APPLICATION OF THE IOT SMART CITY TECHNOLOGY IN IMPROVING THE TRANSPORT SECURITY IMPROVEMENT (Keynote paper)

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Summary: The Internet of Things (IoT) Smart City solution and functionality described in this paper will offer local communities as well as all road users the completely new functionality of driving assistance and smart community through the implementation of the xZone solution (neXt generation Zone), as well as full interaction with modern digital infrastructure. All vehicles will use driving assistance as an integral part of advanced navigation systems with special reference to anti-collision and traffic density monitoring on key roads using the SAM (Street Activity Monitor) sensor / module. The aforementioned functionalities are just an early stage towards even more attractive services such as V2V (Vehicle to Vehicle), V2I (Vehicle to Infrastructure), I2V (Infrastructure to Vehicle) and AV (Autonomous Vehicle). The consequence of digitized infrastructure in Smart City and Connected Routes environments, as well as the digitization of vehicles, will significantly reduce the number and consequences of collisions, material damage and most importantly, the number of people injured and lives lost.

Keywords: Internet of Things, Smart Cities, Security, Nagel-Shrackerberg

1. INTRODUCTION

The latest technological trend in the process of digitizing infrastructure in all urban and rural areas, as well as the digitization of vehicles themselves, marks the second decade of the 21st century as the beginning of a period of massive implementation of the Internet of Things (IoT) Smart City solution.

The IoT Smart City concepts, solutions and functionalities described in this paper will offer and bring to the local communities as well as all road users completely new driving assistance and smart community functionalities through the implementation of the xZone (neXt generation Zone) solutions and full interaction with modern digital infrastructure.

2. TRAFFIC MONITORING AND MANAGEMENT

There are several approaches to research focused on traffic monitoring and management:

1) Treatment of the traffic network in the context of fluid dynamics where individual traffic participants are not seen but the entire traffic network is treated as a pipe system.

2) The second approach is a “microscopic” model where traffic is viewed as the interaction of a large number of particles that actually represent traffic participants.

The microscopic model has received a lot of variations in recent decades through the development of numerous models for monitoring, analyzing and planning traffic infrastructure based on the concept of cellular vending machines. Cellular Automata have been especially promoted through the research and papers of Steven Wolfram, Wolfram (1986, 2002).

2.1. Cellular models for monitoring traffic flows

One class of mathematical and computer models for monitoring, planning and analyzing traffic flows and densities on roads are cellular automata. One of the better known cellular automata researchers is Stephen Wolfram, Wolfram (1986). The cellular vending machine model used in traffic research for the xZone Smart City study is based on the **Nagel-Shrackerberg** model (Nagel, Schreckenberg, 1992).

The basic idea of the **Nagel-Shrackerberg (NG-SH)** model is to view the road as a series of cells of a certain width and to define a set of four basic rules to define the behavior of vehicles in normal traffic, in deceleration, in acceleration and in randomization of occurrences in the model. The simplest set of rules was introduced by Nagel and Schreckenberg, (Nagel and Schreckenberg 1992).

To monitor the condition of the street using this cellular vending machine, the street was divided into cells of 7.5m length. This corresponds to the typical space occupied by a standard passenger car plus the distance to the previous car when stopping.

Each cell can be filled. An individual vehicle is described by its current speed v which can have speeds v = 0,1,2, ..., vmax. Here is a **vmax** speed limit that is the same for all cars. In variations of the Nagel-Shrackerberg model, these restrictions may differ for different car classes. The usual path configuration for the Nagel-Shrackerberg model is shown in Figure 1.

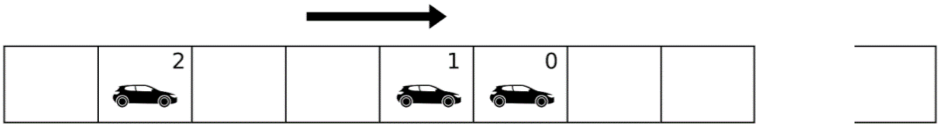

Figure 1, Standard Nagel-Shrackerberg path representation for their cellular vending machine, (xCube Int. Labs)

The list of rules for vehicles in the **Nagel-Shrackerberg** model is as follows:

Step # 1: Accelerate
All cars that have not reached the maximum vmax speed are accelerated by one step:

$v = v + 1$

Step number 2: Safe distance rule
If the vehicle has d empty cells in front and its speed v (after step 1) is greater than d, then it reduces its speed to d:

$v = min \{d, v\}$

Step # 3: Randomization
With probability p, the velocity decreases by one unit (v after step 2):

$v = v-1$

Step # 4: Driving
After steps 1-3, the new velocity vn for each car n is preset to vn in the cells:

$xn = xn + vn.$

Traffic density can be increased to the desired level and is based mainly on the choice of stochastic parameters in the module and testing of parameter sets to obtain conditions on the streets of the model as close as possible to real conditions. One of the most famous applications of this model is the monitoring and forecasting of traffic density in the German province of North Rhine-Westphalia. **[6]**

2.2. IoT variation of Nagel-Shrackerberg model for Smart City, IoT Cellular Automata (IoT-CA)

With the digitization of infrastructure in the Smart City environment, a large number of digital communication nodes will be implemented that will communicate wirelessly with the environment. Possible technologies are DSRC (Dedicated Short Range Communications), RDS, WiFi, ZigBee.

