Intellection Traffic Control on Cloud

Hahanov V.I., Chumachenko S.V., Litvinova E.I., Dahiri Farid, Dementiev Sergey

Kharkov National University of Radioelectronics, Ukraine, 61166, Kharkov, Lenin Ave, 14, room 321

hahanov@kture.kharkov.ua

Abstract. *A cloud on-line service "Green Wave Traffic" called the Intellectual Road Infrastructure (IRI) is proposed to monitor and control traffic in real-time mode through the use of traffic controllers, RFID cars, global satellite navigation and positioning (GPS, GPRS) in order to improve the quality and safety of vehicle movement, as well as for minimization 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 and environmental problems associated with creation and use of a cloud for monitoring and management is developed. All of these technologies and tools are integrated into the automaton model of real-time interaction between monitoring and management clouds, vehicles and road infrastructure. Each car has a virtual model in a cyberspace - an individual cell in the cloud, which is invariant with respect to drivers of vehicles.*

1 Introduction

Where does it go real cyber world? Corporate networks, personal computers, as well as individual services (software), go to the "clouds" of a cyberspace, which have an obvious tendency to partition the Internet for specialized services, Fig.1.

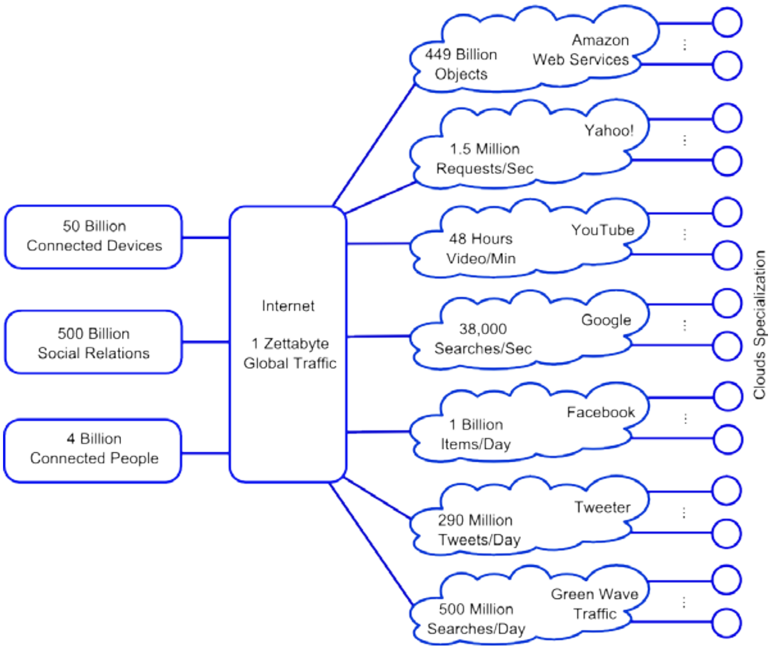

Fig. 1. Virtualization of the real world

If today 4 billion users are connected in the Internet (1 zettabytes = $10^{21} = 2^{70}$bytes) by means of 50 billion gadgets, in five years each active user will have at least 10 devices for connecting in cyberspace. Use of personal computers without replicating data to all devices becomes impossible. But even simple copying requires more non-productive time for servicing systems and projects, which can reach 50% if several devices or servers with identical functions are available.

Unprofessional (bad) service of such equipment creates problems reliable data retention, as well as unauthorized access. Also, there is a problem of remote access to the physical devices when migrating users in the space, and obtaining the necessary services and information from gadgets left at home or in the office is difficult. Economic factor of effective use of purchased applications installed in gadgets and personal computers, force the user to give up their purchase in favor of almost rent free services in the clouds. All of the above is an important argument and undeniable evidence of imminent transition or the outcome of all mankind to cyberspace of virtual networks and computers, located in reliable service clouds. Advantages of the virtual world lie in the fact that the micro-cells and macro-networks in the clouds are invariant with respect to numerous gadgets of each user or corporation.

Cloud components solve almost all of the above problems of reliability, safety, service and practically don't have disadvantages. So far as the corporations and users go to the clouds, protection of information and cyber components from unauthorized access, destructive penetrations and viruses is topical and market appealing problem. It is necessary to create a reliable, testable and protected from the penetrations cyberspace infrastructure (virtual PCs and corporate networks), similar to currently available solutions in the real cyber world.

Thus, each service being developed in the real world should be placed in the appropriate cloud cell that combines components similar in functionality and utility. The above applies directly to the road service, which has a digital representation in cyberspace for subsequent modeling all processes on the cloud to offer every driver quality conditions of movement, saving time and money.

The goal of the project is improving the quality and safety of traffic through creating intelligent road infrastructure, including clouds of traffic monitoring and quasi-optimal motion control in real-time by using RFID-passports of vehicles, which allow minimizing the time and costs of traffic management and creating innovative scientific and technological solutions of social, humanitarian, economic and environmental problems of the world.

