Cyber Physical System – Smart Cloud Traffic Control

Vladimir Hahanov

Agenda

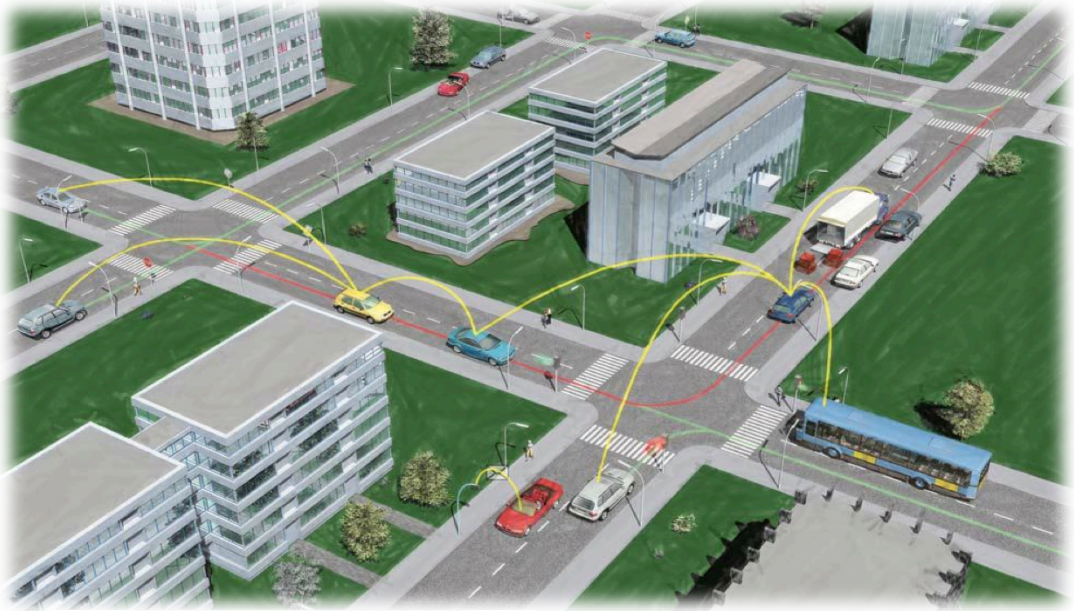
- iCloud Traffic Control and Monitoring
- Worldwide IT-trends
- Formal cloud cyber-system control model
- Mobile vehicle gadget + RFID
- Detailed structure of iCTC-system
- Practical examples of iCTC-system
- Invitation to collaboration

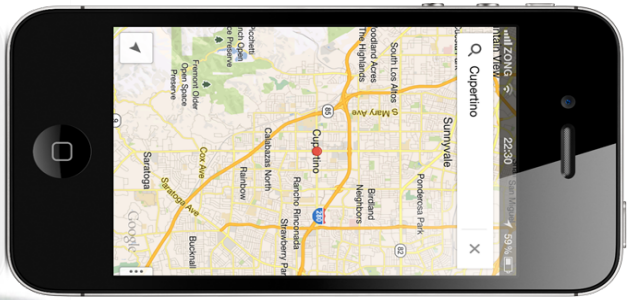
The grounds of research

- The capitalization of the business project in Ukraine after three years of the exploitation of IRI cloud - $ 100 million.
- The project is focused on providing services for 7 million drivers in Ukraine and 8000 companies. Analogues of such systems exist in every country and in lots of cities. There are separate components for creating the infrastructure: electronic maps, satellite location and navigation systems, specialized databases in clouds, tools for monitoring, collecting and protecting information, centrally controlled traffic lights, cellular communications.
- 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) are represented in (Hahanov et al. 2013, Bondarenko et al. 2012).
- Experience in the development and implementation of embedded and RFID digital systems for road monitoring is described in (Lu Antao et al. 2011, Pandit et al. 2009, Jiang et al. 2010, Chen and Wei, 2011, Dudnikov and Boenko, 2007).
- 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 (Manikonda et al. 2011, Samad, 2001, Schutte, 2001, Zingirian and Valenti, 2012, Branisso et al. 2012).

Rubbish at the past >> green at the future

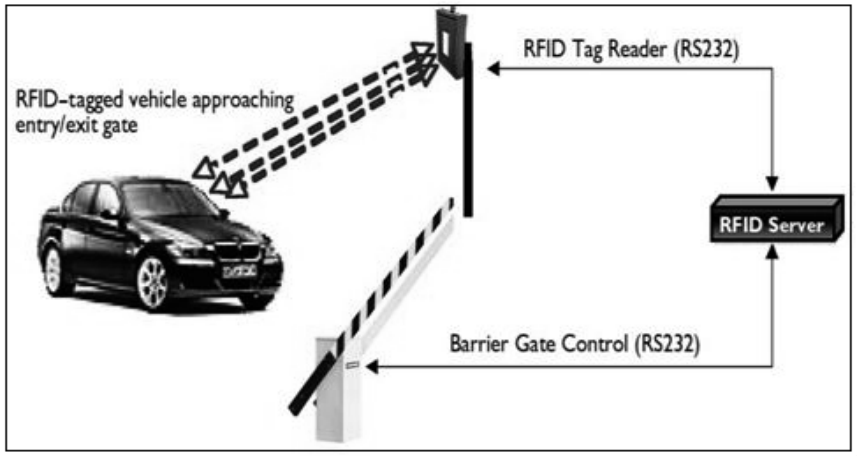
Innovation: the practical goal is to remove street lights and “Rubbish” of road street lights and signs to the cloud.