DSRC is a technology that will work in conjunction with other technologies and the purpose of this technology is to provide a wireless connection between vehicles on the move and devices on the roads. The range is about 300m and operates in the licensed band of 5.96 GHz and the speed is 6 Mbps. DSRC has been accepted as a standard in the USA and EU.

The **IoT Cellular Automata (IoT-CA)** traffic monitoring, forecasting and traffic management model envisions a modified **Nagel-Shrackerberg** cellular automata model so that any traffic can be monitored with as realistic parameters as possible in real time. Each street and road in the **IoT-CA** model has as many lanes as the road being monitored. A **Street Activity Monitor** (SAM) sensor set up at the key points of each monitored road is used to connect real-world data and input it into the **IoT-CA** model (Figure 2).

Each SAM sensor detects the speed and dimensions of the vehicle being introduced into the model (**Figure 3**). Unlike the **NG-SH** model, the **IoT-CA** model also contains information about the dimensions of individual vehicles, making traffic density closer to the real situation on the ground.

SAM main sensors (Figure 5) or virtual SAM sensors are defined on the links of main roads with side streets and roads, statistically generating traffic data commensurate with the statistics of tracked roads, roads and settlements. The denser the SAM sensor network, the more realistic the IoT-CA model reflects the true state of the field.

road, while the IoT-CA model monitors vehicle density in all lanes as it is positioned at key points and roads (Figure 5). For streets where no SAM monitors are installed, randomizers are used.

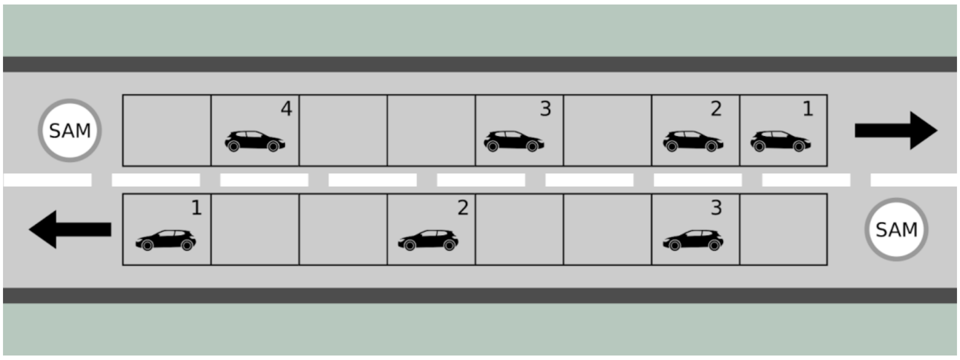

Fig. 2, Modified Nagel-Shrackerberg cellular automaton using input data from SAM sensor (xCube Int. Labs)

An overview of the operation of the SAM sensor in the Smart City environment is shown in Figure 3.

The pilot installation was carried out in early 2015 at Slobodan Bursać Street, Zrenjanin, Republic of Serbia, and testing of the IoT-CA models continued until early 2018.

IoT Street Activity Monitor (SAM) is a replacement of a randomizer from the original NG-SH model so that the actual fits the vehicle speeds and sizes into the model. For passenger cars, a cell of 8 meters size (7.5m in the original model) is used, for buses and trucks a cell size of 18 meters is used which does not exist in the original model. Unlike the original model used by the randomizer, vehicle speed is determined in real time at observed points. The original NG-SH model monitors only the movement of vehicles in a row on the

Figure 3, SAM Sensor, Upper right sensor monitors 4 parking spaces. At the bottom right is an identified passenger vehicle entering the street. (xCube Int. Labs)

In addition to vehicle dimensions data and their speed in the IoT-CA model are entered and micro-meteorological data which in addition temperature, humidity and atmospheric additions provide a list of additional data related to the degree of contamination of micro locations (Figure 4).

All the additional data entered into the model gives enough elements that the IoT-CA model can overlook the occurrence of fog and ice on individual routes and pass that data to driving assistants in the vehicles themselves, whether they are steered or autonomous vehicles.

3. IMPACT ON TRAFFIC SAFETY

Driving assistant devices in vehicles moving in a Smart City environment and having available a traffic monitoring system based on the IoT-CA model can significantly improve traffic safety and efficiency. With the advent of snow, rain and low temperatures, the coefficient of adhesion of the street changes, so the microclimatic data being inserted into the IoT-CA model as well as the ability to predict fog occurrence will further improve the quality of driving assistant information obtained from the IoT-CA platform. The presence of IoT devices in vehicles with a sensor 3Axis accelerator in Smart City environment where Vehicle to Infrastructure (V2I) communication exists is an additional aspect of research to improve overall road safety.

