Information Security

IoT APPLICATION IN SMART CITIES WITH AN ACCENT ON T RAFFIC AND TRANSPORTATION

Čekerevac Zoran
DSc, Professor
"UNION-Nikola Tesla" University in Belgrade (Serbia)
e-mail: zoran@cekerevac.eu

Prigoda Lydmila
DSc, Professor
Maikop State Technological University, Maykop, Adygeya Republic, Russia
e-mail: lv_prigoda@mail.ru

Bogavac Milanka
PhD, Professor
"UNION-Nikola Tesla" University in Belgrade (Serbia)
e-mail: bogavac.milanka@gmail.com

Abstract
With the increasing influx of population, live in cities is becoming increasingly difficult. The paper analyzes the implementation of IoT in some areas of functioning of "smart cities" with emphasis on the organization of transport and the application of new technologies in this regard. Some examples from advanced cities are also presented.

Keywords: *smart city. IoV. IoT. transportation. urban traffic*

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INTRODUCTION

With the increasing influx of population, live in cities is becoming increasingly difficult in every respect. From the organization of supply, life, and work, to the liberation of cities byproducts of the population living in them. Each area individually needs to be refined, and it is improving. Since the improvement of one area of life usually influences another, and that the accelerated development of one area does not mean general improvement, there appeared the concept of the so-called "smart" cities. They should provide an overall comfortable, economical, sustainable, and safe life for their residents. Basic support for this idea is provided by information technologies based primarily on IoT, wireless communications, innumerable sensors, and above all by the Internet and LPWAN and 5G networks. Deployment of a wide range of IoT applications should provide smart infrastructure in areas such as transportation, electricity, water supply, waste disposal, residential construction, and public services.

We will not discuss here the potential harmfulness of new technologies to health since hardly any epochal invention has remained unused. We will keep the focus on the technical, technological, and social aspects of the application of IoT in traffic in smart cities hoping that living organisms can evolve aligning with new living conditions.

SMART CITIES AND IoT

According to Gulan [1] in January 2019, there were 4,709 settlements or villages in Serbia (according to the Constitution of the Republic of Serbia, there is no category of villages), of which 1,200 are in the phase of disappearance, with 50,000 empty houses without owners and another 150000 in which no one is living. At the same time, the population of the capital, Belgrade, from the million it had in the early 1970s, rose to 1,639,121, of which 1,166,800 live in the central part (according to the 2011 Census [2]**), with a tendency of further growth towards an estimated 1,215,996 inhabitants in the central part of the city in 2020** [3]**. According to the Bureau of Statistics** [4] **during 2018, 122,193 persons changed their place of residence, i.e. permanently moved from one to another settlement of the Republic of Serbia. Mostly, migration leads to cities. Also, the total population of Serbia tends to fall.**

The situation is similar in the surrounding countries and the whole world. According to the UN, today, 54% of people around the world live in cities, and by 2050 that percentage should rise to 68% [5]. The growth of urbanization will also entail an increasing number of problems. More and more people in a confined space will mean higher traffic density, and therefore more air and noise pollution, less green space, and more traffic jams, leading to the need for intelligent transport systems and vehicles with fewer emissions of toxic components. In this, one should not see only air pollution, but pollution of nature in general.

A smart city is a framework, consisting mainly of information and communication technologies (ICT). A large part of the ICT framework is an intelligent network of connected objects and machines that transmit data using wireless technology and the cloud. Cloud-based IoT applications receive, analyze data, and enable real-time responses. Communities can improve energy distribution, facilitate the waste collection, reduce traffic density, and even improve air quality with the help of IoT.

Many cities have started implementing some IoT solutions. Planned or unplanned, but IoT solutions are being introduced in many areas. One of the most visible is the introduction of surveillance systems that provide insight into the movement of vehicles (and people). In addition to allowing traffic congestion to be monitored, these systems are also used for other purposes, including controlling the speed of vehicles on the streets.

