The Method of Modelling Wireless Network Using Telematics Maps

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Abstract—**The paper describes development of the methods and algorithm for predicting telematics on the vehicle's route. Described data management technology on global and local wireless networks, provides methods for managing data on the telematics environment, implemented a prototype of the data management subsystem. The time dependencies of the execution of queries are analyzed depending on the amount of data for the data warehouse on board the vehicle and for the cloud service. The result of the work is recommendations for developing connection management methods in wireless multiprotocol networks on vehicle devices. The paper describes the result of the development and research methods for predicting the telematics environment, for obtaining and analyzing the temporal characteristics of their functioning from global and local telematic maps.**

I. INTRODUCTION

Vehicles traffic intensity in urban agglomeration conditions causes high costs in the process of movement, associated with increased accident rate, excessive fuel consumption, low average speed.

The solution to these problems is the intellectualization of the vehicle, which is associated with predicting behavior on the entire proposed route [1]. Information services that are located outside the vehicle allows to organize an operative exchange of data about the transport situation. Effective implementation of such exchange is caused by areas without coverage by global networks, limited coverage areas by stationary local access points, vehicle transport dynamics [2].

The existing solution to ensure continuous data exchange with information services is increase number of communication channels, use the channels with different physical layers, dynamic routing in data networks and predicting the sequence of connection to data networks on the route of the vehicle. Building a forecast of available network resources on the whole route of the vehicle via the data management service of the telematics environment — “Telematics map” [3]. Connecting vehicles to the service provides a sequence of connections to wireless networks on the entire route of the vehicle, which will optimize the interaction with external information services.

II. RELATED WORKS

The authors of the article [4] offer an architecture called Car4ICT. The proposed architecture consists of two objects interacting with each other The first kind of entities are the vehicles that are responsible for the search for information services and their distribution through the network. In addition, each vehicle can act as a gateway for the second kind of entities - users requesting various kinds of information services. The user is a person using the services offered by the Car4ICT architecture, referring to the network using their own smartphone. For connection, the networks of such wireless technologies as Wi-Fi and DSRC are used.

The possibility of simultaneous use by vehicles of several radio station types by dynamic selection of network interface connections is described in the article [5]. Proposed the intelligent mechanism for selecting the network interface, adapted to the hybrid communication between vehicles A new hierarchical decision-making approach is introduced in which the selection of the network interface on vehicles is completely controlled by the remote central server.

The article [6] describes technical aspects and information system implementation representing telematics map: the implementation of technologies for collecting, generalizing and creating rules for the network lists generation in the system prototype. The prototype demonstrates the feasibility of the technical solutions manage task lists on a wireless network of vehicles. To obtain data on available networks in the region of vehicle traffic, a telematics map is used [7].

The problem of frequent loss of data transmission in mobile self-tuning networks due to the exit of vehicles from network coverage areas is considered in the article [8]. The solution to this problem consists in using several data transmission paths that complement each other. The article proposes a new mathematical relation for choosing the type of interface for the transfer of the certain type of data, such as telemetry, video and images.

The article [9] shows that with a local network radius of 300 meters and the vehicle speed of 12–20 m/s, data on the time and signal strength of the local fixed local area network can be approximated. It is proposed to take into account the vehicle speed and effective data rate, which depends on the level of the signal to the RSU [10].

III. MAIN PART

The solution of the problem under consideration consists in the implementation algorithm for predicting telematics on the vehicle's route, the algorithm combines prediction methods with the priority of the transmitted user applications traffic.

A. Algorithm for predicting telematics on the vehicle's route

The algorithm for predicting the telematics on the route realizes the choice of the network for stable operation with the user specified applications while the vehicle is moving. The input data for the algorithm are the array of user applications and the dictionary of the list of networks available for connection, where the key is the application identifier, and the value is a list of available networks. The result of the algorithm is the connected network for working with user applications. Listing of the algorithm 1 is given below.

