The Technology of Management of Data About Wireless Networks for Vehicle's Telematics Map

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Abstract: The article studies temporal characteristics of functioning of the system of registration and data updating about the wireless networks signal level by the vehicle telematics card. The article presents algorithms of placement and retrieval of data about the signal level of wireless local area network of a geographical region into the database of multi-protocol unit of the vehicle; conditions and results of experiments on the study of functioning time of the system of database management of telematics cards. The experiments showed that the technology for collecting and updating map data on $2Hz$ request frequency can be applied. The results of experiments can be used as a basis for development of a specialized layer of GIS to provide information services of a moving vehicle to a driver and passengers.

1 INTRODUCTION

In a moving vehicle the problem of uninterruptible access to informational resources outside of the vehicle occurs (Zheng et al., 2015; Gerla et al., 2014; Zaborovskiy et al., 2013). The problem relates to locality of data about available wireless networks at current position on the route. The solution is to expand the scope of available wireless networks for driver and passengers on the whole route (Jaworski et al., 2011). In this case, implementing the technology of management of the telematics map gives the opportunity to schedule the provision of telematics resources to the driver and passengers during the movement of the vehicle.

Continuous supply with actual data about wireless networks of the region relies on the telematics map (Popov et al., 2015), which is a set of geoinformational system layers containing data about type, name and signal level of wireless networks of the area. In particular, it contains data about Wi-Fi, cellular, DSRC network (Miller et al., 2010; Dupuis et al., 2014). For the telematics map to operate correctly, each vehicle is continuously gathering data about surrounding wireless networks and writing it into the local (onboard) database where generalization occurs, after which these data are ready to be extracted and used for scheduling the data transmission upon a vehicle movement along the route (Glazunov et al., 2015).

The article covers one of the option of the telematics map implementation, which suggests to store the signal level of wireless networks in the regular grid of geographical coordinates. The choice of grid spacing is defined by the mean coverage area of Wi-Fi networks, GPS accuracy, and vehicle's speed. Different spacing leads to corresponding among of stored data about wireless networks signal level in the multiprotocol device's database. The analysis of dependencies between queries execution time and the grid spacing values allows to draw a conclusion about applicability of regular grid technology implementation in production samples of multiprotocol devices.

The purpose of the study is to gather and analyze dependencies of execution times of the queries which perform generalization and extraction of the data about telematics resources in the area on the regular grid spacing using relational database.

2 ALGORITHMS OF MANAGEMENT OF DATA ABOUT WIRELESS NETWORKS SIGNAL LEVEL IN THE AREA

The process of management of data about wireless networks signal level within the vehicle consists of

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two subprocesses: gathering and generalization of data about surrounding wireless networks signal level along the vehicle's route, and extraction of corresponding data at any arbitrary location of the vehicle. The first subprocess is functioning continuously and independently, while the second is starting only by the user applications request. Figure shows the structural diagram of processes of service and user data transmission 1.

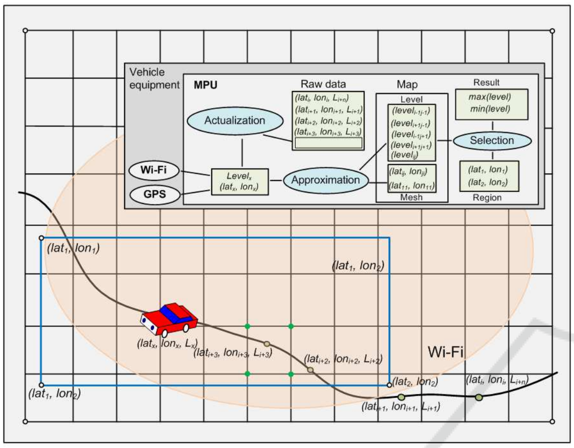

Figure 1: Structural diagram of wireless networks data management within the vehicle.

Data write cycle provides updated representation of wireless networks signal level, while read cycle is a service for determining the networks availability. Each subprocess is implemented as distributed algorithm which is functioning on both vehicle and server sides (Popov et al., 2015). In our work we set up both parts on a single telematics device to eliminate the impact of delays and bandwidth of communication channels and to get the accurate data about cooperative functioning of telematics map application and database, GPS and Wi-Fi devices and services.

The algorithms handle the environment which includes geographical region data defined by the latitude and longitude from upper right corner to lower left one, current vehicle's coordinates, and coordinates of the area where the wireless networks availability data must be obtained.

To represent the geographical area on the telematics map we specify a regular rectangular grid with fixed spacing. Each node of the grid stores the value of wireless network signal level. This value is then updated with the new values from the vehicle's onboard telematics unit. To implement the proposed concept we have developed and examined the algorithms for gathering, generalization, updating and extraction of relevant data about wireless networks availability.