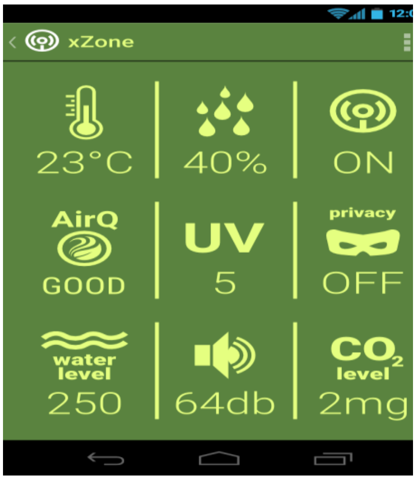

Figure 4, IoT xZone assistant that provides information on all weather conditions in the area where we are moving. (xCube Int. Labs)

4. DYNAMIC ROUTING

In further development and improvement of digitalisation of the road network based on the IoT-CA model, it is necessary to test the possibilities and effects of application of routing technologies developed for the needs of computer packet networks, since with the application of SAM sensors in the IoT-CA Smart City model we approach the model of routing of traffic on roads. computer networks.

Many sophisticated routing algorithms are used in packet-based computer networks to transmit and route packets through the system. Some of these algorithms use only predefined routing paths, while routing techniques known as "multiple path routing" can also be applied in the IoT-CA module. the potential of this model was used to its full potential. Figure 5 shows the complex traffic that by installing an adequate SAM sensor network can be fully digitized through the IoT-CA model and take full advantage of the extremely high quality algorithms developed for optimal routing of packet computer networks to further improve the efficiency and security of road networks in Smart City environments.

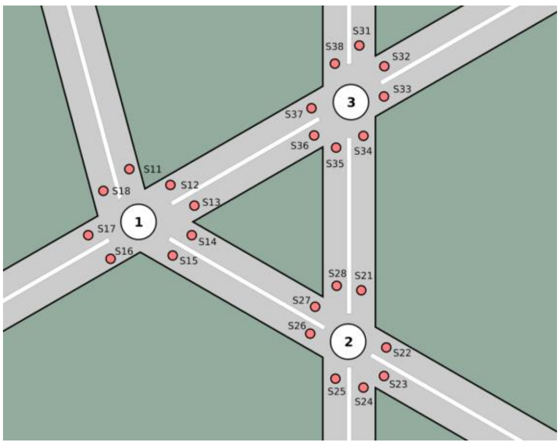

Figure 5, SAM Sensors - street layout in Smart City environment. Sensors S22, S23, S32 (xCube Int. Labs)

5. CONCLUSION

Many authors are exploring the possibility of improving traffic management patterns in order to avoid congestion on the road network and increase road safety. Research and testing conducted during the development of the **IoT Cellular Automata (IoT-CA)** model over a three year period (2015-2018) on a pilot installation showed that the application of IoT technology in cities and its integration with cellular automata models manage the traffic infrastructure in Smart City environments can be raised to a very high level. All vehicles that start using driving assistance as an integral part of advanced navigation systems will enhance their safety by automatically becoming part of the Connected Route system and open to advanced features such as anti-collision. The consequence of digitized infrastructure in Smart City and Connected Routes environments, as well as the digitization of vehicles through driving assistance systems, will significantly reduce the number and consequences of collisions, property damage and most importantly, the number of people injured and lives lost. The aforementioned functionalities and models described are just an early stage towards even more attractive services such as V2V (Vehicle to Vehicle), V2I (Vehicle to Infrastructure), I2V (Infrastructure to Vehicle) and AV (Autonomous Vehicle).

7. LITERATURE

1. iRAP, http://www.irap.org/en/, 12/20/2015.
2. IDS: 1 and 13, (2011). Traffic Control Through Traffic Lights Management: A Comparison Study
3. Lipovac, K., Jovanov, D., Jovanović, D. (2009). A modern approach to improving road safety. Road and Traffic, 56 (4), 32-37.
4. Lipovac, K., Nešić, M. (2005). European Road Safety Action Program - halving road accident victims in the European Union by 2010 - a shared responsibility. Security, Belgrade, 47 (3), 513-533
5. Nagel, K.; Schreckenberg, M. (1992). "A cellular automaton model for freeway traffic". Journal de Physique I 2 (12): 2221. doi: 10.1051 / jp1: 1992277.
6. North Rhine-Westphalia's OLSIM traffic forecasting system, http://www.autobahn.nrw.de/, 01/15/2016.
7. K. Nagel and M. Schreckenberg, A cellular automaton model for freeway traffic, J. Physique I 2, 2221 (1992)
8. Schadschneider, Andreas, (Apr 04, 2000), http://www.thp.uni-koeln.de/~as/Mypage/traffic.html, (Jan 15, 2016)
9. ViDA online software tools, http://www.irap.org/en/resources/vid -online-software, 01/20/2016.
10. Wolfram, Stephen (May 14, 2002). A New Kind of Science. online. Champaign, IL: Wolfram Media, Inc. ISBN 1-57955-008-8. OCLC47831356.
11. Wolfram, Stephen (1986). Theory and Applications of Cellular Automata. World Scientific.