Algorithm 1 Algorithm for predicting telematics on the vehicle's route

Require: *netDictionary¡appId, netList[]¿* and *applications[]*
Ensure: *networkForConnect*

```
begin
appNetworkDictionary¡key, value¿
foreach(item:applications)
begin
methodNumber=find(priorMatrix[item.class])
if methodNumber=1 then
    begin
    methodResult = FIRST_METHOD(netDictionary)
    appNetworkDictionary.put(item.Id, methodResult.getFirst5Rows)
    end
else if methodNumber=2 then
    begin
    methodResult = SECOND_METHOD(netDictionary)
    appNetworkDictionary.put(item.Id, methodResult.getFirst5Rows)
    end
else if methodNumber=3 then
    begin
    methodResult = THIRD_METHOD(netDictionary)
    appNetworkDictionary.put(item.Id, methodResult.getFirst5Rows)
    end
end if
methodResults[]
foreach(item:appNetworkDictionary)
begin
if methodResults.contains(item.value) then
    begin
    continue
    end
else
    begin
    methodResults.add(item.value)
    end
end if
networkForConnect = getBestNetwork(methodResults)
end
end
```

The main steps of the algorithm are as follows:

- For each user application, a list of available networks is searched.
- The list is limited to a list of five networks.
- The availability of networks is determined by the priority matrix. The strings are the classes of traffic that are transmitted: conversational, background, streaming and interactive, and columns are methods for predicting telematics.
- The cells of the matrix set priorities for which traffic class which methods are the most optimal from the point of view of an uninterrupted network exchange.
- In case of signal loss, the algorithm will be restarted for execution with the same parameters specified by the user at the stage of selecting the vehicle's route.

B. Method for obtaining the highest average level of the WLAN signal on the selected route

The essence of the method of obtaining the largest average signal level of the network is to form a list of networks sorted by descending the average signal level. The average signal level of the network is calculated as follows:

$$level_{mid} = \frac{\sum_{i=1}^{n} level_i}{count}, i = \overline{1, n},$$

where $level_i$ — network signal strength in i-th point on the route, $count$ — the total number of points on the route in which selected network was detected.

The method is intended for applications with conversational traffic class.

C. The method of obtaining the largest coverage of the network on the route

The method of obtaining the largest coverage of the network realizes the compilation of networks list sorted by increasing their calculated values of the largest coverage on the route.

The net coverage on the route is calculated using the following formula:

$$network_{coverage} = \frac{count_{trajectory}}{count_{network}},$$

where $count_{trajectory}$ — total number of geographical points making up the selected route, $count_{network}$ — the number of geographical points on the route in which this network was discovered.

The method is intended for applications with an interactive traffic class.

D. Method for obtaining the smallest number of network disconnects along the route

The method for obtaining the smallest number of network disconnects realizes the compilation of the list of networks sorted by the increase in the number of discontinuities along the route of the vehicle.

The method is designed for applications with background or streaming traffic classes [11].

TABLE I. PRIORITY MATRIX FOR THE MAIN TRAFFIC CLASSES

Class/Method	FIRST	SECOND	THIRD
conversational	3	7	10
background	7	10	4
stream	10	7	4
interactive	10	3	5

E. Priority Matrix

To associate various traffic classes with methods for predicting the telematics environment, the concept of a priority matrix is introduced. For this work, the priority values are listed in the table I.

The classes of the transmitted traffic are indicated as rows of the matrix, and the columns are the methods for predicting telematics on the user selected vehicle route. FIRST — the method for obtaining the highest average level of the WLAN signal, SECOND — the method of obtaining the largest coverage of the network, THIRD — the method for obtaining the smallest number of network disconnects. In total there are four main classes of traffic transmitted over the network [12]: conversational (IP-telephony), background (large data exchange), stream (video) and interactive (web browsing).

IV. EXPERIMENT

For the experiment, software and hardware [13] were developed with a block diagram of the modules which is shown in Fig 1.