Object of research is technologies for monitoring and management of vehicles integrated with cloud services, based on the use of the existing road infrastructure, RFID, radar and radio navigation.

Subject of research: traffic and road infrastructure of Ukraine and its regions, as well as advanced software and hardware RFID systems for monitoring and road management, based on the use of road controllers, global systems for positioning, navigation (GPS, GPRS), and cloud services in the Internet.

The essence of research is creation of intellectual road infrastructure (IRI) – cloud service "Green Wave" for monitoring infrastructure and management of road in real-time, based on creating cloud virtual road infrastructure (Fig. 2), integrated with road traffic controllers, RFID of vehicles in order to improve the quality and safety of vehicle movement, minimization of time and costs when realization of routes.

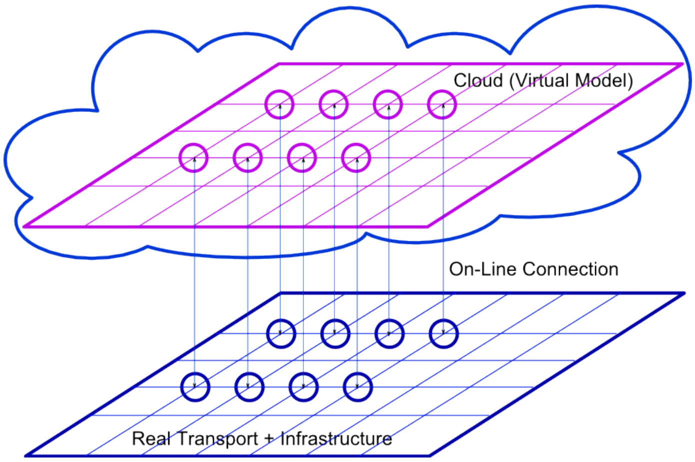

Fig. 2. Mapping of infrastructure and transport in the cloud

2 Innovative appeal and system models

The proposed intelligent system (infrastructure, transport, cloud) for monitoring and road management differs from existing ones by structural integration of three related interactive components:
1) existing mapping services with radiolocation and navigation tools;
2) a novel cloud service for monitoring and road management, based on road controllers;
3) advanced radio frequency identification tools for cars and access to cloud services for comfortable movement on the route, optimization of time and material costs.

Scientific novelty of the project is determined by the system integration of cloud for monitoring and management, RFID blocks of vehicles, monitoring and managing tools of the road infrastructure, which makes it possible to automate the optimal management of vehicles and traffic in real-time in order to solve social, humanitarian, economic and environmental problems.

Automaton model for monitoring and control with vehicles is shown in Fig. 3, where the cars send on-line their identifiers (personal data), the motion parameters and the current coordinates to the cloud, and in return receive in real-time services of optimal route (by time, cost, and quality) and motion mode to achieve final destination. Integrated analysis of road conditions based on processing operational data from vehicles and infrastructure monitors makes it possible to optimal manage road controllers for switching traffic lights on-line.

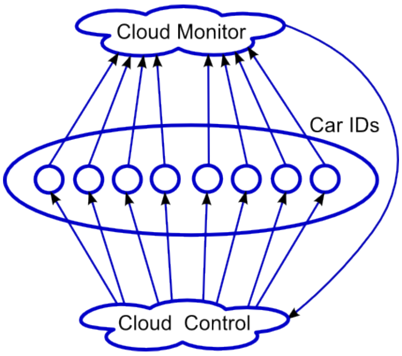

Fig. 3. Structure of vehicle and cloud interaction

The interaction of the real world (car and infrastructure) with a cloud forms two types of relationships defined by the automaton models (Fig. 4): 1) transport infrastructure with a cloud for monitoring and management; 2) a car with a cloud for optimization and providing efficiency of movement.

Here the following signals are represented: X_1, Y_1, X_2, Y_2, C, M – input conditions or operands are necessary to ensure the ordered services; the output warning signals, confirming the execution of service operations; input control signals, forming queries for executing services; output variables, which form and identify state of management system; the signals of intelligent driving or road infrastructure; warning signals about execution of operating service.

Automata models of road and car management system are represented in the form of variable interaction by the functions of transitions and outputs of the automaton of first kind:

$$CC = \{X, Y, C, M, f, g\},$$

$$\begin{cases} Y(t) = f[(X(t), M(t), Y(t-1)]; \\ C(t) = g[(X(t), M(t), Y(t-1)]. \end{cases}$$

Here, each of the two automata for interacting infrastructure and transport with the cloud has two input variables (services order and state of managed object) and two outputs signals for monitoring the automaton (cloud) state and management of cloud services.

