iCloud Traffic Control and Monitoring

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Abstract — An intellectual (smart) road infrastructure is proposed to monitor and control traffic in real-time through the use of global systems for positioning and navigation, mobile gadgets and the Internet in order improve the quality and safety of vehicle movement, as well as for minimizing the time and costs when vehicles are moved at the specified routes. A set of innovative scientific and technological solutions for solving social, human, economic, fuel, energy and environmental problems associated with the creation and use of a cloud for monitoring and management are developed.

Keywords—Traffic Control; Road Infrastructure; Vehicle Mobile Gadget

I. INTRODUCTION

Solving the problem of nano-technological focused development of quantum computer allows radically change all processes and phenomena in the macrocosm, which develops in the form of cyberspace of the planet and passes through the following periods [1]: 1) the 1980s – formation of personal computers; 2) the 1990s – the introduction of Internet technologies in production processes and people’s lives; 3) the 2000s – improving the quality of life through the introduction of mobile devices and cloud services, and 4) the 2010s – the creation of a digital infrastructure for monitoring, control and interaction of moving objects (air, sea, ground transportation, and robots); 5) 2015 – the creation of a global digital infrastructure of cyberspace, where all the processes and phenomena are identified in time and in three-dimensional space and become smart.

II. FORMAL MODELS OF CLOUD MANAGEMENT AND INVESTIGATION OBJECTIVES

The goal of the project is improving the quality and safety of traffic through creating virtual intelligent road infrastructure, including monitoring and control in real-time [1], based on using mobile gadgets of vehicles and cloud traffic lights, which allow minimizing the time and costs of traffic management and creating innovative solutions of social, humanitarian, economic and environmental problems.

Innovative proposal: intelligent cloud traffic control (iCTC) aims to transfer the traffic lights to the clouds, which radically changes the entire road infrastructure on the ground and creates the potential to save thousands of tons of metal for manufacturing traffic lights, hundreds of thousands of kilowatts of electricity for maintaining operability, millions of dollars for installing traffic lights and operating costs, as well as faster installation and updating traffic lights in the virtual urban infrastructure during a few minutes.

The formal cybersystem model is represented as two cloud components or engines [1]: 1) f – monitoring and management; 2) g – executive infrastructural engines, which are interconnected by signals for monitoring, management and initiation of both components for implementing the services. An analytical form for describing iCTC-system and its structural equivalent are represented in Fig. 1.

\[
A = (f, g, \mu, \nu, X, R, Y, P),
\]

\[
\left\{ \begin{array}{l}
Y_1 = f(\{X, R, \mu\}, Y_{1-1}); \\
\{P_1 = g(\{X, R, \nu, Y_1\}).
\end{array} \right.
\]

\[
X = (v, p, s); Y = \{G(k), L, M, P\};
\]

\[
R = (G, P)_{R}; P = (G(k), L, M, P)_{P};
\]

\[
\mu = \{G(k), L, M, P\};
\]

\[
\nu = \{L_1, L_1, L_2, L_3\} = L;
\]

\[
G \{R, P\} = \{G(k), L, M, P\}.
\]

Figure 1. Analytical and automation form for describing iCTC-system

In the model there are the following elements \( A = (f, g, \mu, \nu, X, R, Y, P) \) correspondingly: control and execution units, monitoring and control signals, inputs of control tasks and executive resources, outputs for indicating the status of the algorithm of task execution and providing a service. Here, also there are signals of external traffic management \( X = (v, p, s) \) for regulating the movement of government person, police cars and special purpose vehicles,
Transport control signals \( \nu = \{L_{1}, L_{t}, L_{h}, L_{x}\} \) use a virtual traffic light working in the following modes: 1) intellectual one, functionally dependent on road conditions; 2) automatic one with fixed switching periods; 3) virtual manual mode based on digital monitoring of intersections on a screen of police computer its analog is air traffic control by using the monitor of flying control officer at the airport; 4) emergency stop \( L_{x} \in \nu \) of a vehicle on a digital request of police, which is visualized on the screen of the car gadget. The following objects are subject to cloud monitoring: \( \mu = \{G(k), L, M, \tilde{P}\} \) all mobile gadgets of cars with their coordinates, status of traffic lights tied to terrain map \( M \), as well as execution of ordering traffic routes.

Transfer the traffic light \( L \in \{\nu, P\} \) from real crossroads to cloud one completes the creation of a virtual infrastructure of the planet, forming a closed loop of monitoring and control system involving a single real component in the form of mobile gadget \( G(R, P) = \{G(k), L, M, \tilde{P}\} \) of road user (RU). Gadget realizes the interface function for communication with the cloud: R- Enter to the cloud – the order of service \( R = (G, \tilde{P})_{R} \) (delegation of ID-gadget and movement path to the cloud) and P-exit from the cloud – obtaining service \( P = [M, G(k), \tilde{P}, L] \) (map, gadget coordinates, the best route, traffic light).

