Implementation of the Algorithms to Retrieve the Data About Local and Global Wireless Networks from the Telematics Map

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Keywords: Connected Vehicle, Wireless Networks, Wi-Fi, Multiprotocol Unit, Spatial SQL Queries, Telematics Map.

Abstract: This paper describes implementation and research of the algorithms to select the data about surrounding wireless networks from the moving vehicle. The data are retrieved from the telematics map, which is a cloud service containing the data about all the available wireless networks in the region. The paper contains the description of three scenarios of data extraction, relational queries to the telematics map which serve these scenarios, and the experiment to test the data extraction from the cloud service under real road environment. The experiment has shown that the time needed to extract the data about available local and global wireless networks does not exceed 0.2 sec, which is acceptable for the tasks of scheduling the wireless connections between the vehicle and the cloud services during the whole route. The results of this work may be used to retrieve the list of available wireless networks in the algorithms of intelligent scheduling of bidirectional data transmission for the connected vehicles.

1 INTRODUCTION

Modern intelligent transportation system (ITS) consider each vehicle as an active source and destination for data flows containing traffic behaviour information, which is important in prevention of road accidents, reduction of emissions, decreasing the time spent by the driver and passengers in traffic jams. To achieve these goals each vehicle keeps bidirectional connection between the vehicle and cloud services located outside of the car (Zaborovskiy et al., 2013; Annese et al., 2011; Kutscher and Ott, 2006), it allows to continuously obtain data about surrounding road conditions, local traffic fluctuations, unwanted weather changes. It is not an easy task to provide the consistent connection because of large number and dynamic behaviour of the vehicles on the city roads, short range of local wireless technologies, presence of the areas without cellular coverage, variability of the network traffic among the vehicles. The fundamental approach to this problem is to continuously retrieve the data about possible connection points not only near the current vehicle's location, but at any point of the selected area. Selection of the current geographic region networks provides a combination of data management technologies of the telematics map and the multiprotocol unit (Glazunov et al., 2015). The proposed idea allows to implement the technologies of gathering and aggregation of data about available wireless networks of the region (Mikhail et al., 2015). The first part of our paper contains the review of the related works. In the second part we describe three scenarios for the method of selection of the available wireless networks from the telematics map and the algorithm of communication between the vehicle and the cloud service. The third part covers the implementation of spatial queries to the relational storage of the telematics map. The fourth part includes the description of the testbed, description of the experiment, and the result of trials on data retrieval from the moving vehicle. The proposed approach allows to select the potentially available wireless networks for arbitrary number of vehicles, thus providing flexibility to schedule the data transmission to or from the connected vehicle.

2 RELATED WORKS AND THE GOAL OF THE RESEARCH

At the initial stage in the development of vehicle networks the problem of efficient selection of the access points was solved by specifying positions of these points and sequentially switching among them using static algorithm (Deshpande et al., 2009). The prob-

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lem of continuous uninterrupted access to the network was solved by using multiple Wi-Fi interfaces and connecting them to different access points simultaneously (Annese et al., 2011). Active development of the "connected vehicle" technology required to deploy the large amount of road infrastructure equipment, and the continuous connection with these devices must be maintained. These connections are the important part in tasks of fog (Jain and Singhal, 2016) and cloud (Ko et al., 2016) computing, thus requiring self-organizing sensor, ad-hoc, or mesh networks. The other option is to deploy the additional road infrastructure equipment which communicates with the vehicles using the WAVE protocol and ad-hoc technologies (Salahuddin et al., 2015), it is also possible to use smartphones of drivers and passengers for continuous access to cloud services (Wahlström et al., 2016). But in this case the problem of efficient communication between the vehicle networks and road infrastructure still exists. To address that and find the suitable connection there are local static and dynamic algorithms of selection of the best available network. These algorithms combine the wireless networks scan mode and connection mode to work within the selected network (Mouton et al., 2013). Statistical methods of selection of the best available network allow to analyze the connection time for each network and to choose the one which provides the longest active connection (Mostafa et al., 2011). To achieve even better results there are fuzzy logic methods to select the best networks based on the driving parameters (Ndashimye et al., 2016), or by distributing the vehicles among the networks based on the QoS model (Xi et al., 2014). We propose the approach that allows to retrieve the data about available wireless networks in case when the number of access points, their status, and number of vehicles constantly changes. The goal of this research is to compute and analyze the execution time of the queries that retrieve data about the telematics resources of the region. We consider three different scenarios while acquiring the data to predict the telematics environment on board of the vehicle.