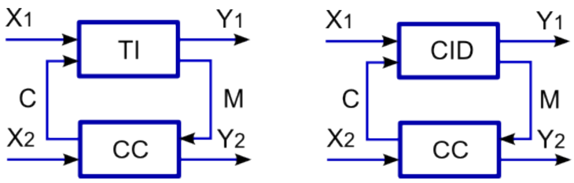

Fig. 4. Interaction of infrastructure, transport and cloud for monitoring and control

More detailed representation of the interaction between real, virtual components and the cloud system for transport monitoring and control is shown in Fig. 5 (buffer computers of road infrastructure, intellectual traffic lights, the Internet, smart dust, Car-ID, satellites of navigation and location, car, electronic map, protection tools of IRI, government services, and communication gadgets or interfaces for the Internet).

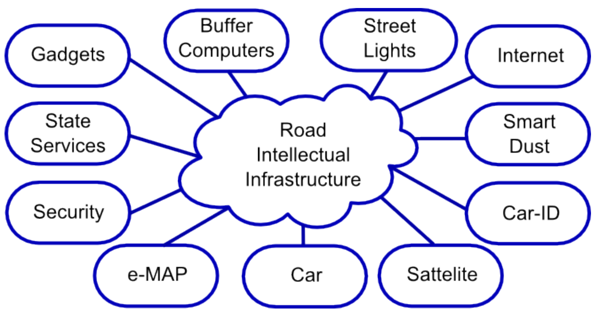

Fig. 5. Intelligent road infrastructure

3 The grounds of research

1) Market appeal. The capitalization of the business project in Ukraine after three years of the exploitation of IRI cloud - $ 100 million.
2) The project is focused on providing services for 7 million drivers in Ukraine and 8000 companies. Analogues of such systems do not exist in the world. 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. Availability of reliable cellular communication provides the necessary infrastructure for the project. Tools for navigating and monitoring vehicles are financially accessible to drivers. Software, hardware and network centralized management of traffic across the country, as well as cloud computing technologies are available. The technologies used in the infrastructure of roads and cyberspace are continuously improved, and their cost is reduced. Computer, mobile and internet literacy of people is enhanced. The state government understands the need for creating and use of intellectual infrastructure and cloud service for qualitative and safety road.
3) Project (draft) of the state program "Road Safety" with a planned budget of 5.43 billion hryvnas.
4) Theoretical basics of the project (intelligent and brain-like models, methods and engines for analyzing cyberspace related to discrete optimization of searching, recognition and decision-making) are represented in [1-6].
5) Experience in the development and implementation of embedded RFID and digital systems for road monitoring is described in [7-16, 29, 30].
6) 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 [17-27].
7) The developed distributed road management system in large and major cities is based on highly reliable Siemens computing equipment [37-41].

4 Objectives of research

1) Make an overview and analysis of existing technologies for monitoring and road management, based on interaction of embedded RFID vehicles, cloud services and road infrastructure.
2) Investigate the necessity, possibility and inevitability of creating intelligent cloud service for monitoring and road management that optimizes realization of transport routes by all road users.
3) Create an intelligent road controller for managing traffic, based on programmable logic controller S7-1200 from SIEMENS.
4) Develop metrics and engines to analyze data on the quality and effectiveness of virtual road infrastructure when realizing routes by vehicles.
5) Create intelligent models, methods for synthesis and analysis of virtual infrastructure for evaluating the quality of road traffic, traffic modeling, generation of the optimal route based on the technical, climatic and social factors, the quality of roads, the number of traffic signals, left turns in order to create new and reconstruction of existing road infrastructure.
6) Develop RFID block and equipping transport by tools for access to cloud services, as well as equipping the critical points of road infrastructure by sensors for stationary traffic monitoring.
7) Provide cloud services for transport corporations to improve the quality of passenger service and optimize time and cost within taxi, bus, freight and other transportation companies.
8) Provide cloud services for the driver in order to improve the quality of travel for a given route and optimize the time and cost.
9) Ensure the collection of traffic information of road infrastructure through the use of «smart dust» (car RFID, traffic lights, video cameras) to monitor traffic.
10) Collect the statistical information (intellectualize global, corporate and personal infrastructure) by accumulating traffic history, changing its parameters in time and space in order to route the quasi-optimal paths for future trips.
11) Create a virtual intelligent cloud infrastructure, which map and simulate movement of vehicles in space and time for service road in real time.
12) Creation of information security and authorized access to personal and corporate data in the cloud. Each user can only see his car in the cloud and anonymous traffic flows. All vehicle identifiers are available only for special transport public services.

5 The benefits of implementing cloud services

1) For government agencies (the police, traffic police) they include the exact vehicle identification, monitoring the positioning of vehicles in time and space, including theft; significant reduction of accidents, reducing the impact of road traffic accidents, increase of safety and comfort of road users;

2) For transport companies – monitoring locations and movement of vehicles, quasi-optimal transportation of passengers and cargo for minimizing the material and/or time costs;
3) 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;
4) 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.