The proposed solution allows to dynamically manage connection states that vary depending on the application requirements and the current driving mode. The developed solution supports backup and aggregation of data channels [14]. The architecture shown in Fig. 1 includes modules: planning, connection management, generation rules. The database stores a regular grid with 5 meters step. This choice was based on the fact that 5 meters is the lower limit of GPS accuracy [15].

After the completion of the experiment cycles using methods and algorithm for predicting telematics, the results are written to a file. A total of three experiments determining: dependence of the execution time of the prediction algorithm on the number of networks on the route, error counting for each prediction method and calculating the difference in the query time to the local and remote database, depending on the user-defined radius of the area of interest in meters.

The limitation of the frequency of receiving coordinates from the GPS receiver in 2Hz is related to the features of the realization of the receiver and the programm driver of the device operating at a speed of 4800bit/s via the local communication port.

Software configuration feature is the independence of the polling frequency of local and global networks on the frequency GPS survey unit that ensures the functioning of these processes in different operating system threads, improves the accuracy of signal representation level.

A. Execution time analysis the prediction algorithm from the number of networks on the route

Main goal: obtaining time dependence of the execution time of the telematics prediction algorithm on the vehicle route depending on the total number of detected and available wireless networks. The scheme of the experiment is shown in Fig. 2.

TABLE II. EXPERIMENTAL PARAMETERS

Parameter name	Value
Route lenght, km	1.8
Coordinate source	GPS
Step grid, m	5
Frequency of obtaining coordinates, Hz	2
Polling Wi-Fi frequency, Hz	10
Polling LTE frequency, Hz	2
Traffic type	UDP
Operating system	Debian 7.4 (i386)
DBMS	MySQL 5.5.40
Programming language	Java
Hardware	Intel Core i5, 2.4 GHz, 8 GB RAM

Laptop with a connected GPS receiver was used as the client. To analyze the execution time of the algorithm for predicting telematics on the vehicle's route from the number of available local wireless networks(WLAN), the algorithm was launched for execution with number of networks from 10–200. The data on the telematics map was stored in the local database located on the client. As the initial data of the executable algorithm used the number of applications launched by the user during the driving of the vehicle along the selected route, where applications realized as separate independent threads.

Data on the execution time of the algorithm for predicting the telematical environment, depending on the number of networks on the selected route, are shown on Fig. 3.

Obtained dependence shows a linear increase in the execution time of the algorithm with an increase in the number of networks detected on the selected route of the vehicle. The execution time of the algorithm increases by a factor of 10 with the number of running applications increasing by 10 times, which demonstrates the linear dependence of the execution time on the number of networks.

B. Analysis of the network selection error by the three prediction methods

Main goal: obtaining error distributions of the three prediction methods relative to each other allowing to obtain results on the degree of compatibility of methods depending on the requirements for the type of application traffic. The scheme of the experiment is shown in Fig. 4.

An analysis of the error in selecting the local wireless network recommended for connection to ensure the smooth operation of user-initiated applications was made by counting the error of each of the three methods for predicting the telematics situation: the method of obtaining the largest average network signal level on the selected route (FIRST_METHOD), the method of obtaining the largest coverage of the network on the route (SECOND_METHOD) and the method of obtaining the least number of network disruptions along the route (THIRD_METHOD) The error was calculated as follows:

1) Execution the algorithm for predicting the telematics situation, the result of which is the recommended network for connection.
2) For each forecasting method, the result of which is a list of available wireless networks on the selected