3 IMPLEMENTATION OF SCENARIOS TO RETRIEVE THE LIST OF NETWORKS FROM THE MOVING VEHICLE

The data upload and download may occur when the vehicle is moving on the route. When these data flows appear we should select the best available point of connection to the wireless network and perform the transmission. To select the specific point we take into account the set of high-level parameters, such as: link bandwidth, time when the vehicle is in the coverage of the network, traffic cost, connection establishment time. However, we can redistribute the incoming and outgoing traffic if we know the data size, the traffic flows priorities, the time when these data should be ready for use, and the vehicle's route. Then the data management scenarios could be local, when we request the data in the area close to the vehicle, or global, when we work with the data relevant for the whole route. Based on this idea we can define three basic scenarios of retrieving the data by the moving vehicle from the telematics map when driving in city or highway cycles: local, which is based on the vehicle's current position, and global, which is based on the vehicle's proposed route:

1. When the vehicle is on the parking or in the garage, or when the vehicle is moving at a low speed, or if the network suitable for scheduled data transmission is present at some place on the route - acquire the list of networks inside the rectangular area close to the vehicle and sort this list by signal level or by the coverage in the selected area.
2. When we schedule the continuous connection of the vehicle to the wireless networks throughout the route - acquire the list of networks which cover the whole route of the vehicle, sequentially switch among them to be continuously connected to the cloud services.

The picture shows a graphic representation of scenarios1.

To implement these scenarios we set up the telematics map cloud service and propose the method to extract the data in form of relational queries to the database. The database schema is described in work (Glazunov et al., 2015).

a) *Scenario 1: obtaining data on the telematics environment around the vehicle.* The initial data for determining the telematic situation is the current position of the vehicle, getting from the GPS global positioning system in the WGS84 system, and the size of the area for requesting data about wireless networks. The size of the area is determined by factors such as the driving direction of the vehicle and the sensitivity of the wireless receiver. The calculation of the area of interest for determining the wireless networks is carried out so that the data on the situation are available the nearest 20*s* or 200*m* around the vehicle. The request returns the SSID of the wireless network and

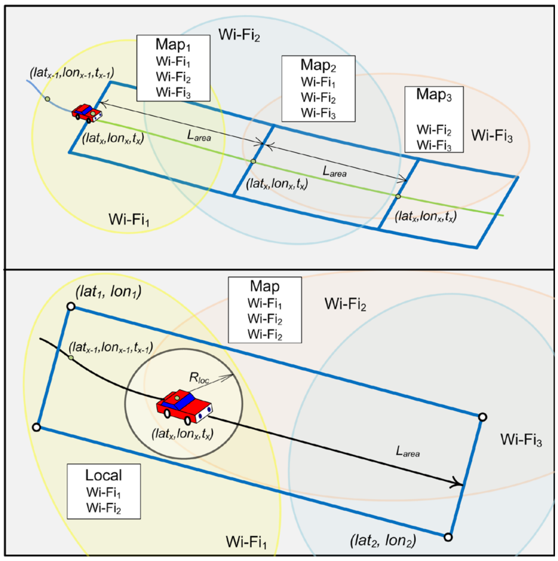

Figure 1: Graphic representation of scenarios to extract the data about the wireless networks of the region.