6 Technical and functional features of a “cloud”

1) 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.
2) Fuel economy, reduce of pollution, and reduce of travel time due to selecting the best route proposed by a cloud.
3) 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.
4) Intelligent management of the switching cycle of traffic lights depending on road conditions at intersections.
5) Generation of reports and recommendations to improve the road infrastructure, placement of signs, traffic lights, and centralized programming the switching cycles.
6) Prevention of vehicle theft and unauthorized leaving the accident scene through the monitoring the location of each vehicle.
7) Informing of the special services through the panic button about the incidents, which occurred on the road or in the car.
8) Alert of the driver about potential hazards on the route based on information obtained from the clouds during the motion.
9) Automatic registration of crash dynamics by using internally identification module; registration of driving style for insurance companies.

7 Components of cloud road services

“Smart dust” is a set of interconnected autonomous functioning components, which form the microsystem with the transceiver and monitoring tools, designed for collecting information about the environment state. The problems, which are solved by “smart dust”:
1. Monitoring environmental conditions (temperature, pressure, humidity, precipitation).
2. Monitoring the movement of transport, frequency of movement, speed, size of moving objects.
3. The interaction between moving objects for positioning, identification of moving objects, transmitting information about objects, moving towards each other, to the management cloud.
4. Creating e-passport of moving object.
5. Preventing theft of vehicles.
6. Ensuring a high level protection of electronic IDs from unauthorized access.

The cost of RFID tag is usually less than 1% of the value of the object identification. Its functionality is to maintain one-to-one correspondence between the label and object during the life cycle of a product.

The real world is in need of advanced and precise monitoring and management of cloud. It has long recognized the need for an absolutely precise radio frequency digital identification of all produce and natural sites on the planet, including humans and animals. The next steps are creating cloud virtual digital models of entities (objects) of the real world for accurate modeling, monitoring and management by all possible relations (natural, social, technical, technological) between them.

8 Problems solved by RFID

1. Identify product (object or subject) in a local or global coordinate system.
2. Save the parameters, which are characterized the basic properties of the object.
3. Accumulate and store the history of the object life cycle.
4. Transfer this information 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. Interact 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 object ID is stand-alone digital system-on-chip with low power transceiver, up to 200 meters, which is able to store information about object, modify it by command of control center, and store information about all the interactions with the surrounding environment to transmit the interaction data to management cloud. Other ID modifications are associated with: 1) mobile phone network; 2) satellite systems for receiving and transmitting information.

The advantages of smart dust, based on low-power active RFID transmitter are:
1) Low cost of Microsystems, implemented in car electronics.
2) Sufficiently low cost of transponders for digital spectrum monitoring of road infrastructure nodes.
3) High accuracy and speed of reading digital information from moving vehicles, including speed, license plates, data about the driver. License plates are not needed, as well as many of the functions of traffic police.
4) Monitoring and prediction of traffic through the analysis of statistical information in the areas of roads and intersections.
5) The possibility of mutual communication by using Microsystems of vehicles moving towards each other, providing information about the traffic on the road sections of the route.
6) Detection of stolen vehicles through global or local monitoring vehicles.
7) Monitoring and alarm of accidents with indicating the exact coordinates of the place and time of the incident.
8) Lock the car engine in case of car theft through the access code of the owner.

9 The arguments against the introduction of “cloud” on a national scale

1. “Violation of the right to privacy, since in theory the cloud provides total monitoring of all vehicles”. Today there is a system of lawful interception of telecommunications, implemented in accordance with international requirements. But the interception of telephone calls of any subscriber is only used during the investigation and with the approval of the court. In particular it is possible to track the location of the subscriber. This fact to law-abiding citizens does not create any problem.
2. “The additional costs for the purchase of hardware and software for vehicle authentication and communication with the cloud”. The value of these tools is low and comparable to the average amount of fines for traffic violations. Economic benefits of a cloud associated with the fuel economy and reduce of travel time, offset costs for the year.

10 Corporate transportation management system

The system is already being used for optimal planning routs to deliver goods to reduce time and cost due to:
1) reduce the cost of fuel;
2) the optimal distribution of orders between cars;
3) forecasting the supply of goods to reduce the storage costs;
4) saving staff time or reducing staff;
5) reduce the number of vehicles for a given volume of traffic;
6) monitoring and operational management of the vehicles when delivering goods in real time.

The market appeal of cloud service of transport logistics is determined by the following: wholesalers, regional distributors of food and industrial goods (bakeries, dairies, meat processing plants, brewing plants, industries, transport companies, retailers, logistics service providers, freight forwarding companies, vending companies, ambulance, cash services, courier services, online shopping, cleaning companies) – more than 7,500 companies in Ukraine only.