The algorithm of adjusting the data about wireless network signal level in the nodes of regular grid.

The data adjustment algorithm performs a task of updating the wireless networks data on the telematics map as far as positioning device and Wi-Fi adapter feed it with new data.

Input data for the algorithm are geographical region which is represented by the regular rectangular grid with spacing of 5, 10, 15, 20, 25, 30 meters, the latitude and longitude of position where new value of signal level was measured and this new value itself. Using the given latitude and longitude values we find the four-linked rectangular area on regular grid, inside of which area the vehicle is located. When the area is found, we calculate the values of signal level in four neighboring nodes and update corresponding data in the database. Listing 1 shows the description of the algorithm in pseudocode.

The algorithm provides continuously repeatable calculations with frequency defined by GPS and Wi-Fi equipment polling rate. Latitude and longitude calculation of four neighboring nodes of the grid take into account the correction factors for parallels and meridians at the location where the data were acquired. For this purpose, we calculate the distance corresponding with one degree of latitude and longitude at the given location, thus allowing to consider correction values for any location.

The algorithm of approximation of wireless networks signal level in the area.

The algorithm's purpose is to approximate the signal level written to the nodes of the grid according to the signal level values gathered by the vehicle's telematics unit during its movement

When a new position with some signal level is determined inside the grid, we calculate the distance between this location and each of the neighboring nodes of the grid, then we normalize this distances and calculate the adjustments that will be applied to the signal level values already stored in the nodes. Schematic representation of this routine is shown on the figure 2.

Let z_x be the signal level at the point x with coordinates (lat_x, lon_x) and signal $level_x$;and let the four nearest grid points with latitude and longitude to $((lat_i, lon_j), (i, j) = [1 \ldots 4])$; a, b, c, d be the distances from the point x to nodes of a regular grid cell;and let K_1 and K_2 be the coefficient of linearity; and let m_1 and m_2 be the length of the diagonals; and let $z_i, i = [1 \ldots 4]$ be the signal levels of nodes of quadruply-connected areas calculated using the algorithm of data update see bellow.

First compute the distance a, b, c, d from the point x to the closest nodes of the cell; then calculate and

Algorithm 1: The pseudocode of the algorithm of adjusting the wireless networks data in the grid nodes

Data: Latitude and longitude (lat_x, lon_x) of the vehicle's location; p_i — regular grid nodes with coordinates (lat_i, lon_i), where $i = [1 \dots 4]$; geographical grid of rectangular area with corners coordinates (lat_1, lon_1); (lat_2, lon_2) and spacing k.
Result: Updates values of signal level at four neighboring nodes.

while *Have GPS and Wi-Fi data* **do**
  GET from GPS (lat_x, lon_x); from Wi-Fi *level*
  lat_m — length of one degree of latitude in meters
  lon_m — length of one degree of longitude in meters
  $N_{lat} = \frac{|(lat_2 * lat_m) - (lat_x * lat_m)|}{k}$
  $N_{lon} = \frac{|(lon_2 * lon_m) - (lon_x * lon_m)|}{k}$
  $z^1_{lat} = \frac{((lat_2 * lat_m) + N_{lat} * k)}{lat_m}$
  $z^1_{lon} = \frac{((lon_2 * lon_m) + N_{lon} * k)}{lon_m}$
  $z^2_{lat} = \frac{((lat_2 * lat_m) + N_{lat} * k)}{lat_m}$
  $z^2_{lon} = \frac{((lon_2 * lon_m) + [(N_{lon} + 1) * k])}{lon_m}$
  $z^3_{lat} = \frac{((lat_2 * lat_m) + [(N_{lat} + 1) * k])}{lat_m}$
  $z^3_{lon} = \frac{((lon_2 * lon_m) + N_{lon} * k)}{lon_m}$
  $z^4_{lat} = \frac{((lat_2 * lat_m) + [(N_{lat} + 1) * k])}{lat_m}$
  $z^4_{lon} = \frac{((lon_2 * lon_m) + [(N_{lon} + 1) * k])}{lon_m}$
  database query
  update(
  (z^1_{lat}, z^1_{lon}); (z^2_{lat}, z^2_{lon});
  (z^3_{lat}, z^3_{lon}); (z^4_{lat}, z^4_{lon}))
end

normalize the given to diagonal distances m_1, m_2; and then on their basis determine corrections to the signal levels at the nodes. At the last step of the algorithm the corrected values are taken as new nodes in the mesh. The block diagram of the algorithm is given in figure 3.