User will receive a service for scrolling map window and traffic lights in real-time on the way \( \tilde{P} \) if he (she) delegates gadget to the cloud. If the way is ordered user receives additionally a quasi-optimal route of travel and priority traffic signals. Actually, in the view of the user a system is created by two components: the cloud and the gadget. At that novelty and originality of the proposed system is in providing cloud service – traffic lights on the screen of the road user gadget. Everything else (maps, routes) already exists and work. Implementation of the proposed iCTC-system will be through the creation of virtual traffic lights, which duplicate real ones in synchronous mode, and then the gradual eliminating all physical devices and signs of ground road infrastructure as drivers purchase new technological culture in an evolutionary way. Moreover, all the major cities already have virtually centralized computing (cloud) control traffic lights. Therefore, the transfer of traffic lights to the cloud will not be associated with substantial additional costs, but rather the opposite large operating costs for maintenance of traffic lights and signs of urban infrastructure in working condition are transformed to zero.

Mobile vehicle gadget \( G \) is the main control unit for iCloud Traffic Control, as well as it is a major consumer of traffic light signals \( L \) of car motion control displayed on the windshield, \( L = \{L_{1}, L_{t}, L_{h}, L_{x}\} = F(L, G, V, T, D, P) \), where \( V \) – special control signals; \( T \) – programmable cycle of autonomous control of traffic lights; \( D \) – accumulated intellectual statistics on traffic lights (avenue, district), including taking into account the time of the year and a day; \( \tilde{P} \) – incoming orders on traffic routes.

Creating virtual system of traffic light allows practically no financial, time, material and energy costs add new traffic lights in the virtual space by programming, as well as remove them from the cloud in the modernization of infrastructure. Visualization of traffic lights on the windshield (mobile monitor) and voice dubbing will improve the quality and safety of traffic, reduce emergency situation for the driver and urban infrastructure in general. Cloud traffic light as a digital signal unlike analog perception of the driver of the real traffic light is a more reliable tool for managing vehicle, including for subsequent introduction the autopilot in traffic that perceives only deterministic control signal.

Road users are identified in the cloud by means of the gadget or the iPhone, which are matched, when he (she) gets in the car. User status increases with the passage of traffic lights if the route to be ordered in advance. Other road users (pedestrians, motorcyclists and cyclists) also have the right to order the route, raising their status for the use of traffic lights. Pedestrians are able to get the service for ordering a combined route, including all kinds of ground and underground transport (bus, metro).

For a vehicle, a control system forms the functional for optimizing the quality of service, which depends on the following variables (time, length and route quality): \( Q = \min f(T, \tilde{P}, K) \). For the traffic light a control system forms the functional, minimizing the total downtime of vehicles during the day \( Z \) switching cycle of the traffic light:

\[
Q = \min \frac{1}{n} \sum_{i=1}^{n} \left[ \frac{1}{Z(P_{i}, V_{i}, L_{i}, J_{i})} \right]^{-1}.
\]

The numerator and the denominator show the functional dependence of downtime and cycle on the parameters in brackets.

Actually there are summed parts of traffic light cycles required for the passage of each vehicle through the crossroad. If the result is the evaluation of the quality, which is close to unity \( Q = 1 \), then the crossroad is functioning normally. Otherwise, it is necessary to modify the switching cycle or reconstruct the intersection.

The detailed structure of iCTC-system is shown in Fig. 2, where the basic blocks are car gadget and cloud, which is divided into two parts. The first one «\( f \)» contains infrastructure with the following components [1] map of the area, the coordinates of the gadget-car, traffic lights and road signs, as well as memory for storing ordered routes and statistics of transport movement. The second part of the cloud «\( f \)» includes memory, blocks of monitoring and management, as well as protection against unauthorized access.

Thus, the proposed innovative iCTC-system is characterized by the presence of only cloud interrelated components: infrastructure, monitoring and traffic control,
including traffic lights, which allows quasi-optimal managing each vehicle in real-time through the use of existing communication channels and mobile gadgets matched with the car computer, optimizing processes of traffic management by time, cost and quality for solving social, humanitarian, economic and environmental problems, substantially reducing the real traffic infrastructure and saving materials of road signs and traffic signals, as well as saving power needed to ensure their operability, finances for the installation of traffic lights and operating costs through creating traffic lights in a virtual infrastructure of the planet.

Theoretical basics of the project (intelligent and brain-like models, methods and processors for analyzing cyberspace related to discrete optimization of searching, recognition and decision-making) is represented in [1].

Experience in the development and implementation of software and cloud services for optimizing vehicle routes of Ukrainian corporations in order to minimize the financial and time costs and improve the quality of passenger service is represented in [2, 3].

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The developed distributed road management system in large and major cities is based on highly reliable computing equipment [2].

IV. PROBLEMS SOLVED BY DIGITAL IDENTIFICATION

Already today, there are many topics and practically oriented problems, which can be solved using radio-digital passports: 1) Identification of a product (object or subject) in a local or global coordinate system. 2) Saving the parameters, which are characterized by the basic properties of the object. 3) Accumulation and storing the history of the object life cycle. 4) Transfer information about an object or phenomenon to the management cloud on the authorized request. 5) Receive the confidential information, making it possible to modify the individual properties of the e-passport of the object. 6) Sanctioned interaction with e-passports of other objects in the field of radio-frequency visibility of the object. 7) Transfer information about all interactions of an object with other ones within the radio visibility.

