# Prototype of the Telematics Map Cloud Service

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***Abstract*—User experience of the vehicles' telematics services depends on quality of bidirectional network connection between the vehicle and stationary high-performance computing system. In this case, there is a task of ensuring continuous data transmission between the vehicle and stationary computing system in the conditions of highly dynamic networks. The answer is to retrieve data about surrounding networks from external sources. The source may be a telematics map - set of low-level methods, which provide management routines for data about available networks. While vehicle moves along the route, these methods handle the data about surrounding networks, generalize them by geographical and temporal principles, execute queries to a database retrieving list of networks available in the area. As a result, we can schedule connections to wireless networks throughout the route. The article covers technical aspects of implementation of the telematics map information system: data collection and generalization technologies, networks list composition rules. The prototype demonstrates ability to solve the task of networks lists management in moving vehicle under real world radio conditions.**

## I. Introduction

Modern intelligent transportation systems provide high-level services to the vehicles. Examples of such services are: routing and navigation, weather information, traffic information, embedded software/firmware updates, vehicle's devices and components condition control. These services allow to increase safety and ecology of transportation infrastructure. Quality of described services relies on continuous bidirectional interaction between vehicle and cloud resources [1], [2]. Today, only one communication channel to the global network is used for data exchange. Because of this, external service may become inaccessible in areas with poor network coverage.

Increase in the number of networks, through which vehicle could be connected to the cloud, increases number of connection options, thus improving the reliability of service provision. In this case, there arises a problem of choice among available networks. This problem can be solved with the relevant list of networks available in selected area. The concept of multiprotocol unit, which we've introduced earlier, allows to connect vehicle to multiple networks of different technologies and transmit data using any of them, which is available now [3].

However, data about surrounding networks and their signal quality were limited by current vehicle's location, thus excepting the ability to build a networks usage strategy for multiprotocol unit over the whole route.

This article covers the automatic technology of managing data about available wireless networks surrounding the moving vehicle and peculiarities of technical implementation of the methods of telematics map cloud service.

First part of the article describes data flows relative to the data used to describe wireless networks. Second part contains description of telematics data and queries to the telematics map database[4]. Third part describes hardware and software components of the cloud service. Implementation of the prototype of telematics map will confirm the operational capability of our method to inform the moving vehicle about available wireless networks at any given point of the route.

## II. Related works

Modern development of automotive telematics assumes utilizing communication channels of different technologies to implement driver's and passengers' services. Particularly, Ford Motor Company uses "Sync" technology for persistent connection of vehicle to the cloud [5], [6], [7]. Other manufacturers also provide similar systems, for example, Mercedes-Benz, BMW, Audi [8]. They rely on LTE global network connection and GPS receiver data [9], [10]. Technologies like DSRC are often used for payments on toll roads. VANET and MANET technologies, which target at communication among moving vehicles on the road, also actively developing [11]. Embedded GPS receivers provide vehicle's location data, which are then sent into global network for later analysis [12]. However, these functions are implemented in isolation, the traffic from one service can't pass over the network equipment intended for other services [13], [14]. Aggregation of data flows into unified telematics network will reduce delays, transmission time, network absence time and data transmission expenses. This requires to provide the vehicle's communication system with data about available networks.

## III. Data management in task of telematics map building

We propose usage of telematics map to receive the data about available wireless networks in areas surrounding the moving vehicle. The map service provides automatic collection, processing, storage and distribution of data about available local and global wireless networks.

The idea is to create complete cycle of data transmission: each vehicle gathers data about surrounding wireless networks, send them to the cloud service, which process them and send back to the vehicles. Fig. 1 shows data management chart of telematics map.

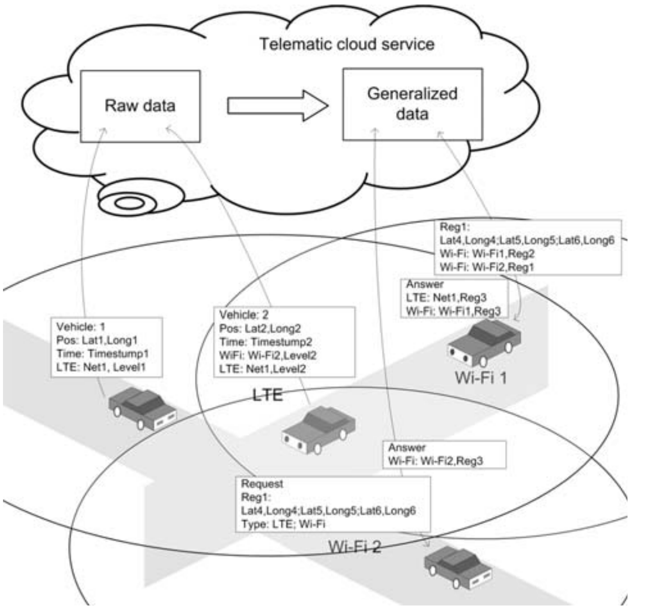


Fig. 1. Local and global wireless networks data transmission chart

Source data set is implemented in primary data instance. The instance presents combination of data about the vehicle, transmission time, transmission location, network type, network parameters.