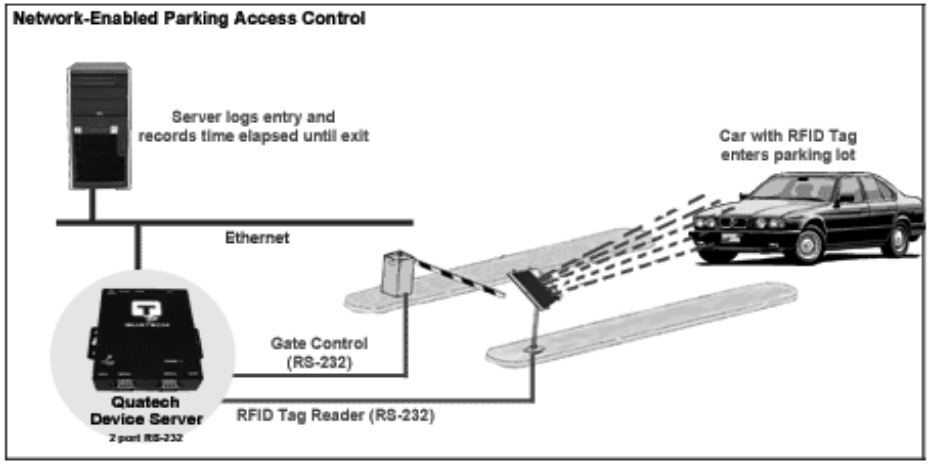


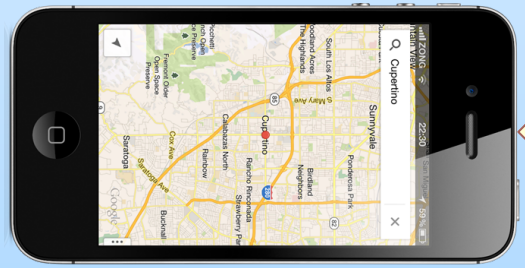


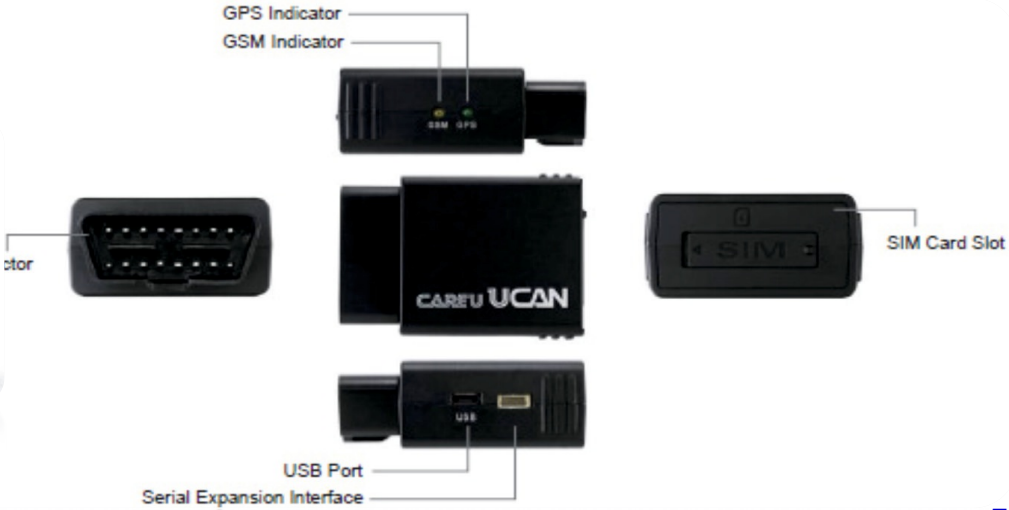
Technical support Gadget+RFID

Telemetry module“SHERLOCK”









Interaction of physical and virtual objects

- The technological environment, combining real and virtual components of the cybersystem for traffic optimizing on a global scale, is the Internet.
- The phenomenon of its formation and development is characterized by integration of the interaction of physical and virtual objects in space and time by layering and subsequent deep mutual penetration of historically evolving Internet culture: 1) Layer for combining desktop computers into a single web to improve the computational and informational capacity of the world. 2) Layer for integrating mobile devices, enabling communication between users in social networks and access to the Internet, which is invariant to the location of the person. 3) Layer for combining all smart objects, processes and phenomena (Smart Everything) for their recognition, monitoring and control – Internet of Things. 4) A layer of integration services for all moving objects on the planet in order to monitor living things, positioning, navigation and unmanned control of artificial appliances and vehicles. All moving mechanisms autonomously interact with each other through the Internet, which services enable their precise positioning and quasi-optimal navigation without human intervention. Thus, the four layers of the Internet, created over the past 40 years, are a closed cyber-physical system of the world, which combines the physical and virtual worlds to improve the quality of human life. 5) Layer for integrating information accumulated by mankind in Big Data structures and filled with intelligence and history, and extra-high-power parallel computer services for their analysis have finished creating mankind cyber-brain, which will manage the cyber-physical space of the planet and its improvement.