Belgrade, Serbia, and surroundings

Initiatives related to the smart city approach are often mentioned in Serbia, but except for the Smart City Festival, the Smart City SEE19 regional conference, and individual competitions for "best smart city solutions", there is little organized action. What leads to a smart city generally takes place within the individual, weakly, and rarely connected projects. Noticeable displays are showing the number of vacancies in certain public city garages, several displays on the part of the highway passing through the city, which indicate the state of the highway. And, this is more or less all that is visible to the residents. The city of Niš was selected to be a pilot project of the smart city initiative. If the project realizes as it was conceived, Niš could become the first smart city in the region. Sensors will guide drivers to the parking spot. Digital monitoring of waste containers will show when the containers are full. Remote detection of malfunctions in the water supply system will be applied as well as the systems that read the energy consumption. [6]

At the end of 2019 and early 2020, an air quality measurement system arose to the focus of the people in Serbia. The population was able to monitor the level of air pollution in some cities and some parts of the cities. It turned out that the air breathed by the people very often and for a long time was at the level of "dangerous" and that Serbian cities, including Belgrade, were in the group of the most polluted cities in the world. The situation was similar in Sarajevo, Tuzla, Zenica, Pljevlja, Peja, Strumica, Lisice, etc. A network of Klimerko devices was formed in Serbia, which provided the population with results on the state of the air through the website vazduhgradjanima.rs. Although the accuracy of measurement can be discussed, it is evident that these IoT systems have influenced the awareness of the population. Many went for the purchase of masks and air purifiers, and a significantly reduced number of people on the streets was visible.

Amsterdam

Amsterdam, as one of the leaders in creating smart cities, launched an initiative ten years ago to improve its economy, environment, government, living, and mobility. Within the Smart City (ASC) project, seven areas have been identified with several different activities. More details on this initiative can be found at [7], and only some of them, closely related to the topic of this paper, will be cited here.

1. Infrastructure and technology:

a) *Investing in Internet traffic*. Due to its geographical location, Amsterdam is in a situation where 11 of the 15 transatlantic data cables either pass through or are connected to Amsterdam. In this way, Amsterdam is the second-largest Internet exchange point in the world.
b) *IoT living lab*. An area of 3,700 square meters was equipped with IoT-enabled smart beacons that communicate via LoRaWan. Users can access data from the beacons using Bluetooth-enabled devices. The data user can use for developing their apps. The idea was to let startups and innovators test IoT solutions in real urban environments.
c) *City alerts*: oriented to provide operation instructions to rescuers in real-time. [8]
d) *Smart city lighting*: Special LED lighting goes up when cyclists are nearby and dims after they pass.

2. Smart energy: Amsterdam is working to increase energy use from renewable sources. In addition to maintaining such facilities, the city also allows residents to produce electricity and exchange it using the GridFriends system. They can also install solar panels. The Comfort cooling system is in use to cool buildings in the Amsterdam Houthaven district by transmitting heat to a river that flows nearby.

3. Smart mobility: Amsterdam residents traditionally use their bicycles for transportation massively. 63% of residents use their bicycles daily. Also, there is an increase in the number of electric cars by 53% in 2016 and in the car-sharing, which saw an increase of 376%. Although noticeable, car-sharing is still at the level of somewhere about 1% of the total number of car rides. [9] Also, it is interesting the application of the Parkshuttle, an autonomous platform that can carry around 2500 passengers daily with five stations using six vehicles.

4. Circular city: The idea is that everything produced in the city is recycled in the city for producing new products and services, and to reduce waste and costs for the procurement of raw materials.

Seul

By 2024, Seoul plans to invest the US $ 1.24 billion in turning the city into a “capital of big data.” [10]. According to the same source, over 50,000 IoT sensors will be deployed throughout the city. These devices will collect data on dust, light intensity at night, pedestrian and vehicle movements, and many other things that will help city authorities come up with an appropriate policy. And surveillance cameras will get smarter. The Seoul administration plans to install additional 17,280 surveillance cameras by 2021 with algorithms that automatically notify the police about brawls/fights and other forms of misconduct. Free Wi-Fi will expand so that all city buses will have free Wi-Fi in 2020. [11] Also, electricity consumption in 1000 single-member households with one senior member will be monitored to avoid dangerous situations.

Singapore

Singapore is using digital innovation to offer the best public services to its citizens, and the local government has implemented many projects under the "Smart Nation" initiative. For example, more than 52,000 surveillance cameras have been set up to enable police to respond quickly in the event of any problem. Also, the "eXchange" platform enables state-owned agencies to exchange data, while the "OneService" mobile application directs citizens' complaints to the competent institutions. [12]. Within transportation projects there were launched [13]:

– *Autonomous vehicle trials in Singapore*; In 2015, A*STAR's self-driving vehicle was the first vehicle of its kind to receive regulatory approval for public road testing.

– *Contactless fare payment for public transport* uses RFID technology.

– *On-demand shuttle*; The shuttle can be booked using smartphones, and the shuttle can pick up passengers from their doorstep, as a taxi does.

– *Open Data and Analytics for urban transportation*. Tracking the vehicles, the land transport authority reduced the rate of overcrowded buses by 92%.