Logistics technology is in follows. Transportation of goods is a complex, multi-criteria problem that includes a large number of parameters determining the effectiveness of performance of the contract with the customer, and thus profits. Transportation problem is NP-complete, where the number of cases is in the exponential function of the number of input values.

The exact solution can be obtained by complete enumeration of all possible variants. For real business problems quasi-optimal methods are used, which do not provide the exact solution, and hence the maximum possible cost savings. It is proposed the optimal method for solving the transport problem based on the original algorithm that significantly reduces the time. It becomes acceptable for the analysis of most practical situations on maps of the region [28].

Business models are:
1) the sale of licenses to use the software with post-paid service maintenance;
2) the sale of services in accordance with the subscription fee for using the road cloud.

11 Organization of the communications “cloud – car” and “cloud – infrastructure”

The most important aspect of technological (technical) IRI implementation is organization of communications between four system components (Fig. 6), integrated with the cloud: Cloud Servers for creating a cloud of long-term storage of distributed data and services; Buffer Computers for collecting data from infrastructure monitors and delivering management services to road controllers; C-RFID – computer blocks for radio frequency identifying vehicles; I-CMC – infrastructure controllers for traffic monitoring and control based on radio frequency identification of vehicles.

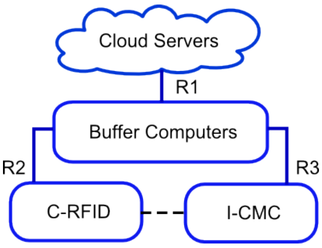

Fig. 6. The structure of communications between IRI components

The structure of communication integration of four IRI components is represented by the transactions: (R1*R2) = (SC,BC,C-RFID) is delivery of cloud services to the customers; (R1*R3) = (SC,BC,I-CMC) is delivery of control signals to the road controllers. The route of the first type uses the traditional technologies GPRS, HSPA, Wi-Fi, WiMAX based on Internet. For the transaction of second type additional scientific and technical research is needed when creating a scalable prototype, because the transaction are important and high requirements are imposed to reliability, security and protectability.

It is assumed that the block C-RFID will store an individual vehicle code (CID), the electronic code of residence registration (NID), and the code of the driver (DID), who uses the vehicle at the current time. Reading the triad of codes (CND-ID) is performed by radio devices, which will be located on all the traffic lights, bridges, tunnels, level crossings and other points of the road network, significant from the standpoint of traffic management, including the critical control points.

The structure of the C-RFID unit is shown in Fig. 7, where the modules (CND-ID, CT, SP, ALB, M, D, CU) mean: universal car code, transceiver, protection module, arithmetic and logic unit, memory module, display and control module.

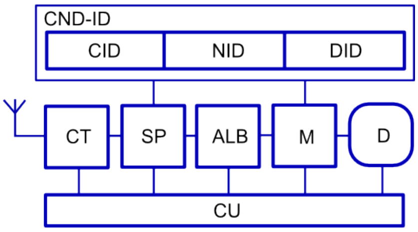

Fig. 7. Structure of C-RFID unit

World experience of RFID application in transportation allows making optimistic forecast concerning the introduction of such technologies in Ukraine. In May 2012 the Ministry of Interior of Russia successfully tested RFID-tags of license plates in the framework of project “Smart City”. In this case, the RFID chip was integrated into the license plates, produced by JSC “Vanguard”, St. Petersburg. In Malaysia, the compulsory setting RFID-chip on the license plates was introduced in 2007.

Traffic police can check any car, not even stopping it, as from a fixed position, and from a mobile patrol car. In the United States since the early 1990s, a system 3M GM Automotive Adhesive was used, which can be considered the prototype of the modern RFID technology. The absence of label with a unique number on a vehicle is cause for its detailed review.

Research conducted by Moscow University of Technology in 2001, showed that RFID technology can identify stationary objects and moving vehicles with high accuracy and reliability, and also has high reliability, durability and protectability [29]. However, along with the many benefits of this technology there are also its disadvantages. First of all, the range of RFID-tags is poor.

However, research results of Russian scientists published in Components & Technologies claim to range up to 300 meters. It is also noted the negative impact of electronic chips on living and nonliving organisms. Thus, in June

2008 Journal of the American Medical Association published the results of RFID impact on medical equipment [30]. Electronic interference from RFID-tags resets settings of intravenous infusions, reprograms the electronic pacemakers and are cause of malfunctions of medical equipment.

More than a third of tests did reveal malfunctions of medical equipment, which was located at a distance from centimeters up to six meters from the source of RFID. In another third of the tests the serious irregularities of the artificial respirator functioning, infusion pumps, devices for hemodialysis, ECG monitors were revealed. The negative impact of transponders on living organisms and human at times exaggerated in the media and the Internet, which makes it difficult real introduction of electronic passports for population.