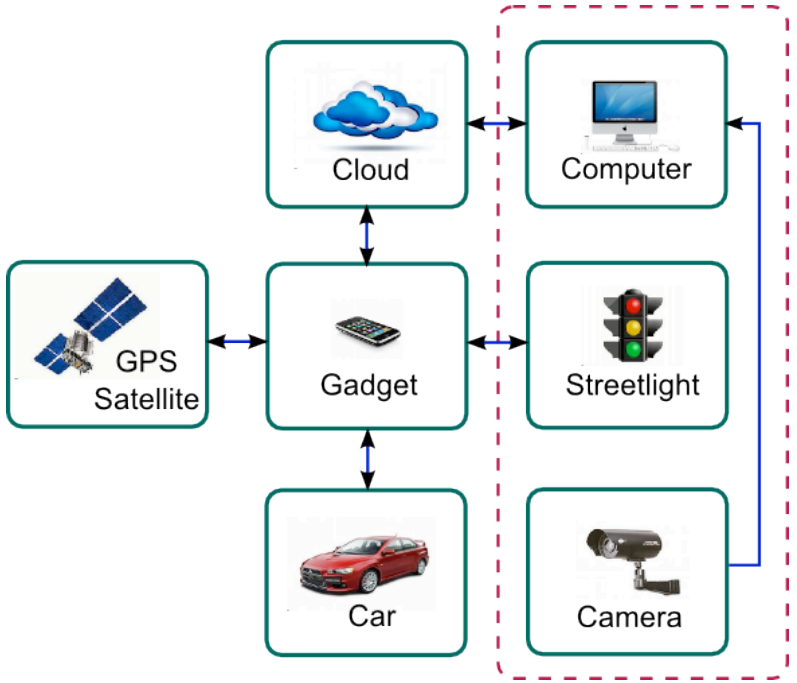
Intelligent virtual traffic light

- A key innovative component of the infrastructure TCS is virtual and/or real smart traffic light (Smart-Streetlight, SS) that is a stationary microcontroller (digital system-on-chip) with the transceiver directly related to cloud of traffic management.
- It generates the wireless network to communicate with the vehicle computers (Car-Computer, CC) at distances up to 100 meters via Wi-Fi. Traffic light state is available for monitoring in a cloud Internet service and displayed on the screens of all vehicles, which according to the routes intersect the crossroad and are in the area of its competence. Traffic lights can be controlled remotely by special services or requests from vehicles crossing the intersection. Smart traffic light scans and processes all requests from vehicles coming through the TCS-cloud in real time.
- It generates the appropriate control signals, which functionally dependent on the traffic situation on the sides of the crossroad. All the traffic lights of the city are united to a technological network layer of a cloud service that serves the infrastructure of streets and roads in the intellectual and/or off-line mode with manual and/or remote control.
- A method for managing traffic light uses taking a Boolean derivative along the lines of movement. The last ones have linear diagrams of accumulating $\mathrm{N}^{\bullet} = k^{*}\mathrm{t} + b$

and passing $\mathrm{N}^{\circ} = -k^{*}\mathrm{t} + b$ through the crossroad – the bottleneck of road infrastructure – with the scan period of vehicles equal to 1 second. Here k is bandwidth or the number of vehicles passing through the crossroad per second; t is real time; b is the initial number of vehicles at the crossroad.

Traffic light

- Traffic light as originally primitive tool for regulating traffic at a crossroad is gradually transformed into a specialized computer system for monitoring and control, including the following components: LED-monitor, video camera, Wi-Fi transceiver for communication with car computers and the Internet, software for intelligent traffic management.
- The system of traffic light agents or sensors for monitoring transport includes the following: relatively expensive video detectors and inductive loops embedded in the pavement, sound indicators of noise and microwave radars are used much less.
- Eliminating all traffic agents is possible by digital identification of vehicles, based on the precise positioning of car gadget or computer.
- Today such agent may be a mobile phone of the car driver, which delegates its location to the cloud of traffic management by using global positioning system. In response, the mobile phone receives all services for traffic management: the signals of cloud virtual traffic light, synchronized with real traffic lights, the best routes of movement, "green wave" with the non-intensive traffic, saving time and fuel.