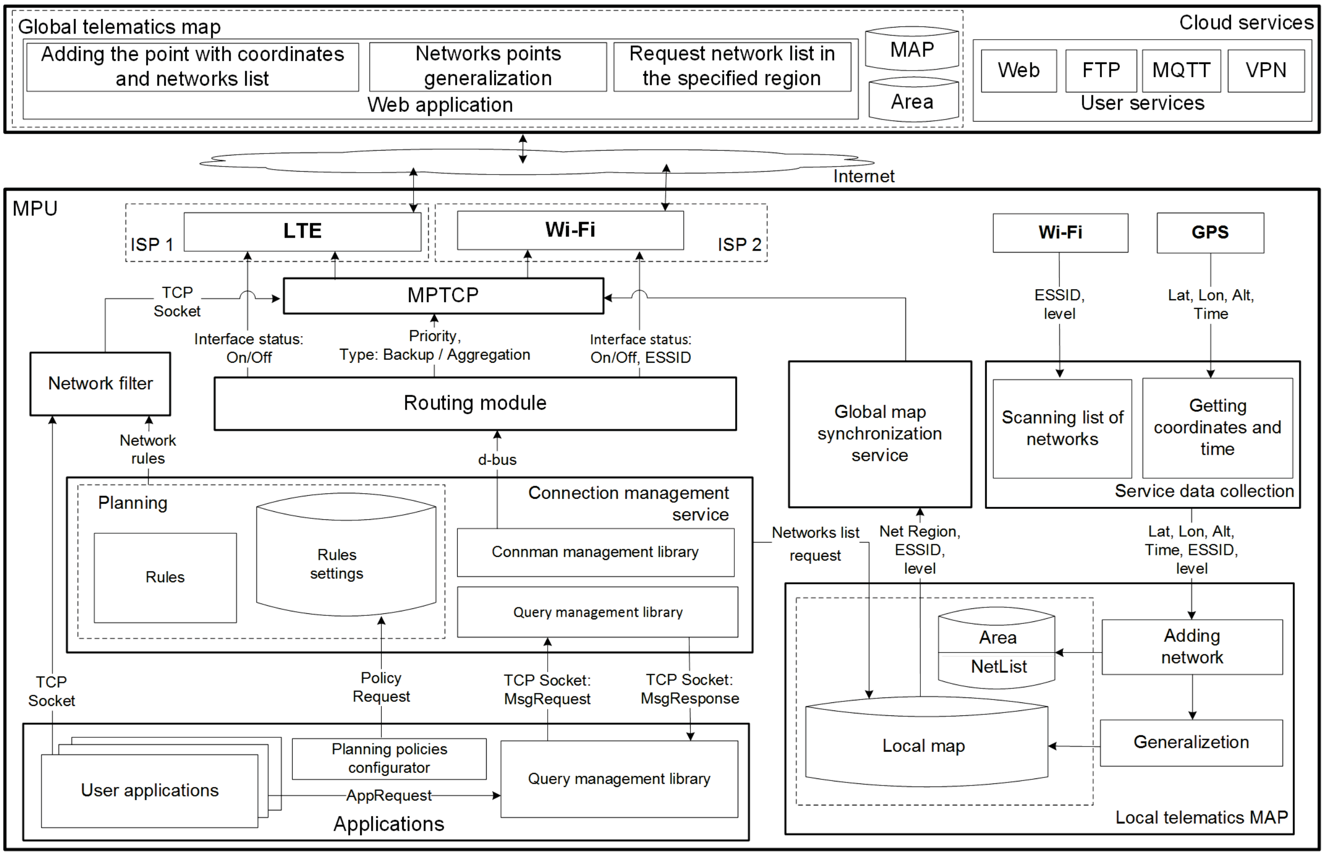

Fig. 1. The architecture of the connection management system

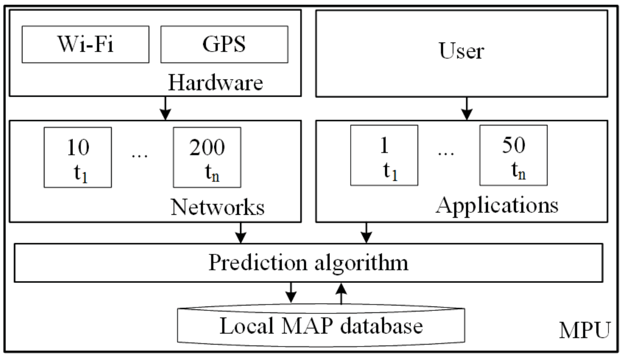

Fig. 2. Scheme of the experiment for analyzing the execution time of the prediction algorithm

route sorted by its values, the error is calculated by the formula:

$$error_{method} = 1 - |\frac{x-y}{z-y}|,$$

where x — the recommended network value obtained in step 1; y — the last value in the list of available networks; z — the first value in the list of available networks.