Helsinki

Helsinki is constantly listed as one of the most affordable cities to live in, but in 2019 it was named Capital of Smart Tourism. Vapaavuori said [14]: "We are big enough to enable tests, demonstrations, and pilots in a systemic relevant way. But at the same time, we are small enough to make it happen and good enough to make it feasible. … we see the city as a platform, as an enabler, as a partner, not as a bureaucracy". One of the interesting solutions implemented in Helsinki is that ten years ago a metro station was built in Kalatasama, a district that was then "mostly wasteland and grim office buildings". With the opening of the metro station, conditions were created for the rapid settlement of the area, but on a "smart city" basis. The goal of this successful initiative was to disperse the city center and keep the city comfortable for life despite its expansion.

SMART CITIES AND IOV

The car is being an important factor in the lives of people for a long time, not only those who drive it or work in the automotive industry but also those who are exposed to its influence, whether it be the exhaust, noise, or physical endangerment. For traffic jams, solutions are found through projects based on the use of computer systems and simulations of different traffic cases. Thus, modern cars have become mobile platforms that supply drivers with a wealth of information about the condition of the vehicle and the state of the environment in which the vehicle moves, and even assume some of the functions of vehicle control. The application of modern information technologies encourages the establishment of new infrastructure consisting of networks of roads, railways, airports, stations, and ports connected by Internet-based systems. The efficiency and quality of transport are significantly influenced by intelligent systems that improve the mobility and safety of road users. By implementing an IoT solution, traffic regulation has the effect of increasing safety, thereby directly reducing the number of traffic accidents while increasing passenger satisfaction. Future solutions will be based on the implementation of smarter and more environmental-friendly vehicles and their connection to infrastructure facilities such as streets, signage, gas stations, parking lots, garages [11].

The term Internet-of-Vehicles (IoV) represents the paradigm of one of the directions for the development of smart traffic and an area that has been given special attention in recent years, both from a technical and technological point of view, for example [15], and from an ethical point of view, e.g. [16].

IoV involves the hybrid use of IoT devices, various wireless communication technologies, cloud and Internet services, and applications. This concept enables the collection and sharing of information about vehicles, infrastructure, and the environment. Moreover, IoV makes it possible to process, calculate, share, and publish information on information platforms available to most users today. On the other hand, based on this data, real-time monitoring, and management of the city's traffic-transport system, as well as the creation of BigData for the full range of multimedia and mobile Internet applications, are enabled.

The most important task of IoV architecture is to connect vehicles to heterogeneous wireless networks, as well as to interconnect them. In doing so, copies of the data generated on the vehicle itself are transmitted in different ways to the environment while retrieving data from the same environment. Many sensors, microcontrollers, RFIDs, and other technical solutions are built into the whole process. This plethora of data, vehicles, infrastructure objects interconnected using a distributed ad hoc vehicular network had created a new network and computing paradigm specifically designed for vehicles—the vehicular fog [15]. The urban vehicles fleet is evolving rapidly to the Internet cloud, and a network of autonomous vehicles (AUVs). In its path, the IoV architecture has many unresolved issues, primarily caused by the heterogeneity of networks and devices. One of the first solutions of a layered architecture is proposed in the paper [17]. This five-layer IoV architecture is shown in Figure 1. Given that it is explained in more detail in the original paper, only some basic characteristics of individual layers will be indicated here:

1. The Perception layer is characterized by a variety of sensors and devices connected to the network.
2. The Coordination layer is reflected in the virtual universal network coordination module for heterogeneous networks.
3. The third level is represented as the virtual cloud infrastructure, and it is the brain of IoV and responsible for the information received from layer 2 and decision making based on the critical analysis.
4. The application layer consists of smart applications and it is oriented to the end-users.
5. The fifth layer of the architecture, represented by the operational management module of IoV, is aimed at foresight strategies for the development of business models.

The interaction model of IoV network

The IoV network model should enable the efficient, safe, and reliable functioning of the IoV system, both by elements and as a whole. The way the model works has been analyzed in numerous pieces of literature, with each part broken down into details, but here it is convenient to use the model to be divided into hardware, software, and users. These components can be considered individually, but also unified as in the case of users, communications, and clouds that work closely together. This division of the IoV model emphasizes the functionality of its concept. Sensors and devices installed at the site of use are the first basic elements. The choice of sensors and devices depends on what one wants to accomplish, so they are very heterogeneous.

Software is what brings life to the system and makes it possible to achieve the goal. This includes all types of software, from drivers and communications software to user applications. Different types of devices or smart applications may individually implement one or more of the same or different types of wireless access connections, depending on the priority and preference for services.