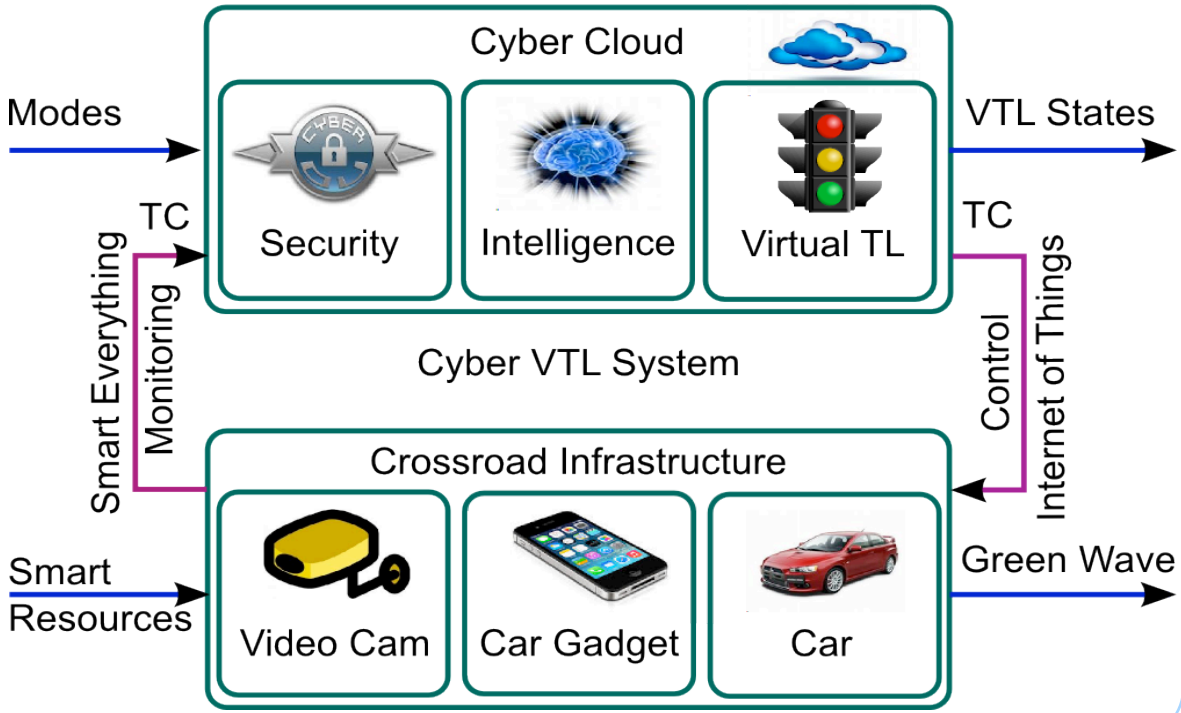


Crossroad

- The analysis shows that by 2020 most of the road accidents will occur at crossroads.
- The most frequent causes of accidents are inadequate observations (44.1%), false assumptions about the maneuvers of other vehicles (8.4%), turning with insufficient field of view (7.8%), illegal maneuvers (6.8%), internal distraction of attention (5.7%), incorrect estimation of the interval and velocity of other vehicles (5.5%).
- Further improvement of the street traffic light in the infrastructure of cities is due to its conversion into cyber physical traffic management system as it is shown in Figure 2.

The cyber VTL-system is designed to provide a «green wave» when driving a car at a crossroad and it contains two main components: the virtual one – Cyber Cloud and physical one – Crossroad Infrastructure.

The first component is designed to generate the control actions, which form the traffic signals, depending on the history and real traffic at the crossroad. The second one monitors road conditions by using video cameras, smart sensors and automotive gadgets.



The main point of the research

- The goal is to improve the quality and safety of traffic by creating a cyber physical system – intelligent traffic control system (TCS), which provides monitoring and control in real-time [1,3], based on the use of vehicle mobile gadgets and cloud (virtual) traffic lights that makes it possible to improve the quality of life of the driver, to minimize the time and cost in the organization of traffic, and generate innovative solutions for social, human, economic and environmental problems.
- The main point of the research is the creation of a cyber physical system in the form of Smart Cloud Traffic Control in real time on the basis of developing a cloud traffic infrastructure (see Fig. 2), integrated with the virtual street traffic lights and road signs, mobile tools for vehicle identification in order to improve the quality and safety of vehicle movement, minimizing the time and cost when performing the specified routes.
- Innovative proposal: Smart Cloud Traffic Control has the purpose of the introducing the time parameter in the digital map of the planet, as well as the gradual transfer of traffic signs and traffic lights in the clouds, which radically improves of traffic infrastructure and creates the potential for savings thousands of tons of metal for the manufacture of traffic lights and unnecessary car numbers, million kilowatt hours of electricity, millions of dollars for the installation of traffic lights, road signs and operating costs as well as reducing the time to install and update the traffic lights in the virtual infrastructure of cities from a few days to a few minutes.

Formal model of cyber system

- Formal cybersystem model is represented as two cloud components or engines:
- 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.
- Analytical form for describing TCS-system and its structural equivalent are represented in Fig. 3.

$$A = (f, g, \mu, \upsilon, X, R, Y, P),$$

$$\begin{cases} Y_t = f[(X, R, \mu)_t, Y_{t-1}]; \\ P_t = g[(X, R, \upsilon, Y)_t]. \end{cases}$$