The algorithm performs the following mathematical operations:

calculation of distances to the grid points a, b, c, d, for example, on distance a:

$|a| = \sqrt{(lat_x - lat_1)^2 + (lon_x - lon_1)^2}$;

calculation of the lengths of the diagonals m_1 and m_2, for example on m_1:

$|m_1| = \sqrt{(lat_2 - lat_1)^2 + (lon_2 - lon_1)^2}$;

calculation of the normalized distances:

to the first diagonal $m_1 = y_1 + y_4$: $|y_1| = \frac{(a^2 - d^2 + m_1^2)}{(2m_1)}$; $|y_4| = m_1 - y_1$;

for the second diagonal $m_2 = y_2 + y_3$: $|y_2| = \frac{(c^2 - b^2 + m_2^2)}{2m_2)}$; $|y_3| = m_2 - y_2$;

Calculation of the normalization coefficients: $K_1 = \frac{y_1}{m_1}$; $K_2 = \frac{y_2}{m_2}$

the calculation of the correction of the level signals is based on the following formula:

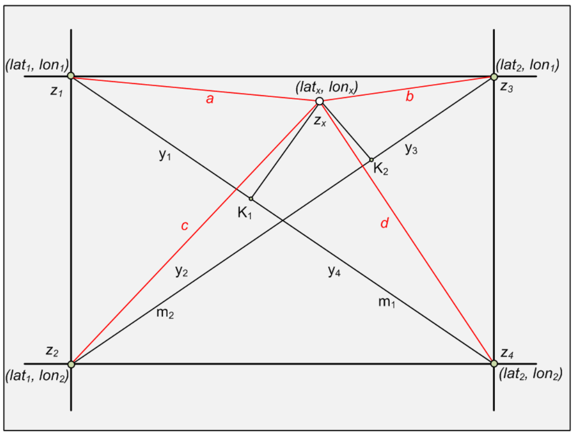

Figure 2: Graphics representation of the algorithm of signal level approximation.

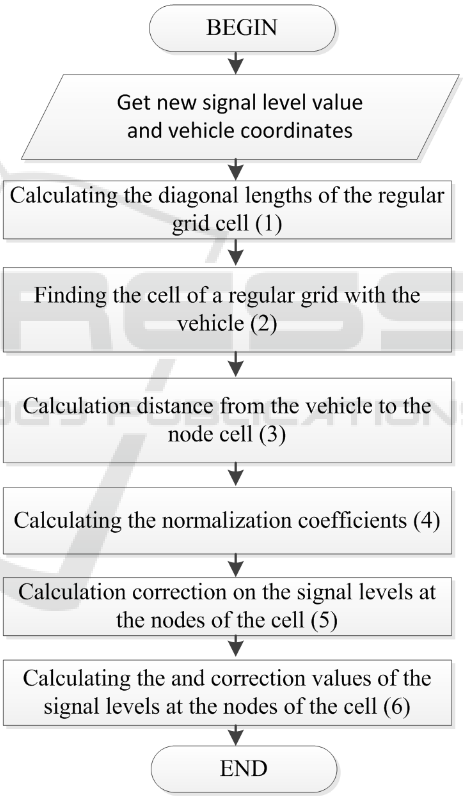

Figure 3: Flow chart of the algorithm of linear approximation of the signal level.

for the first node: $\Delta z_i = z_i + (z_x * level_x * K_i^2)$, where $i \in [1 \dots 4]$;

following equations are used to calculate new values of signal levels of node cells:

for the first node: $z_i' = \Delta z_i + |\frac{(\Delta z_i - z_i)}{n_i}|$,

where $i \in [1 \dots 4]$ and n_i is the number of changes of the signal level in the corresponding unit cell.

The algorithm supports continuous updating of the values of the signal level at the nodes of a regular grid.

The algorithm of selection of signal level data of wireless networks available in the area.

The algorithm of selection of wireless networks signal level allows to schedule the provision of telematics resources to the driver and passengers during the vehicle's movement along the route. Schematic diagram of the algorithm is shown on the figure 4. Input data for the algorithm are: latitude and longitude of diagonal corners of the rectangular geographical area where the signal level values must be obtained.

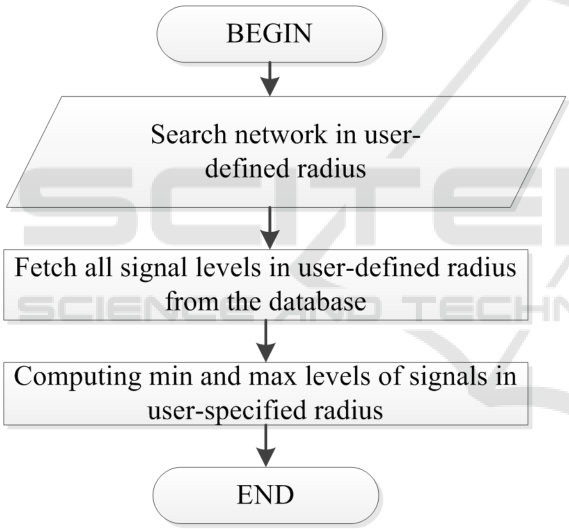

Figure 4: Schematic diagram of the algorithm of selection of wireless networks signal level.