Primary data are then sent to cloud service which aggregates them for later processing. Data transmission may be executed in two modes: online and offline. Online mode means that we send new data immediately after they are collected at every new measured location, while offline mode allows to accumulate data through some period of time and send them later.

Generalization of data allow to maintain the map in relevant condition, generalization process is based on spatio-temporal query. Main goal of this procedure is to supply the map with most recent and relevant data about wireless networks, so that each described network could be found with maximum probability. Method implemented in the prototype also maintain density of location points at constant level for each wireless network. In our method we analyse the surrounding points for every new point added to database, and if density of surrounding points is lower than treshold, we then add this new point to the map. Otherwise, we replace the oldest one of surrounding points with our new point. Fig. 2 shows graphical interpretation of the method.

Generalization procedure is part of telematics map cloud service, result of procedure is stored in a database, which handles the requests from the vehicle.

Vehicle's multiprotocol node provides storage for local part of telematics map data. These data are fetched from the cloud by request from the multiprotocol node, which then stores the result in local database. Result may be then used in online or offline modes. For example, in areas without global network coverage.

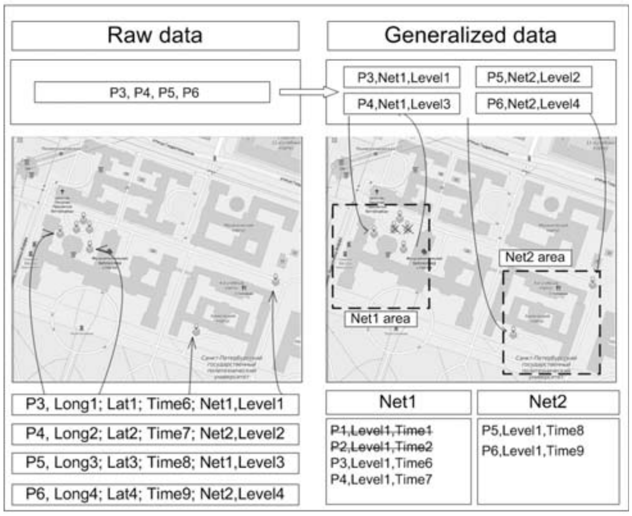


Fig. 2. Graphical interpretation of method of telematics map data generalization

Limitations for the query are: geographic boundaries of region aroud the vehicle and list of appropriate wireless networks. Query is executed once for the area surrounding current vehicle location, when the local map is blank. Then, corresponding regions are incrementally added to the local map, as far as vehicle moves along the route. Fig. 3 shows execution scheme for queries from vehicle to cloud service, answering procedure and distribution of data between global and local telematics maps.

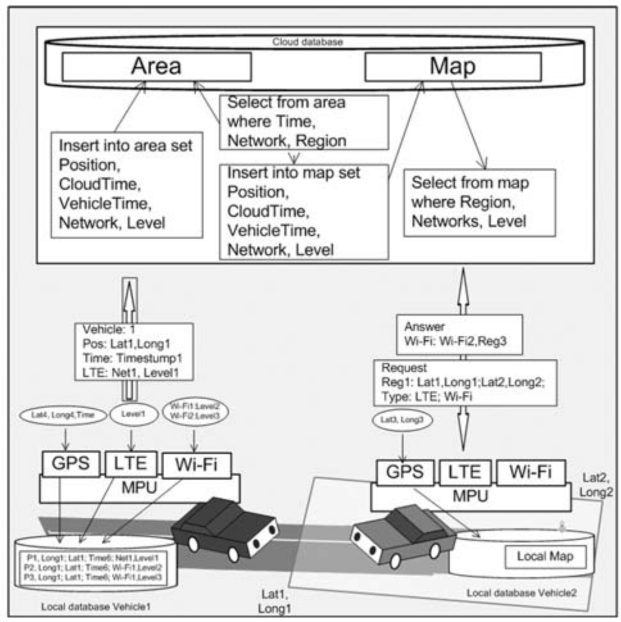


Fig. 3. Queries execution scheme and distribution of data between global and local telematics maps

Proposed technology provides continuous information for the vehicle about surrounding wireless networks in online and offline modes during vehicle's movement. Selection of time instants for sending and receiving data is done automatically, depending on vehicle's speed and network coverage.