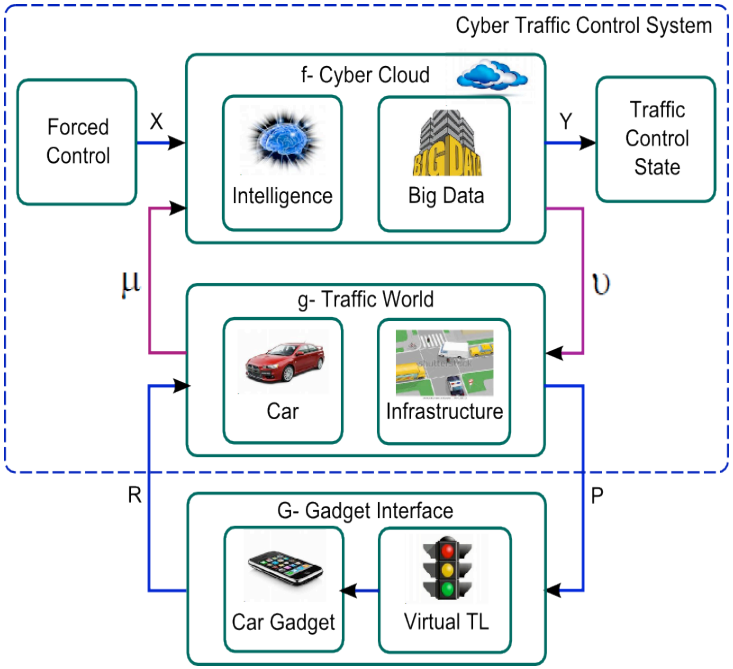
$$X = (v, p, s); \; Y = [G(k), L, M, \vec{P}];$$

$$R = (G, \vec{P})_R; \; P = (G(k), L, M, \vec{P})_P;$$

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

$$\upsilon = \{L_i, L_t, L_h, L_x\} = L;$$

$$G\{R, P\} = \{G(k), L, M, \vec{P}\}.$$



Mobile vehicle gadget

- Mobile vehicle gadget G is the main control unit for TCS, as well as it is a major consumer of traffic light signals L of car motion control displayed on the windshield,

$$L = \{L_i, L_t, L_h, L_x\} = F(L, G, V, T, D, \vec{P})$$

- 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 year and day;. $\vec{P}$ – incoming orders on traffic routes.
- For vehicle a control system forms the functional for optimizing the quality of service, which depends on the following variables (time, length and route quality):

$$Q = \min f(T, \vec{P}, K)$$

- For traffic light a control system forms the functional, minimizing the total downtime of vehicles during the day (Z – switching cycle of traffic light):

$$Q = \min \frac{1}{n} \sum_{i=1}^{n} \left[\frac{T_i(\vec{P}_i, V_i, L_i, J_i)}{Z(\vec{P}_i, V_i, J_i)} \right]^{-1}$$

Quality of service

- For urban infrastructure a control system forms a functional for optimizing the service quality of vehicles during the time interval (hour, day), depending on the total travel time of vehicles on specified routes on recommended speed, downtime of cars at traffic lights and in traffic jams, divided on the ideal passed routes on the permitted speed without delays at traffic lights and traffic jams:

$$Q = \min \frac{1}{n} \sum_{i=1}^{n} \left[\frac{T_i(\vec{P}_i, V_i, L_i, J_i)}{T_i(\vec{P}_i, V_i)} \right]^{-1}$$

- For avenue of a city a control system forms a functional, optimizing the total travel time of vehicles from the beginning to end of the street for a period of time (hour, day):

$$Q = \min \frac{1}{n} \sum_{i=1}^{n} \left[\frac{T_i(V_i, L_i, J_i)}{T_i(V_i)} \right]^{-1}$$

iCloud Traffic Control allows: 1.