The third basic element is the network of users whereby the user can be understood as a human participant in the traffic (driver, passenger, pedestrian) as well as the autonomous vehicle.

No.	Layers	Representation	Functionalities
5.	Business	Graphs, Flowchart, Table, Diagram	• Business model and investment designs • Resource usage and application pricing • Budget preparation, data aggregation
4.	Application	Smart applications for vehicles and vehicular dynamics	• Smart, intelligent services to end users • Service discovery and integration • Application usage data and statistics
3.	Artificial Intelligence	Cloud computing, big data analysis, expert systems	• Storing, processing, analysis of data • Analysis based decision making • Service management based on profit
2.	Coordination	Heterogeneous Networks: WAVE, WiFi, LTE	• Unified structure transformation • Interoperability provisions • Secure transportation of information
1.	Perception	Sensor and actuator of vehicles, RSU, personal devices	• Data gathering: vehicle, traffic, devices • Digitization and transmission • Energy optimization at lower layers

Figure 1. The five-layered architecture of IoV
Source: [17]

Different interactions can be established between these components of the IoV model. A systematic schematic presentation of these relationships is shown in Figure 2.

If looks at Figure 2, one can see the full variety of model factors. They vary in many characteristics, including the technology they use, response speeds, signal strength, the protocols they use, and their relevance to specific issues. If a communication network is considered, there are two types of communication. The intra-vehicular communications are focused on communications inside the vehicle supporting V&P devices, V&S, and Sensors and Actuators (S&A). The extra-vehicular communications are focused on communications between the vehicle and surroundings.

Most modern IoT networks are based on LPWAN (Low-Power Wide-Area-Network) which is designed to wirelessly connect the "things". LoRa (Long Range) is a spread spectrum modulation technique derived from Chirp Spread Spectrum (CSS) modulation technology. [19]

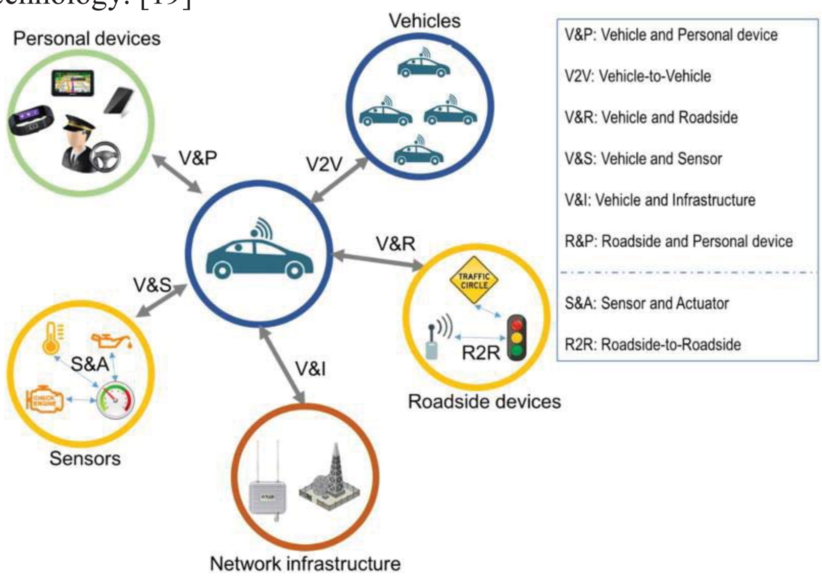

Figure 2. Device-to-device interaction model for IoV
Source: [18]

Many LPWA technologies allow communication over distances measured in hundreds of kilometers, but their flow rates are limited to a few kilobits per channel and second. Although much hope is being placed in 5G networks, 75% of the IoT market is expected to come from LPWA network solutions, and 25% to high-bandwidth low-latency 5G applications. [20] One of the main advantages of LPWAN is that such networks already exist and that it will take years of work to deploy 5G networks. Another advantage is that the LPWAN does not require massive infrastructure like in the case of 5G networks. The network can be formed based on small, very smart, and not very expensive devices.

