technology (PICMET). Portland, pp. 485–494.

Harrison, C. et al., 2010. Foundations for Smarter Cities. IBM Journal of Research and Development, 54(4), pp.1–16.

Khekare, G. & Sakhare, A., 2013. A smart city framework for intelligent traffic system using VANET. In International Multi-Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s). pp. 302–305.

Kyriazopoulou, C., 2015. Smart city technologies and architectures: A literature review. In International Conference on Smart Cities and Green ICT Systems (SMARTGREENS). pp. 1–12.

Liebner, M., Klanner, F. & Stiller, C., 2013. Active safety for vulnerable road users based on smartphone position data. In IEEE Intelligent Vehicles Symposium (IV). pp. 256–261.

Liu, N. et al., 2010. When Transportation Meets Communication: V2P over VANETs. In IEEE 30th International Conference on Distributed Computing Systems (ICDCS). pp. 567–576.

Madakam, S., Ramaswamy, R. & Tripathi, S., 2015. Internet of Things (IoT): A Literature Review. Journal of Computer and Communications, 3, pp.164–173.

Mehrotra, S. & Dhande, R., 2015. Smart cities and smart homes: From realization to reality. In International Conference on Green Computing and Internet of Things (ICGCIoT). pp. 1236–1239.

Milanes, V. et al., 2012. An Intelligent V2I-Based Traffic Management System. In IEEE Transactions on Intelligent Transportation Systems. pp. 49–58.

Miranda, J. et al., 2015. From the Internet of Things to the Internet of People. In IEEE Internet Computing. pp. 40–47.

Neves, J. et al., 2015. Artificial Neural Networks in Diagnosis of Liver Diseases. In E. M. Renda et al., eds. Information Technology in Bio- and Medical Informatics. Springer Inter. Publishing, pp. 71–80.

Rose, K., Eldridge, S. & Chapin, L., 2015. The Internet of Things: An Overview T. I. S. (ISOC), Available at: http://www.internetsociety.org/sites/default/files/ISOC-IoT-Overview-20151221-en.pdf.

Scholl, H. et al., 2009. E-Commerce and E-Government: How Do They Compare? What Can They Learn from Each Other? In 42nd Hawaii International Conference on System Sciences (HICSS 09). pp. 1–10.

Silva, F. et al., 2013. Sensorization and Intelligent Systems in Energetic Sustainable Environments. In G. Fortino et al., eds. Intelligent Distributed Computing VI. Springer Berlin Heidelberg, pp. 199–204.

Silva, F. & Analide, C., 2016. Sensorization to Promote the Well-Being of People and the Betterment of Health Organizations. In J. Machado & A. Abelha, eds. Applying Business Intelligence to Clinical and Healthcare Organizations. p. 20.

Skouby, K. & Lynggaard, P., 2014. Smart home and smart city solutions enabled by 5G, IoT, AAI and CoT services. In International Conference on Contemporary Computing and Informatics (IC3I). pp. 874–878.

Wu, Q., Domingo-Ferrer, J. & Gonzalez-Nicolas, U., 2010. Balanced Trustworthiness, Safety, and Privacy in Vehicle-to-Vehicle Communications. In IEEE Transactions on Vehicular Technology. pp. 559–573.

Zanella, A. et al., 2014. Internet of Things for Smart Cities. IEEE Internet of Things Journal, 1, pp.22–32.