the percentage of the area of the area of interest on which it will be available, taking into account the sensitivity of the receiver in the vehicle. The vehicle on-board software can select the best network from the list and connect to it to receive or transmit data.

b) *Scenario 2: obtaining data on the wireless networks situation on the planned route.* The initial data for the execution of the scenario is the planned route of the vehicle's movement that to be received from the car's navigation system or the user's smartphone. The planned route is determined by a set of points in the WGS84 coordinate system and the times at which the vehicle is supposed to be in this position. The configuration of the area of interest is determined by factors such as the planned route of the vehicle and the sensitivity of the wireless receiver. The calculation of the area of interest for determining the wireless networks is carried out so that the data on the situation are available the nearest 20s and 200m around the vehicle. The request returns the List of the wireless networks, the percentage of the area of the area of interest on which it will be available and the position on the planned route, from where this network is available. The wireless network availability point is calculated taking into account the sensitivity of the vehicle receiver.

The presented algorithms are implemented as client-server application on the testbed with multiprotocol nodes (Popov et al., 2014). A multiprotocol server includes: WiFi, LTE transceivers and the GPS positioning receiver. Also navigation

Algorithm 1: The procedure for requesting data about wireless networks around the vehicle.

Data:
- Wi-Fi receiver sensitivity — *level*;
- Length the area of interests L_{area};
- Latitude, longitude of vehicle — lat_x, lon_x, t_x;
- Data new acquisition area ($lat_1, lon_1; lat_2, lon_2$).