Thus, the electronic digital identification of the object is stand-alone digital system-on-chip with transceiver, which is able to store information about an object, modify it by command of the control center, and store information about all interactions with the surrounding environment to transmit the interaction data to the management cloud. Other variants of ID communications are associated with: 1) mobile phone network; 2) satellite systems for receiving and transmitting information.

V. CASE-STUDY OF IMPLEMENTING ICTC-SYSTEM COMPONENTS

A software application for managing corporate transportation [1] is used for optimal planning of trips to deliver goods, leading to reduction in time and cost due to: 1) reduce the cost of fuel and lubricants; 2) the optimal distribution of orders between cars; 3) forecasting the supply of goods to reduce storage costs; 4) save staff time or reducing staff; 5) reducing the number of vehicles to execute...
the specified traffic; 6) monitoring and operational management of the delivery of goods vehicles in real time. Market feasibility of cloud service transport logistics lies in follows: wholesale companies, regional distributors of food and industrial goods (bakeries, dairies, meat packing, beer and soft factories, industries, road transport companies, retail chains, logistics operators, freight forwarding companies, vending companies, ambulance, collection service, courier services, online shopping, cleaning companies).

Telemetry module "SHERLOCK" [1] is designed for the creation of distributed monitoring and control system, including mobile. The module is an electronic device, based on three new technologies Mobile-to-Mobile, GPS and GPRS.

When rendering the icons display on the map the states of the objects and their movement routes for the selected time interval and duration of stay. The size and location of the map can be changed by using the mouse and control elements. There are control elements for quickly switching between the parts of the route and objects, as well as statistical information. If the user chose to display only one object there is a feature for calculating distance.

VI. SCIENTIFIC NOVELTY, MARKET FEASIBILITY AND SOCIAL IMPORTANCE

Scientific novelty of the project "Intelligence Cloud Traffic Control" (ICTC) lies in the transfer of traffic lights to virtual cyberspace. This completes the creation of a virtual traffic infrastructure to improve the quality of life for drivers, reduce travel time and fuel costs, save thousands tons of metal for manufacturing traffic lights, hundreds of thousands of kilowatts of electricity for maintaining operability, millions of dollars for installing traffic lights and operating costs, as well as faster installation and updating traffic lights in the virtual urban infrastructure during a few minutes; in the aggregate all of which makes it possible to automate quasi-optimal traffic and road management in real time and to solve social, humanitarian, economic and environmental problems.

Practical value of research is defined by obtaining new services to road users, traffic police, special services and organizations: 1. Special control service for on-line switching traffic lights to provide free traffic on the route for special machines (children, important government officials, ambulance, fire department, military convoys, and dangerous goods). 2. We propose a cloud service to manage virtual traffic lights depending on the traffic situation in real crossroads. Traffic light signals are displayed on the screen of a mobile gadget. 3. A model for planning the quasi-optimal route to the destination is developed. It takes into account the real traffic, the time of a day and year, the quality of the pavement, left turns, weather and repairs, which can significantly reduce the time and cost of travel. 4. Data structures and intelligent device are implemented to the personal vehicle cloud cell for saving the history of vehicle movement with a concrete driver that allows predicting the movement of the vehicle along the desired route without further order. 5. A model for monitoring mobile digital passports of vehicles is proposed; it allows eliminating the license plates from the police system, which creates significant benefits associated with self-latching traffic violations and saving metal for the production of license plates. Digital Passport provides automatic creation of electronic reports about the road incidents, which also means a significant reduction in traffic police thanks to digital monitoring traffic violations and exclusion of corruption by traffic police thanks to the impossibility erase inappropriate management in the cloud. Complete elimination of criminal acts related to car theft is provided by built-in car digital passport that increases observability of the car, if it is not physically destroyed. The number of accidents is significantly reduced due to the global monitoring all offenders and the certainty of punishment. The planet is becoming greener due to reducing carbon emissions, reducing the idle time at crossroads and selecting the optimal route of the vehicle. High market feasibility of cloud service for traffic monitoring and management ensures high profits to investment companies and individuals from the exploitation of cyber - physical system from hundreds of millions to tens of billions of dollars depending on the scope of services: city, country, and planet. 11) Near future. The next steps are creating cloud virtual digital models of entities (objects) of the real world and all possible relations (natural, social, technical, technological) between them to create services for precise digital modeling, monitoring and management of processes and phenomena in the world. 12) The creation of digital infrastructure for monitoring and traffic control based on the usage of direct radio signals of high precision is the future of transport without drivers, crashes, collisions on land, in water and air. For this, it is necessary to provide technologically two- and three-dimensional standards of radio-digital measurements and identification of planetary space with the ability to monitor and control each of its cells with the size up to 10cm.

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