## IV. Running the Queries and Responses to the Telematic Map

Data analysis allowed to identify the main entity of the task: wireless networks, vehicle, multiprotocol unit and point of transmit data. Each point of transmit data from vehicle are defined by the geographic coordinates and the time of transmitting. The vehicle is identified by the VIN-number and the properties of unit as: the types, numbers and condition interfaces. The wireless network is defined by the name, BSSID and signal levels in each point of vehicles driving. The hierarchy between the entities and attributes is shown on the Fig. 4.

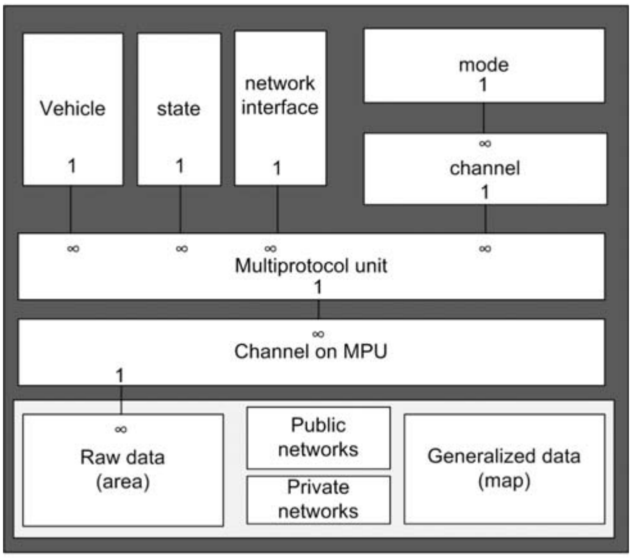


Fig. 4. The hierarchy between the entities and attributes in the wireless networks data control task

The raw and generalized data is stored inside relational database. Databases are installed on the cloud service and multiprotocol nodes.

The cloud services database stores the raw data from vehicles, generalized maps data and access rights to public resources.

The multiprotocol unit database stores raw data from interfaces before sending their into the cloud service, availables wireless networks around the vehicle and the access rights to connect to private networks. The database schema is a multiprotocol host is the copy of cloud service database. Fig. 5 shows the database schema. The different part of databases clouds and units are shown in the rectangle named "Private access rules".

In operation systems can be identified streams of requests to local and global databases. They can be divided into streams of requests from the hardware and software.

The flow of requests multiprotocol site include:

- from the software to the local database:
  - determining available Wi-Fi networks;
  - determining the level of the LTE signal network;
- from the hardware to the local database:
  - query to transfer of primary data about the available networks;
  - query of generalized data from the telematic maps.

The queries are implemented inside the software modules of the multiprotocol unit.

In the cloud services the raw data are generalized by the flow of queries. Each query contains updating of the telematic maps for different wireless networks.

Request is implemented as a triggers by means of language databases.

The Fig. 6 shows graphic presentation the flows of queries between multiprotocol node and cloud service.

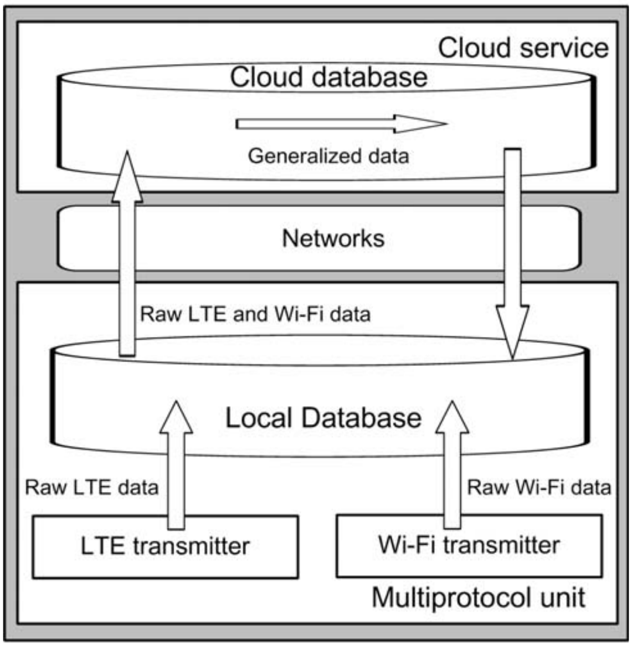


Fig. 6. Diagram of requests between hardware and databases

Queries flow provides a continuous bidirectional communication between the node and the multiprotocol cloud service.