Result: $Net\{SSID, S\}$ list of networks $Map\{SSID, level\}$,

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, sorted by area of coverage.
while (new request of wireless network list) do
    begin
        Get data from GPS receiver
        (lat_x, lon_x) ← GetGPSPosition()
        Calculate the area of interest arround
          vehicle
        (lat_1, lon_1; lat_2, lon_2) ←
          GetArea(L_area, level)
        Create the SQL Query
        SELECT SSID, S
        FROM map NATURAL JOIN network
        NATURAL JOIN network_value
        WHERE network_level ¡ level and
        latitude ¿ lat1 AND latitude ¡ lat2 AND
        longitude ¿lon1 AND longitude ¡ lon2
        Run the SQL query
        Query_result ← Query
        Save a network list
        Net{SSID, S} ← Query_result
    end
end
```

system with a route-laying function are connected with multiprotocol server in the vehicle. The data from the hardware, sent by HTTP protocol to the cloud service of the telematics map over available wireless networks. The requests received in the cloud service and its results are send back to the vehicle. Schema of data streams under the display of 2. Data streams are generated inside the vehicle from the GPSd server includes NMEA coordinates. The navigation system (Yandex Maps) generates a traffic route and sends merged packet with data to the cloud service via a HTTP POST request. On the server, the received data is processed by the WEB-application and accumulated in the MySQL database. The server returns a list of the networks sorted by the coverage area of the networks relative to the route of the vehicle.

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Algorithm 2: The procedure for requesting data about wireless networks on the vehicle route.

Data:
- Wi-Fi receiver sensitivity — *level*;
- Latitude, longitude and time of vehicle — lat_x, lon_x, t_x;
- Planned vehicle route — $R(lat_{area}, lon_{area})$.

Result: List of networks $Map\{SSID, S, \{lat, lon\}\}$, sorted by area of coverage and the point where this network can become available

. **while** *(new request of wireless network list)* **do**
  begin
    Get data from GPS receiver
    $(lat_x, lon_x) \leftarrow GetGPSPosition()$
    Get data from navigation system
    $R(lat_x, lon_x) \leftarrow GetRoute()$
    while *(for each point from R)* **do**
      Calculate the area of interest arround point
      $(lat_1, lon_1; lat_2, lon_2) \leftarrow GetArea(R(lat_{area}, lon_{area}, level)$
      Extend the query to a new area
      $Area(lat, lon) \leftarrow (lat_1, lon_1; lat_2, lon_2)$
    end
    Create the SQL Query
    SELECT $SSID, S, lat, lon$
    FROM map NATURAL JOIN network
    NATURAL JOIN network_value
    WHERE network_level ¡ *level* and
    (latitude AND latitude) in $Area(lat, lon)$
    Run the SQL Query
    $Query\_result \leftarrow Query$
    Save a network list
    $Map\{SSID, S, \{lat, lon\}\} \leftarrow Query\_result$
  end
end

4 REALIZATION AND TESTING THE ALGORITHMS TO RETRIEVE DATA FROM THE TELEMATICS MAP

The goal of the experiment is to obtain data on the average time execution of two scenarios for obtaining data about wireless networks from the vehicle in the real traffic situation. The trajectory of vehicle driving during the experiments is shown in the figure 3. Blue indicates the part of actual trajectory, green - planned for the request of the situation.