The error distributions of the three prediction methods relative to each other in the sequential selection of each of them are shown in Fig. 5, 6 and 7.

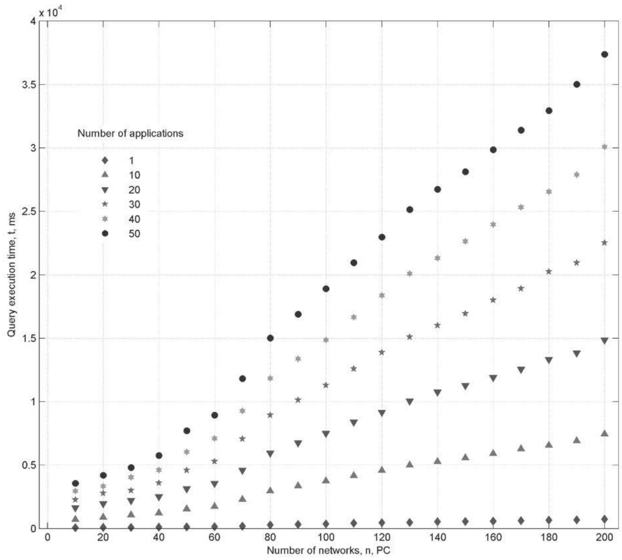

Fig. 3. Dependence of execution time of the prediction algorithm on the number of networks

The obtained distributions demonstrate priority status presence of the methods used for predicting the telematics situation, based on the compiled priority matrix, given in the

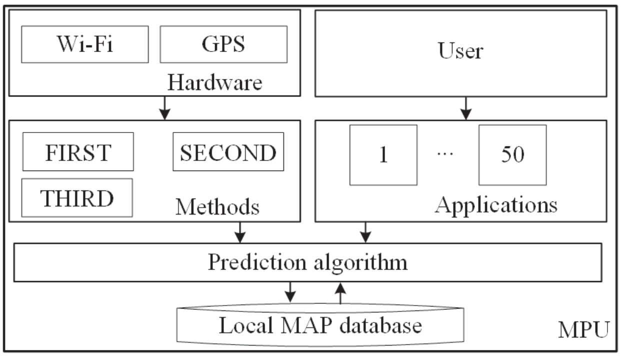

Fig. 4. Scheme of the experiment for analyzing network selection errors

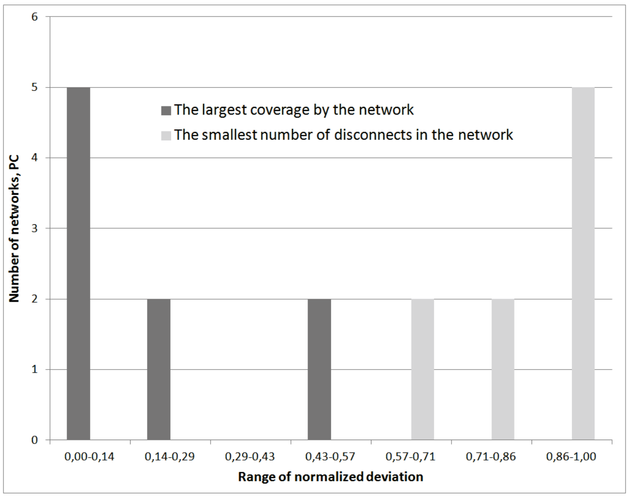

Fig. 5. Error distribution of the method of the largest coverage of the network and the method of the least number of disconnects of the network