In the proposed RFID system the above-mentioned factors are considered. There are used active RFID tags with two data channels - radio and optical. If the active tag is applied the range is limited primarily by output tag power when fixed ratio of antenna directional and the sensitivity of the reception channel. RFID system has the ability to adjust the output power of a transmitter when obligatory limiting the maximum level by +4 dBm.

This excludes any impact on the living and non-living organisms, because it is on several orders smaller than the norm of allowable SAR (Specific Absorption Rate)-specific absorption coefficient of electromagnetic radiation by the human body. SAR is measured by watts per kilogram (W/kg). The Federal Communications Commission in the United States (FCC), Industry Ministry of Canada (IC), as well as the regulatory organizations of some other countries the norm SAR of 1.6 W/kg is accepted.

In the European Union a rate of SAR 2 W/kg is accepted. The output power of the proposed RFID does not exceed several milliwatt as opposed to mobile phones with output power up to two watts. In addition, RFID module is located far away from the driver and passengers, which eliminates the negative effect of high-frequency radiation.

Concerning violations of medical equipment, it is necessary to note, such equipment is missing on the highways, and in ambulance car the medical equipment is located inside the shielded car. The noise are produced primarily an intense magnetic field generated by the reader for powering the transponder (tag), and in our case it does not exist, since power supply of transponders are not due to reader field, but is realized by means of car electrical system or transponder battery. In an extreme case, radio channel of transponder can be switched off and only the optical channel can be used.

Addition to RFID can be GPS navigation. Modern GPS receivers based on the chipset SiRF Star III fix the signal even in the hangars and manufactory shops with reinforced concrete floor. Receivers of the latest generation support modern European global positioning system Galileo and Russian system Glonass.

The disadvantage of GPS navigation is inability to transfer data about the position of the vehicle to a satellite. Thus, the development of the positioning subsystem IRI can simultaneously realize both of these technologies for their detailed research and application to the task of monitoring and traffic management.

12 Structure of unit CAR-ID

The proposed concept of CAR-ID is based on the principles used in the air traffic control system ADS-B [31, 32, 33]. The essence of CAR-ID is that the transponder of the vehicle periodically transmits a broadcast message, which includes the identification information and data on the coordinates and speed of the vehicle, receiving from the built-in GPS receiver. In addition, the controller CAR-ID generates protocol of vehicle dynamics, receiving information from the acceleration sensor.

Sending a message is realized through two channels - wireless and\or optical. Messages are received by vehicles or fixed stations, which are located in the area of optical or radio coverage. Stationary stations are networked and located in places where there is a power (light signals). When receiving a message, CAR-ID checks for it in the “history” and in the absence add it to the memory of controller. When getting into the zone of the stationary monitor (station) rewriting all the information accumulated since the previous reading from the memory controller to the memory of the station is performed. The information packets are formed and periodically sent to the “cloud”.

To ensure high noise immunity, structural stealth of signal and eliminate impact of noise on other radio equipment CAR-ID direct spread spectrum DSSS are used [34]. The unit can operate in the unlicensed ISM band with an output of 0 - 4dBm. This is sufficient to ensure the radio visibility up to 100 meters when using omnidirectional antennas.

All information transmitted via open channels, is pre-encoded. To eliminate collisions in the block the method Slotted – ALOHA is applied [35]. If necessary, the entire information stored by controller for a day, can be read by the police or other fiscal services by using a special reader. Thus, a distributed intelligent wireless network based on RFID unit is created (Fig. 8), the advantage of which is the presence of distributed storage devices and rapid information exchange [36].

The structure of CAR-ID unit contains the following modules: Optical front-end is optical interface; RF front-end is RF interface; Synchrogenerator is frequency generator; Baseband processor is designed for processing signals after demodulation; GPS is positioning module; Cryptomodule is encryption module; Controller, OP-code detect, EEPROM control, Mode control are unit management system; Test connector is switch for unit testing; Test logic (Test points) is module for test management and programming; Memory (EEPROM crypto key, ID code) is memory card for storing data and proprietary information; MEMS sensors are module of sensors.

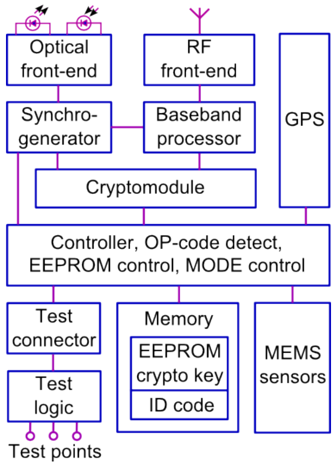

Fig. 8. Structure of CAR-ID unit

13 Road management and monitoring

Modern cities have a complex road infrastructure, where road management is carried out through the traffic lights by using traffic management systems (TMS), which include hundreds of traffic lights. Here, under the traffic lights we will understand TMS subsystem that provides monitoring and control of traffic on the separate section of the road network.