To implement the first scenario, the vehicle moved along the path and at a frequency of $1Hz$ and requested data on the wireless networks from the telematics map. The time of the beginning of the transfer of the query and the end of data reception is registered and accepted as full time of the query execution.

To implement the second scenario, the vehicle moves along a pre-selected path and requests data on the telematics situation for the next 30 seconds of the planned route. The request was repeated at a frequency of 0.2Hz. The query execution time is registered in the same way as in scenario one.

In the table 1 the parameters and constants of the

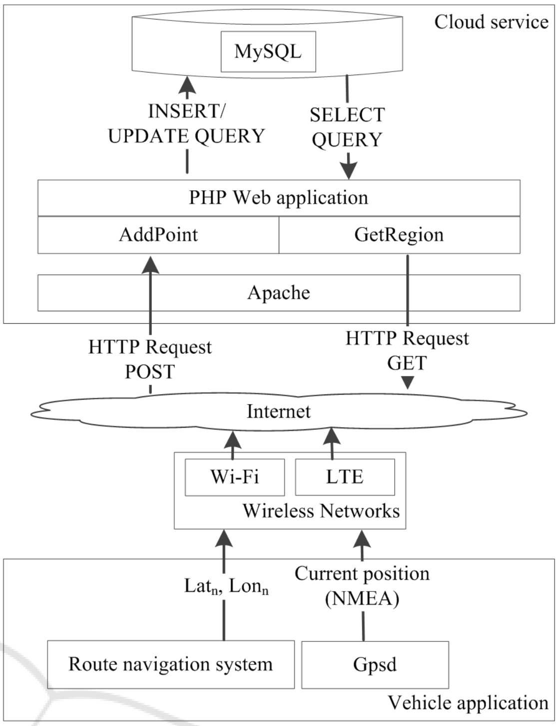

Figure 2: Data flows transmitted between the vehicle and the cloud service.

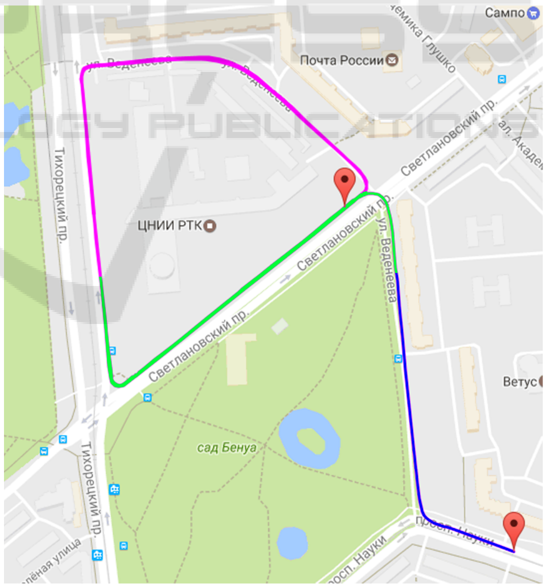

Figure 3: Trajectory of vehicle movement in the process of receiving data from the telematics card.

experiment on the execution of query's to the telematics card are presented.

Table 1: Parameters and constants of the experiment.

Parameters, constants	Values
Data transmission technologies	802.11n/b/g, LTE
System software	Apache, PHP, Mysql
Operstion system	Debian Linux
Scenario 1	
Query frequency, Hz	1
Number of query, pcs	5000
Scenario 2	
Query frequency, Hz	0.2
Number of query, pcs	4900
Length route for query, point	30-60

Data allows analyzing the distribution of the execution time requests to the telematics map cloud service from the vehicle. Such a query frequency provides the vehicle with real-time data. The figure 4 shows the distribution of the query execution time when data is fetched around the vehicle. It can be seen from the distribution that a larger number of requests are executed in a time less than $0.2s$, which allows receiving data with frequency up to $1Hz$, which is comparable to real-time data acquisition.

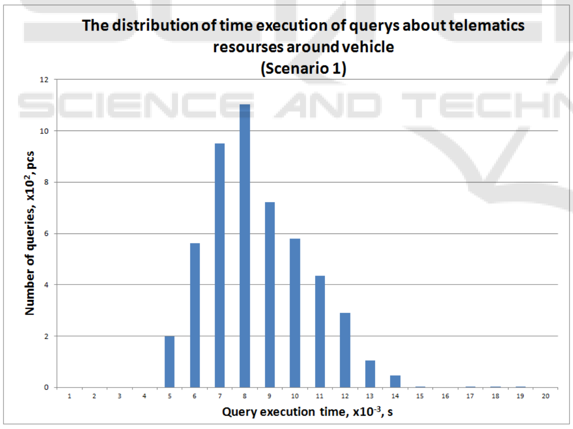

Figure 4: The distribution of time execution of queries about telematics resources around vehicle.

The figure 5 shows the distribution of the query execution time for the planned vehicle route. The distribution shows the predicted traffic route of at least 30 seconds, the query is no more than $0.3s$.

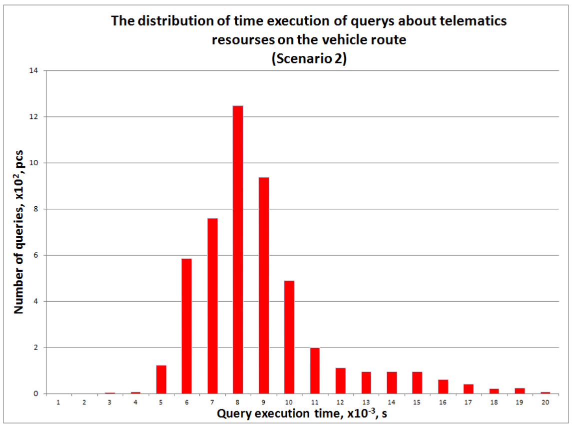

Figure 5: The distribution of time execution of queries about telematics resources on the vehicle route.

5 CONCLUSION AND FUTURE WORK

The article describes the technology of interaction of a vehicle with a telematics card for obtaining data about wireless networks around the car and on the whole planned route of the vehicle. The realization of the prototype of cloud service and vehicle on-board software demonstrated the efficiency of the technology. As a result of the conducted experiments it was shown that the query execution time averages 0.2 s for the local scenario and $0.3s$ for the scenario with the intended path. This allows you to update data on available networks on a vehicle with a frequency of up to 1Hz or to increase the length of the intended path. Results can be used for choosing and direct connection of a vehicle in the current point or for use as networks list for intellectual algorithms of data transmission from the vehicle. Further of this work may be increase in the number of connected vehicles in the real traffic situation, the optimization of the frequency of the execution of query and lengths of the planned route, the integration with the subsystem of planning the telematics traffic on the board. Alternative way of future research is the use the modeling system such as SUMO or NS-3 for study the high intensivity network traffic with the real and virtual vehicles.

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