## V. Software and Hardware Telematics Map Prototype Implementation

The telematics map prototype is implemented on the software and hardware testbed with multiprotocol units [15]. Testbed provides multi interaction between MPU and stationary cloud service in the conditions of the vehicle movement in the city and country roads.

Multiprotocol unit is equipped with a built-in receiver GPS, two Wi-Fi module and LTE. The first Wi-Fi is used to obtain data about available wireless networks, the second — to connect to the selected network. GPS-receiver used to obtain the current time and the coordinates of the vehicle. Cloud

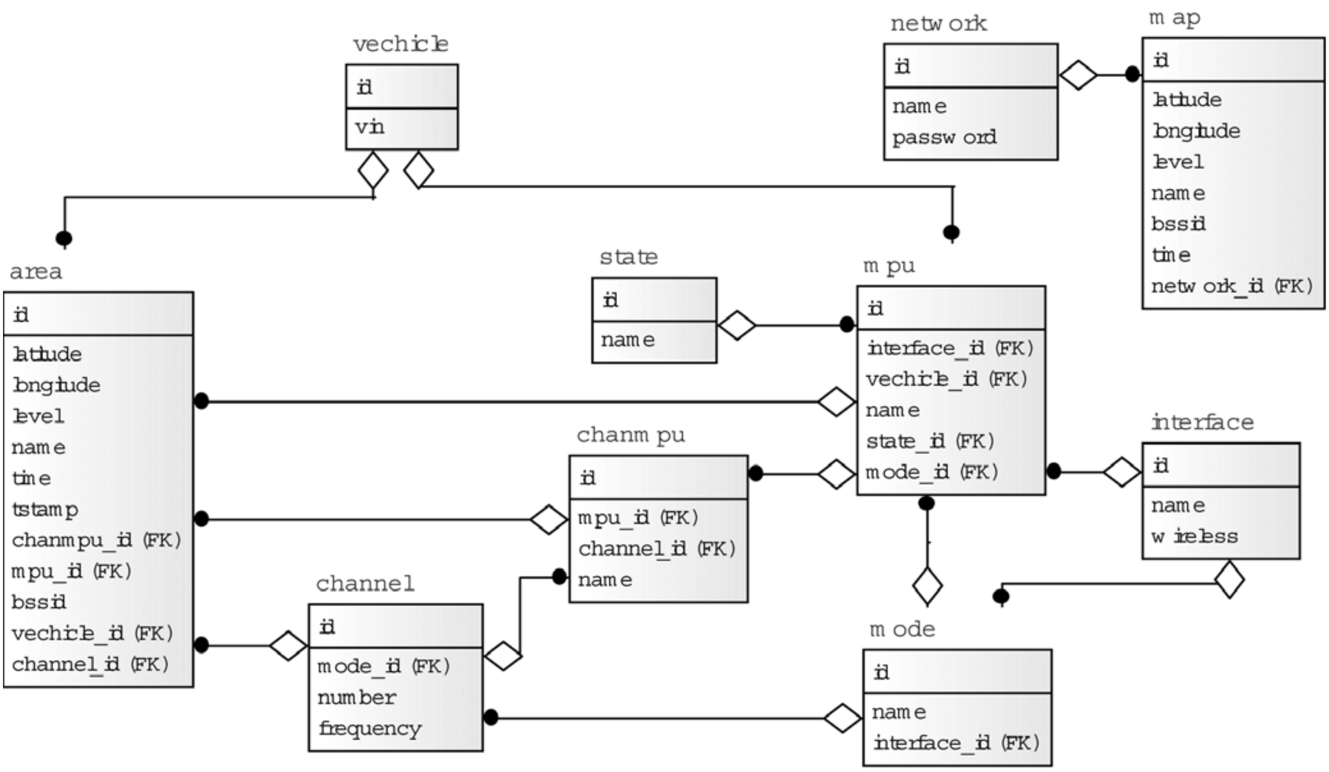


Fig. 5. The database schema

service is equipped with a GPS receiver to synchronize the system clock. The location data of the vehicle obtained via the network through a VPN connection. Hardware components connection scheme of the testbed is shown in Fig. 7.