The central part of the subsystem (see Fig. 9) is specialized traffic controllers (TC) with built-in switched power circuits, which are designed to control the traffic lights. Controllers SITRAFFIC C800 [37] are able to inquire up to 84 vehicle detectors of inductive type and control 48 groups of signals of the total capacity 4 kW in real time with maximum permissible cycle in 300 seconds.

C800VX controller supports up to 120 of these modules in management segment, each segment is able to function independently and integrated into TMS network based on wireless technologies (GPRS, WiMAX); it is centrally managed from the traffic control center (TCC) [38].

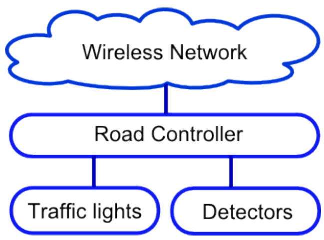

Fig. 9. The general structure of traffic light object

On present trends of road infrastructure expansion, it is clear that the use of such solutions is possible subject to high reliability of such systems. It is known that if TMS structure is extended (the number of traffic lights controlled by the system is increased) the reliability will be decreased [39]. Therefore, developing more reliable TMS structures including advanced distributed automation technology is topical scientific and industrial problem.

Cheaper and much more flexible variant of TMS organization on such principle was proposed in [40], where the authors propose to improve the quality of traffic through distributed automating key processes and creating a system of distributed traffic control. They found that to improve the reliability of the system along with providing information and control functions of the cloud, TMS should be organized according the principle of centralization-decentralization. In this case, the buffer computer of IRI (Fig. 6) executes functions of data server and provides connectivity to peripheral workstations, as well as it manages multiple controllers, segmented (10 – 20 traffic lights per segment) on geographical basis.

This TMS architecture allows positioning servers anywhere in the city and organizing mobile control center that provides the coordinated functioning all TCs at the object. This control structure is implementation of the component I-CMC (see Fig. 6) and it is represented as a matrix (see Fig. 10), elements of which are traffic controllers (R-PLC), and the columns correspond to the segments of the road network, controlled by segment servers (RSS), which in turn are controlled by the buffer computer of IRI.

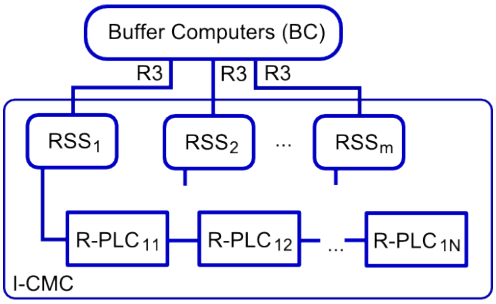

Fig. 10. Structure of I-CMC unit from Fig. 6

Here RSS module is reliable industrial computer; component R-PLC is based on PLC SIMATIC S7-1200, which is compact and power programmable logic controller from SIEMENS for programming engineering process [41]. To solve the problems of automatic control, motion control and can be used in engineering, enterprise management systems, and in many other areas. It is multifunctional and has relatively low cost.

Compact modular design combined with high computing power allows the use of SIMATIC S7-1200 for a wide range of automation problems. The advantages of PLC S7-1200 are:

1) high reliability, the mean time before failure of more than 30 years;
2) the ability of reprogramming of the controller when it is running;
3) service directly at the place of object location;
4) high performance about 10^5 instructions per second under a clock cycle time 15 ns;
5) high accuracy of cyclic commands;
6) programming language STEP-7 Basic with integrated fuzzy logic.

14 Remote module “SHERLOCK”

It 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.

Module specification is represented below. GPS is multi-channel receiver with high sensitivity and low power consumption, designed for utilizing in urban areas and at the presence of reflected signals. GSM is three band GSM/GPRS module that can run in all existing GSM networks in Ukraine. The module has 8 digital and 1 analog inputs, as well as 7 digital outputs (open collector).

Interface is CAN 2.0 bus for connecting to vehicle network, managing actuators and inquiring additional sensors. Memory involves 512 KB of internal memory to store telemetric information. Built-in temperature sensor, built-in hardware self-diagnosis, monitoring of operating temperatures and supply voltages are implemented in the module.

Remote module “SHERLOCK” is realized in small plastic case; it has one 24-pin connector for a power source, actuators and sensors. Two high-frequency SMA connectors are used to connect the GPS and GSM antennas. Remote controller for operation in GPRS requires definition of the access point name (APN, Access Point Name), the name or IP-address of the server and port number.

Operation of the module is performed as follows. Attempt to get in touch with GPRS is taken every 10 minutes. Data on the change of coordinates taken by GPS receiver is transferred to the server at intervals of 10 to 90 seconds depending on the speed of the object, on which the device is installed.