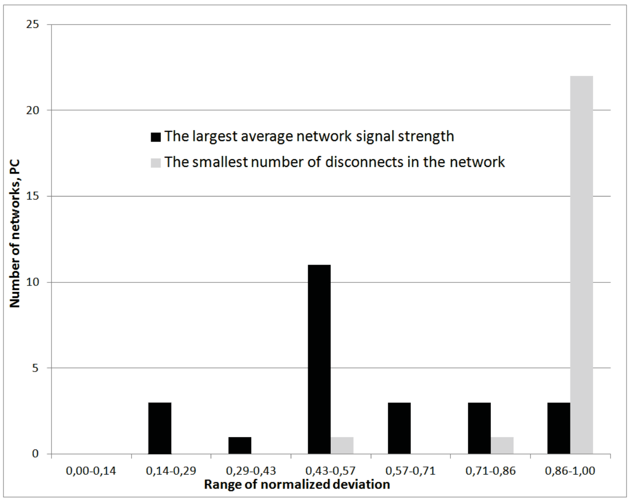

Fig. 6. Error distribution of the method of the largest average signal level of the network and the method of the least number of disconnects of the network

table II. In this connection, available wireless networks selected by the lower priority method of forecasting are less efficient for transmission of the corresponding type of network traffic. So, based on Fig. 5, it follows that for the transmission

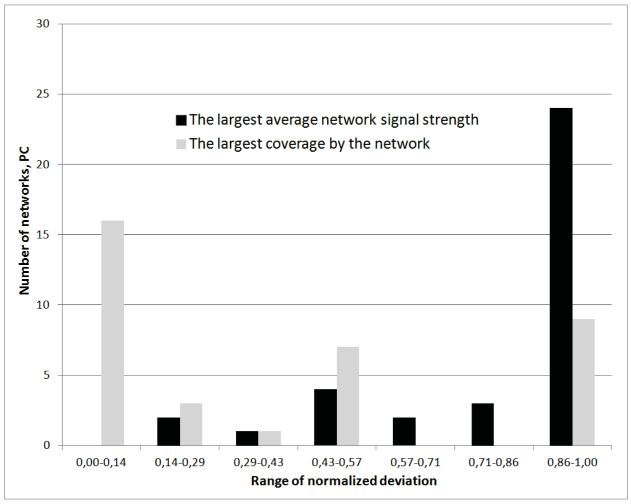

Fig. 7. Error distribution of the method of the largest average signal level of the network and the method of the largest coverage of the network

of conversational class traffic the best method of searching is optimal, from the point of view of uninterrupted network traffic exchange is the method of the largest average signal level, but it is also possible to use the method of the largest coverage of the network, while the method of the least number of discontinuities is completely useless for the type in question application.

C. *Query time analysis to local and global databases*

Main goal: obtaining the time dependence of the query execution time to obtain the list of available wireless networks on the selected route for the local and remote databases from the number of detected networks as a result of the query, which will make it possible to conclude that the remote database can be used as a source of information. The scheme of the experiment is shown in Fig. 8.

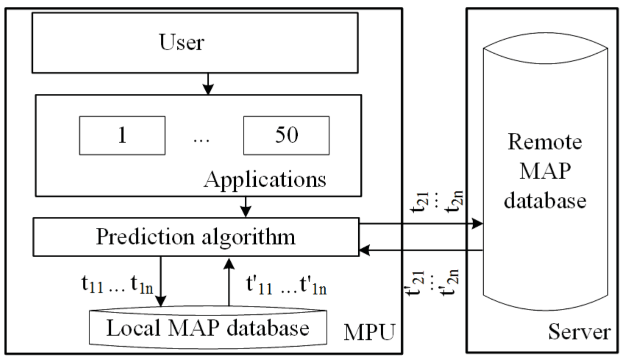

Fig. 8. Scheme of the experiment for the query time analysis to the local and global databases

To carry out the experiment, the algorithms for predicting the telematics environment executed on the client extracted the data of the used telematics map from the local and global databases. The databases on the client and on the server are identical by structure and content. The formula of the temporary difference request:

$$t_i = |t_{1i} - t_{2i}|, i = \overline{1, 50}$$

The software settings during the experiment are shown in the table II. Temporary request t_1 is recorded when accessing the local database, the response received from the database is recorded by time t'_1. Requests for a remote database are marked as t_2 and t'_2.