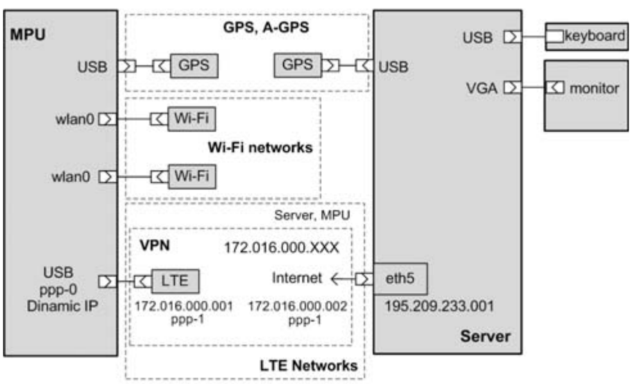


Fig. 7. Hardware components connection scheme on MPU

The architecture developed for the experiments, provides interaction between the system and ap plication software on the MPU, and cloud service based on the operating system GNU/Linux Debian 7.4. The same version of the operating system installed on board the MPU.

On the cloud service and MPU, periodically executes a time synchronization using time signal from the GPS [16], [17]. Time synchronization is performed by ntpd daemon, which receiving a signal from the gpsd daemon with GPS-receiver through common blocks of shared memory (shm). Poll Frequency GPS device is 0.5 Hz.

Kismet server is used to perform data collection on local wireless networks with Wi-Fi module. Connecting to the module via the interface wlan0.

Data sent from the collection module via the API to sql database module and the GUI module for data display. Data from the database with the specified frequency are sent to the database server is located on the cloud service. As a relational database using MySQL version 5.5.35.

The connection between the MPU and the cloud service through a dedicated VPN-channel through global communication channels. Physical device access to the global network is LTE modem 4G, the connection uses an interface ppp0. Wi-Fi transceiver with the interface wlan1 used for for obtaining the list of available networks in current position on the MPU and comparison with the received list from cloud service.

Interaction scheme of system software modules and hardware network interfaces is shown in Fig. 8.

Application software application consists of this modules:

- Wi-Fi polling;
- LTE polling;
- raw data local storage database;
- telematics map update;
- telematics map query;
- local region snapshot from telematics map;

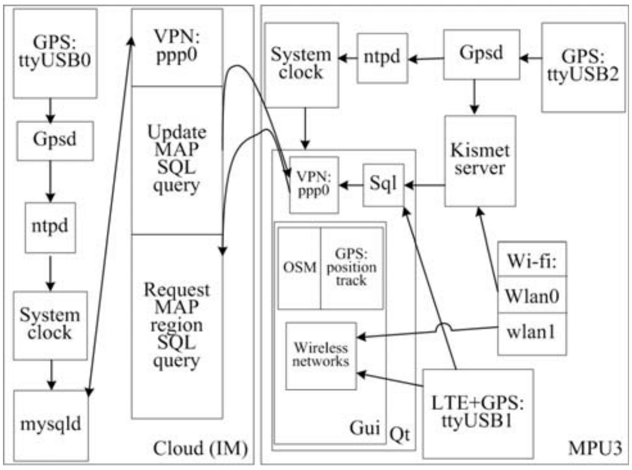


Fig. 8. Scheme of interaction between system modules and device interfaces

- graphical user interdace (GUI).

Scheme of interaction between modules of application software is shown in Fig. 9.

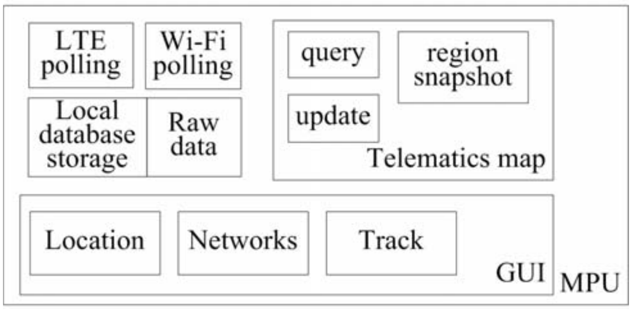


Fig. 9. Software modules interaction

Application software is developed using Qt cross-platform framework. The QtSql module used to interact with the local and remote databases between software. The graphic part of the software is used to display cartographic information location from Open Street Map through QtLocation module. QtGui and QtWidgets modules shows the currently available and expected networks obtained from the cloud service and display it over the vehicle track.

## VI. Conclusion and further work

This paper describes the data management technology of a client-server application, which works with data about local and global wireless networks available from the vehicle moving along the route. Mentioned technology provides methods for data collection, temporary storage, transmission to the cloud, aggregation of data received from multiple vehicles, request for relevant list of wireless networks available in selected area. It allows the vehicle to maintain relevant state of data not only with persistent connection to the cloud, but also under conditions of poor global network coverage and temporary absense of connection to the cloud.While the article only covers the prototype implementation with two types of networks (celullar and Wi-Fi), another network technologies may be included in the telematics map. Vehicles equipped with mesh (802.11s), DSRC and other wireless interfaces will also benefit from proposed solution.

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