IoV software

The software part of the IoV model includes software components that are embedded in sensors and devices and an application, user part. The first group is inevitably tied to the sensor and equipment manufacturer and as such is of little interest to end-users. The second group is much more interesting to the end-users and can be divided into two basic groups:

- ✓ *Security and management-oriented applications:* security, navigation, diagnostics, and telematics; and
- ✓ *Business-oriented applications:* insurance, car sharing, information and entertainment applications
- ✓ By their purpose, IoV security and management-oriented applications are intended for various security functions such as:
- ✓ *Traffic accidents prevention*. This group is a vehicle security M2M [The M2M system is a set of technologies that allow devices to communicate with each other over a wired or wireless network] communication system. Its function is to prevent traffic accidents by exchanging real-time information between different vehicles. Such a system would be very useful for highways and urban areas with high traffic density.
- ✓ *Emergency Call*: It is a system that activates in an emergency when it is necessary to contact emergency services such as police, firefighters, roadside assistance, as well as family or friends.
- ✓ *Navigation:* These applications related to navigation are services based on geo-referenced data. They are already known from GPS devices so far, but it will also be supplemented by data from vehicle video sensors and data from heterogeneous communication networks. There are no obstacles to the introduction of a system that would prevent the driver from driving the vehicle at a speed higher than permitted.
- ✓ *Diagnostics:* The application refers to vehicle diagnostics to protect it. In addition to real-time vehicle condition monitoring, one of the key operations of these applications is the management of vehicle condition data. It is cloud-based. The application in a timely manner indicates the need to repair or service vehicles.
- ✓ *Telematics:* This application gives the ability to remotely access parked vehicles using very secure telematics remote applications. Applications are based on precise remote monitoring, authentication, and authorization methods.
- ✓ *Smart traffic lights:* They are equipped with sensors, data processing, and communication devices. These traffic lights have information about the traffic load (e.g. intersections), as well as the intensity and density of traffic going in all directions. This information can be analyzed and sent to adjacent traffic lights or a central controller.
- ✓ Business-oriented IoV applications group can be classified as applications related to the economic and organizational aspects of transportation in smart cities. They can be oriented to:

✓ *Insurance:* The insurance-related applications are based on a statistical analysis of information including vehicle use, driver behavior, place of use, and duration of vehicle use.

✓ *Ridesharing*: This application is a special hybrid system of shared transport, also called modified passenger car use. Such applications are based on the concept of improving the use of a passenger car to meet the same transport needs in space and time and reducing the personal costs associated with transportation. Typical representatives of this subsystem are the common private car (Carpool), the common private minibus (Vanpool), and the common car (CarSharing). The application locates users who make the same or similar transportation requests and connects them to the car owner. This way a software optimizes the realization of the trip based on the aligning of the same transport requirements of different passengers. Undoubtedly, this approach runs counter to taxi carriers' will.

✓ *Infotainment*: Starting from the concept of connection of home, work and general mobility, this type of application implies the availability of different information while driving, and the synchronization of the onboard display with an office or home computer, smartphone, or other online devices.

Decision making

One of the most important functions of an IoV system is decision making. Due to the movement of vehicles in a changing environment, there is a constant danger to the safety of road users and a constant need for decision making. All data collected has a purpose and is expected to be used in real-time. To ensure that the right decision is made on various issues, it is necessary to create appropriate criteria, boundary conditions, and to ensure the possession of quality data. Given the diversity of traffic conditions, the criteria must be comprehensive and cover even the rarest expected situations. Along with the creation of technical solutions, appropriate legislation should be created, which should be adapted to the new conditions. One of the most logical questions is who is at fault in the event of an accident if the vehicle is autonomous? Until the system is perfected, the driver will often listen to the message "Put your hands on the steering wheel!". However, not all decisions are fateful. There are many decisions that IoV systems can make independently, without endangering traffic users. For example, vehicle and infrastructure data can be provided to the appropriate traffic safety and regulation platform, and the platform can create and forward commands to the traffic light system and driver alert system. This could reduce traffic congestion, fuel consumption, and reduce the emission of toxic gases into the atmosphere.

CONCLUSIONS

Population migration has always existed and will continue to exist. And it is good as long as the migration is small-scale and related to the personal desires of individuals. It is not good when it is massive and a consequence of the struggle to maintain a bare existence. There is a noticeable increase in the population in large cities as a result of the newcomers' hope that they will live better in the big city than in the place of their current life. Instead of providing a better living environment in a place where people are born, society does nothing, and people are moving to (big) cities. Because of the growing population in (big) cities and the difficult organization of life in new conditions, smart cities are a necessary orientation. For the city to survive at all, it must become "smart", and this requires major investments in all areas and especially in technology and technological development, but also in the way of thinking of the people who live in them. There is no technical solution that can meet all the challenges in real-time. The challenges are numerous despite all the technological solutions based on IoT, IoV, M2M, 5G, LPWAN, and other technologies. Life in big cities can be expected to become increasingly uncomfortable. The solution could be found in the decentralization of large cities and the development of villages and towns in the interior.

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