Remote command control is carried out by using SMS-commands:

1) Request status;
2) Mode configuration for GSM/GPRS;
3) Control outputs;
4) Request to execute USSD commands;
5) On-line monitoring service.

Access to the online monitoring service is realized around the clock from link http://gps.rfid.com.ua . To access the service, users have to log in with a username and password. On service home page a map with location data of mobile objects is shown. Map information from company “VISICOM“ is used.

Control tools involve the ability of choosing one, two, or all of the objects owned by the user, and duration of time for which it is necessary to view information about movement. The status of objects and route for the selected time period, as well as the duration of parking are represented on the map. Map size and location can be changed by using the mouse and control tools. At the bottom of the home page there are elements, which allow quickly switching between the parts of the route and objects, as well as statistical information.

If only one object is selected an additional function for calculating the distance is available. On the Settings page, a user can enter information about his/her email address, change password, map size and view a summary of the settings and communication.

Objects page is designed for changing object name, description and parameters. Rules for sending messages about object movement are indicated in appropriate menu item. The rules can be changed on the basis of information about occurrence of an object in the area, leaving it, and the transition from one area to another one. Area control is realized by menu item that allows closing areas on the map, which can be used for setting parameters.

Coordinate page shows a summary statistical information about the location of mobile objects in the current time, as well as information about the nearest geographical object known to the system. The database stores the information about the coordinates of several tens of thousands of addresses in Kiev city. Communication page is used to obtain statistical information about the system.

The last coordinates of mobile objects are displayed, as well as the following information: the time of coordinate receiving, telemetry information, and information about the area where every object is located. Remote module is distributed with antenna GPS, antenna GSM, connecting cable, instruction manual; SIM-card.

15 Scientific novelty, market appeal and social importance

It is difficult to forecast social, technological and technical positive effects of the revolutionary transformation of the existing world related to implementation cloud road services. In the limit, in 10 years, we should expect a service for automatically routing vehicles without driver. However, on the way to full automation some obvious innovative scientific and technological solutions of social, humanitarian, economic and environmental problems associated with the emergence of cloud monitoring and management, are represented below.

Scientific novelty lies in the system integration of three components: cloud for monitoring and management, RFID blocks of vehicles, and road infrastructure tools for monitoring and management, which makes it possible to automate optimal control of transport and traffic in real-time for social, humanitarian, economic and environmental issues.

Practical value of research is defined by following services:

1. 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 of traffic lights on the roads and intersections with accurate digital monitoring traffic through the use of RFID-tags of cars, enabling to minimize the movement time of all road users.
3. 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 comfort (time of day and year, road surfacing, left turns, weather, traffic jams, repairs).
4. Intellectual history 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 RFID blocks (C-RFIDs).
6. Cloud on-line monitoring RFID tags of vehicles that eliminates the license plates from the accounting system and has the following benefits:

1) exclusion of the direct participation of the traffic police in commit traffic violations (speeding, travel to prohibit traffic lights, improper maneuvering);
2) saving thousands of tones of metal to produce numbers 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 (×2 – ×5) reducing the staff of the traffic police, because the history of car movement and its traffic violations is completely transparent for the cloud, which will make it possible to automatically pay the penalties for violations in accordance with country laws;
5) completely eliminate corruption in relation between the driver and traffic police due to inability to erase information about the violation in the cloud;

6) virtually eliminate criminals in car theft, thanks to use built-in car RFID block that provides on-line twenty-four-hour observability of vehicles, on condition that a car is not physically destroyed;
7) simplify the legalization of driver by adding the driver's license to the list of authorized persons of car RFID block via "Bluetooth", which eliminates necessity of special papers and power of attorney for others;
8) reducing in several times the number of accidents and considerably improving the quality of life for drivers and passengers due to total monitoring of violations and the certainty of punishment for them;
9) decreasing by 30% automotive carbon emissions by reducing the idle time at intersections and selecting the optimum mode of transport and routes of movement;
10) ensuring high market appeal of cloud services through selling the services to companies and individuals that guarantees high profits – from hundreds of millions up to tens of billions of dollars – which is scalable depending on the area of service coverage: cities, states, countries, entire world. In the presence of 10 million cars in the country and if the value of one RFID tag equal to $ 100, the cost of equipping the entire fleet is equal to 1 billion dollars. The cost of creating a scalable IRI prototype is $ 10 million dollars plus the overhead of technical support and maintenance of infrastructure – $ 10 million dollars a year. The annual cost of sales for cloud service is not more than $ 100 dollars for each car. This amounts to nearly $ 2 billion dollars in profits after three years of the cloud maintenance. Payback period IRI is 1.5 years.
11) Near future. The real world is in need of advanced and precise monitoring and management of cloud. The problem can be solved only by using radio frequency digital identification of all produce and natural sites on the planet, including humans and animals. 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.

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