The processing of the results of the series of experiments made it possible to verify the practical applicability of the developed methods and the algorithm for predicting the telematics situation along the entire vehicle's route.

The dependence of the execution time of the request for obtaining the list of available wireless local networks for connection on the selected route from the number of detected networks for the local and global location of the telematics map is shown in Fig. 9.

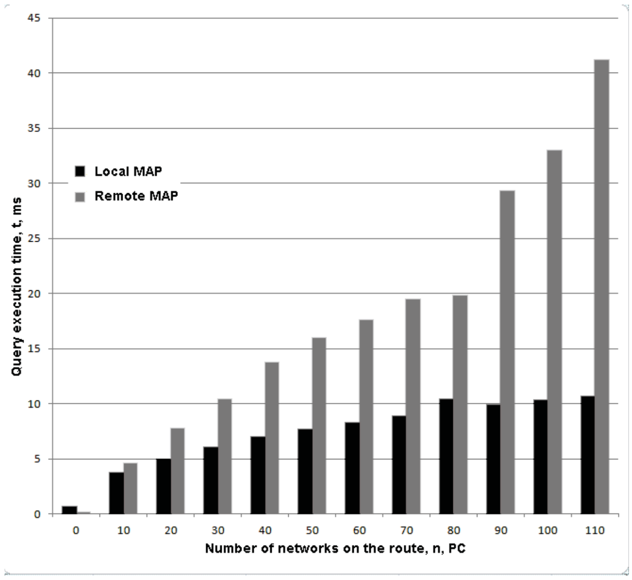

Fig. 9. Dependence of the query execution time on the number of networks for the local and global map location

Based on the obtained dependence, it can be assumed that with an increase in the number found on the basis of the results of completed queries available for connecting networks on the user-selected route, the query execution time to the databases is gradually increased. Moreover, the difference in the execution time of the query to the local and remote databases is not so great and amounts to an average of 10 ms, which allows distributing the load of obtaining telematic data between the local and remote databases, thereby creating a distributed system.

Time indicators of the functioning of the telematics prediction algorithm demonstrate the linear dependence of the execution time on the number of networks detected on the selected route. The running time of the algorithm makes it possible to use it with a dynamically changing number of launched user applications during the movement of the vehicle.

The dependence of the query execution time on the number of networks for the local and global location of the telematics map demonstrates the possibility of the practical distribution of the load of obtaining telematic data between them.

V. Conclusion

Developed methods for predicting the telematics situation on the vehicle's route, which provide the management of data on the telematics situation, which consists in obtaining the highest average level of the wireless local area signal on the user-selected route, the largest coverage of the network along the entire path, and the smallest number of network disruptions along the entire route. The methods are oriented to conversational, interactive and background network traffic classes.

In the prototype of the telematics data access system, the algorithm is implemented for predicting access to global and local telematics resources on the proposed vehicle's route.

Structure of the testbed includes: the hardware receiver of the global positioning system, the wireless local area network (Wi-Fi) transceiver, system software components for synchronization, data storage and developed application software.

For the realized algorithm, the temporal characteristics of the functioning of prediction methods from global and local telematics maps are investigated and it is shown that the time of the telematics prediction algorithm functioning demonstrates the linear dependence of the execution time on the number of networks detected on the selected trajectory, as well as the operating time that does not create additional overheads with increasing number of launched user applications to 50. The dependence of the query execution time on the number of networks for the local and global location of the telematics map demonstrates the possibility of the practical distribution of the load of obtaining telematic data between them.

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