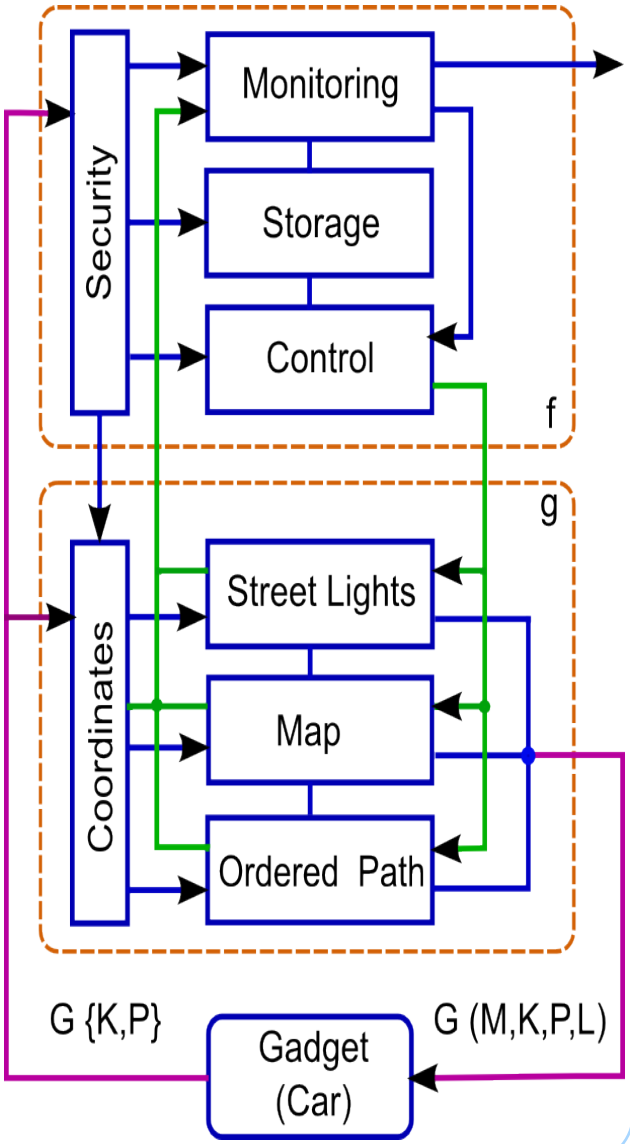
- **Problems** to be addressed for the realization of iCloud Traffic Control (iCTC):
- 1) Development of technology for digital radio-frequency positioning vehicle (gadget) with an accuracy of 2 meters.
- 2) Creation of new system of mnemonic and accompanying audio signals of the monitor, which constitutes cloud traffic rules.
- 3) Development of operational and control automata, which combine all components of iCloud Traffic Control into a common cloud-based system, where car gadget G(k) is input-output and represents a single communication interface with the cloud; it can be positioned in real time with the exact coordinates on the map M of the infrastructure with traffic lights L to control the movements of road user.
- 4) Designing a scalable system iCTC for traffic light, avenue, district, city, country, and planet.
- 5) Development of client services (software applications) for vehicle, pedestrian, cyclist, motorcyclist aimed to optimal control transportation routes, including the video and audio signals linked to the infrastructure and received from iCTC in real time.
- 6) Designing cloud (server) services for solving optimization problems of routing, managing traffic lights, modification of cloud and real infrastructure, as well as operational management of cloud traffic lights, based on traffic monitoring.

iCloud Traffic Control allows: 2.

- 7) Development of qubit data structures and "quantum" matrix processors based on Big Data technologies for the simultaneous and parallel servicing iCTC-cloud users in real time, the number of which in the limit can be equal to the number of inhabitants of the planet.
- 8) Creation of intelligent models, methods for synthesizing and analyzing the virtual infrastructure for evaluating traffic quality, modeling traffic, generating the optimal route taking into account technical, climatic, social factors, the quality of roads, the amount of traffic lights, left turns in order to create new and reconstruction of existing road infrastructure.
- 9) Provision of cloud services for trucking companies to improve the quality of passenger service, cargo, optimizing time and material costs.
- 10) Provision of cloud services for the driver in order to improve the quality of travel on a given route and optimize the time and material costs.
- 11) Collection of statistical information (intellectualization of global, corporate and personal infrastructure) by accumulating the history of traffic, changing its parameters in time and space for generating quasi-optimal routes of future trips.
- 12) Creation of information security and authorized access to personal and corporate data in the cloud. Each user sees only your car in the cloud and anonymous traffic flows. All transport identifiers can be accessed by only special government services by court order or decree of the investigating authorities.

Detailed structure of iCTC-system

- **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 «g» contains infrastructure with the following components: 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.**
- **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 .**



The benefits of cloud services of iCTC-system

- **For the planet** the benefits include environmental conservation by reducing its pollution, increasing longevity and quality of life, saving fuel and energy resources by reducing the travel time due to the choice of the optimal route, reducing the amount and complexity of traffic jams due to the introduction of intelligent traffic signals into the infrastructure.
- **For government agencies** (the police, traffic police) they include the exact vehicle identification, monitoring the positioning of vehicles in time and space, including theft, conflicts, unauthorized routes; significant reduction of accidents due to calculation of maneuver safety, reducing the impact of road traffic accidents, increasing safety and comfort of road users.
- **For transport companies** – monitoring locations and movement of vehicles, quasi-optimal transportation of passengers and cargo for minimizing the material and/or time costs.
- **For the driver** – providing services associated with generating of quasi-optimal routs and timetable under the negative factors of the existing infrastructure in order to minimize the financial and time costs in real time; reduction of accidents by monitoring sections of the road closed for visual viewing and determining safety level of maneuvers.
- **For the passenger** – providing services to monitor the locations and movement of passenger vehicles on bus stops or transportation terminals through the use of stationary computer display or mobile gadgets to communicate with the corresponding cloud services; visualization on the car screen of critical points of the route for a vehicle in real time through the use of surveillance cameras.

Technical and functional features of iCTC

- **Monitoring of the actual speed for all vehicles** and informing the driver about areas of the speed limits; digital monitoring of passage on prohibiting signs and traffic lights.
- **Fuel economy, reducing of pollution, and reducing of travel time** due to selecting the best route proposed by a cloud.
- **Prevention of traffic jams** due to pre-planning of vehicle movement, taking into account the plans of the other traffic participants; adjustment of vehicle route in real-time when changing traffic conditions.
- **Intelligent management of the switching cycle of traffic lights** depending on road conditions at crossroads.
- **Generation of reports and recommendations to improve the road infrastructure,** placement of signs, traffic lights, and centralized programming the switching cycles.
- **Prevention of vehicle theft** and unauthorized leaving the accident scene through the monitoring the location of each vehicle. Cloud digital registration for insurance companies of all the necessary details and dynamics of the accidents, which not injury-related, without the participation of the traffic police.
- Informing of the special services through the panic button about the incidents, occurred on the road or in the car.
- Alert of the driver about potential hazards on the route based on information obtained from the clouds during the motion.

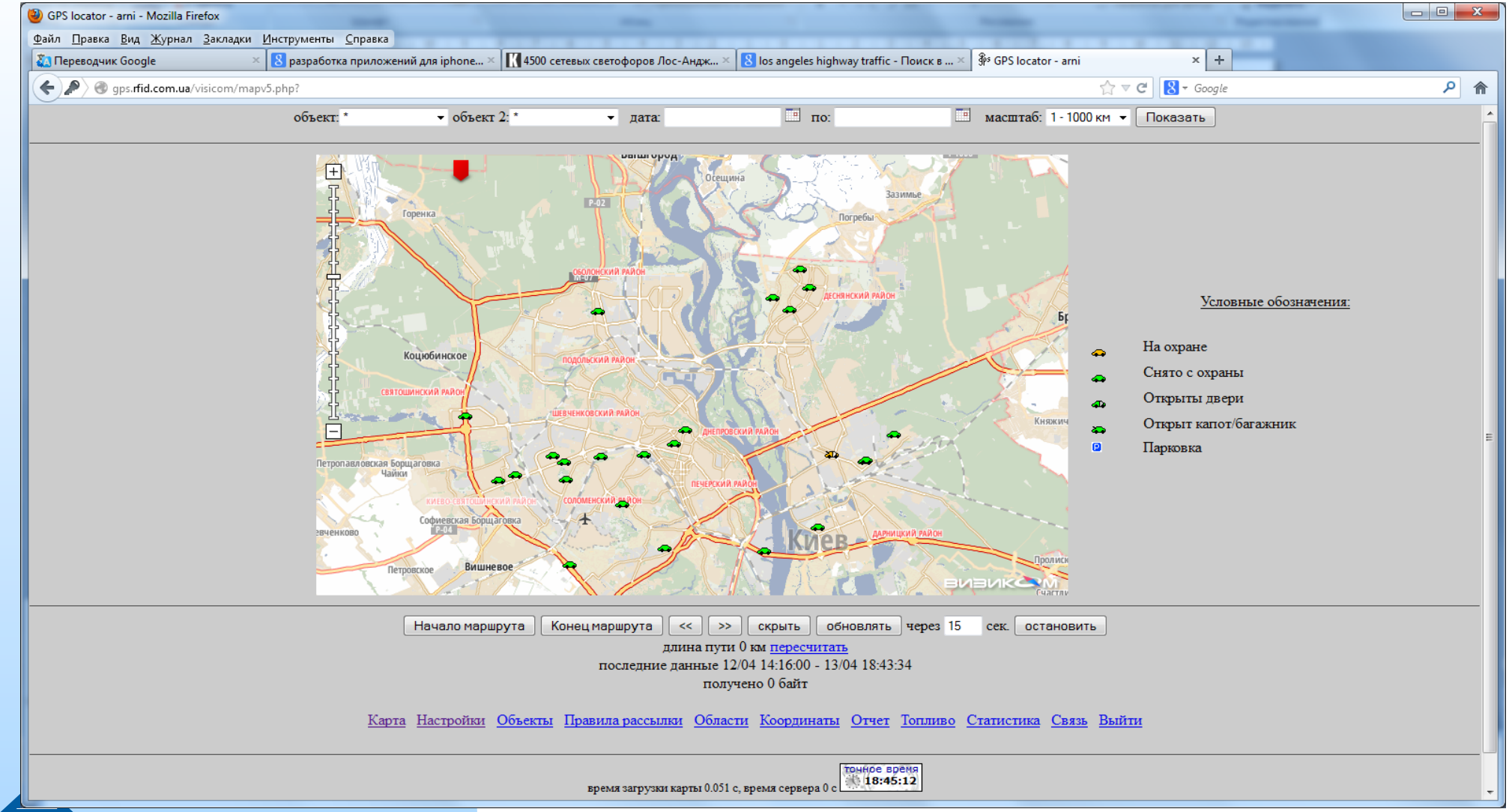
Practical examples of implementing the components of iCTC-system

- Software application for managing corporate transportations 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.
- Telemetry module "SHERLOCK" is designed for creating distributed monitoring and control systems, including mobile.
- The module is an electronic device, based on three new technologies Mobile-to-Mobile, GPS and GPRS.
- The problems solved by the module are:
  - 1) Automatic vehicle location (AVL); 2) Vehicle fleet management, logistics;
  - 3) Automation of taxi; 4) Monitoring the route and timetable of vehicle;
  - 5) Monitoring the operation modes of vehicles.

http://gps.rfid.com.ua.

Example of prototype

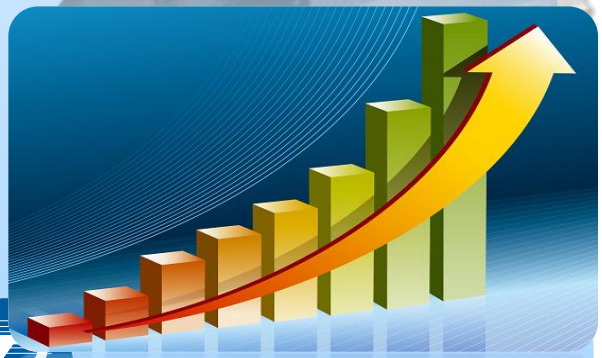
taxi station, kiev http://gps.rfid.com.ua



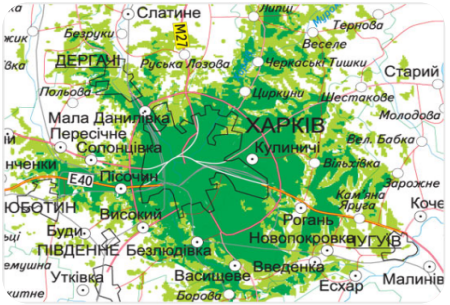
Scalable architecture of iCTC

every change which follows to market success

Street



City



Country

Target group: 7 mln drivers & 8000 companies (in 1 country)

PROTOTYPE REALIZATION:

10 month, $10 mln for Startup

MONEY FEEDBACK: after 12 month in use

PROFIT: $1 bln / year for service sales

Our team

11 universities:
KNURE, KNAU, DAAT, KNAU, NU «Lviv'ska politechnika», DonIZT, DonNTU, TUT, Yerevan Tech University, Montpelier LIRMM France, Jazan University (KSA)

20 leading scientists: professors , Doctors of Science, PhDs, students, engineers

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Видано відповідно до Закону України "Про охорону прав на винаходи і корисні моделі".

Зареєстровано в Державному реєстрі патентів України на винаходи 10.08.2012.

Перший заступник Голови Державної служби інтелектуальної власності України О.В. Янов

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завідувач кафедри

Литвинова Євгенія Іванівна
професор кафедри

Зіарманд Артур Нісарович
асистент кафедри
Кафедра автоматизації проектування обчислювальної техніки
Харківського національного університету радіоелектроніки

ЗА 3 МІСЦЕ У НОМІНАЦІЇ

Кращий проект в області геоінформаційних систем та інформаційного забезпечення транспорту

ПРОЕКТ

Створення системи «Розумні дороги» для організації інфраструктури дорожнього руху (Smart Roads Infrastructure)

Голова організаційного комітету конкурсу інноваційних проектів «IT-KHARKIV» А.В. Моченков

it-kharkiv.com.ua
28 листопада 2013 р.

ACHIEVEMENTS FOR TODAY

2 patents,
9 publications in famous sources,
4 international conference reports,
2 Diploma for the best projects,
Gold medal for 1st place in Regional IT-competition

Scientific novelty, market feasibility and social importance

- **Scientific novelty of the project «Traffic Cyber Physical Systems – Smart Cloud Traffic Control» is characterized by the introduction of the time parameter into a digital map of the planet and the transfer of traffic lights to a virtual cyberspace; these completes the creation of a virtual traffic infrastructure to improve quality of life for drivers, reducing travel time and fuel costs, saving 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 or tuples (children, important government officials, ambulance, fire department, military convoys, dangerous goods).**
2. **Optimal on-line control service for virtual traffic lights on the roads and crossroads with accurate digital monitoring traffic through the use of car gadgets, enabling to minimize the movement time of all road users.**

Practical value of research

3. Service for planning the best route to achieve one or more destinations by a car in time and space, that allows reducing time and cost for a given quality of movement comfort (time of day and year, road surfacing, left turns, weather, traffic jams, repairs).
4. Intellectual history service of car movement, based on car virtual model in cyberspace in the form of an individual cell of the cloud, which is invariant with respect to vehicle drivers. It allows tracking any vehicle movement in the past, and to predict the desired routes and future travels without the driver.
5. Service for intelligent managing traffic light controller, when switch signals are generated depending on the availability (quantity) of vehicles, which send the requests from car gadgets.
6. Cloud on-line monitoring service of mobile digital passports of vehicles that eliminates the license plates from the accounting system and has the following benefits: 1) In non-critical situations exclusion of the direct participation of the traffic police in commit traffic violations (speeding, travel to prohibit traffic lights, improper maneuvering, light collision). 2) Saving thousands of tones of metal to manufacture license plates and simplify registration of cars when buying from a few days to a few minutes. 3) Automated completing written reports about an accident without the traffic police by means of digital monitoring digital map of the incident that has been copied from the cloud. 4) Considerably reducing the staff of the traffic police. 5) Completely eliminate corruption in relation between the driver and traffic police due to inability to erase information about the violation in the cloud.

Invitations!

We will be happy to collaborate with companies, universities and persons for creating Green Planet and a little bit more happy life of humanity.

prof. Vladimir Hahanov

IEEE Senior Member, IEEE Computer Society Golden Core Member

Dean of Computer Engineering Faculty of Kharkov National University of Radioelectronics, Lenin ave.14, Kharkov, 61166, Ukraine

mailto: hahanov@kture.kharkov.ua

office tel: (+380)-57-7021326

office fax: (+380)-57-7021326

cell: (+380)-50-2782198

skype: hahanov