The algorithm allows to extract the data about maximum and minimum signal level of wireless networks within the selected rectangular area.

3 EXPERIMENTAL CONDITIONS AND RESULTS

Using the database scheme from (Glazunov et al., 2015), we had implemented the algorithm of generation of regular grid with given spacing value, data generalization algorithm, and algorithm of extraction of wireless networks data from four-linked area. The prototype of the telematics device used in experiments is the multiprotocol unit, which was earlier used as a part of cloud services test bench (Glazunov et al., 2013).

The algorithm of regular grid management, generalization algorithm, and wireless data extraction algorithm were all tested using a PC with an Intel Core i5 processor clocked at 2.4 GHz, and equipped with 8 GB of RAM. The code and services were running inside a virtual PC environment under Ubuntu Linux 12.04 LTS as a guest operating system. To implement the algorithms, we used PHP version 5.3.10 programming language. As a data storage we used MySQL version 5.5.40 relational database management system.

For each algorithm we wrote the script which includes implementation of the algorithm and time registration routines. As a test area we used the geographical region of 800×300 meters size with coordinates of its center at N60° 0′ 18.94″ E30° 22′ 33.32″. The data updating script generated equidistributed random coordinates (lat_x, lon_x) inside the selected area and signal level values $level_x$ at 2 Hz frequency, and registered the time spent on execution of data updating routines. Data extraction script generated equidistributed random coordinates of rectangular area $(lat_1, lon_1);(lat_2, lon_2)$ and registered the time required to extract the maximum and minimum signal level within the area. Execution times were written to file for subsequent processing. Data updating script and data extraction script executed simultaneously.

After conducting a series of experiments, we got some statistics about operations of data generalization and selection in cases of different grid spacing.

Experiment shows that number of very slow data generalization queries is a fraction of a percent. Minimal query execution time equals for any selected grid spacing, because database updates the first records in the index of telematics map tables. The number of records to store updated telematics map data depends quadratically on grid spacing value. The grid data took one page of the database table, so the size of the table is constant.

Figure 5 shows the distribution of execution time of data generalization routines on the grids with different spacing.

Diagram shows that query execution times distribution is a gamma distribution, and that maximum number of operations for any grid spacing except 5 and 10 meters fall less than 2.50 ms execution time range. Maximum number of values in the range of 2.50–4.00 ms in case of grid with 5 meters spacing is explained by the increasing search time of required

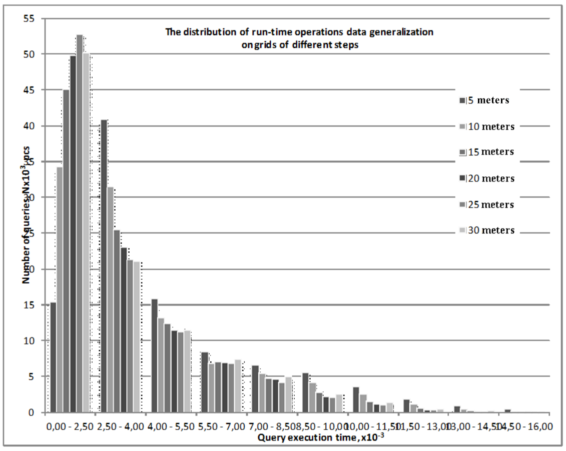

Figure 5: Distribution of execution time of data generalization routines on the grids with different spacing.

range in the database table by the reason of large amount of points.

More than 70% of all queries were executed faster than 5 ms, thus allowing these algorithms to operate in parallel with other applications and processes which use the telematics map.

The distribution of execution times of data extraction routines in case of different grid spacing is shown on the picture 6.

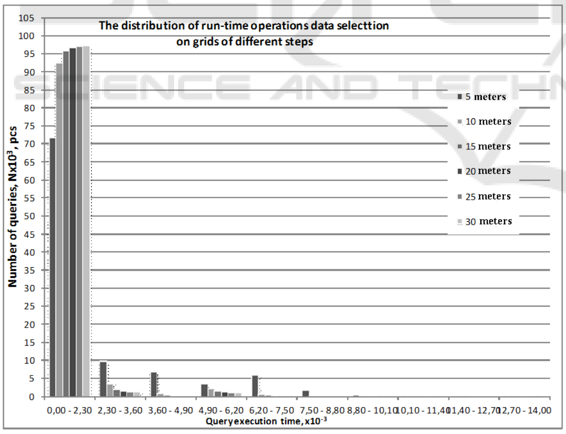

Figure 6: The distribution of execution times of data extraction routines using different grid spacing.

Diagram shows that 90% of all operations require less than 2 ms to complete, thereby providing uninterruptible processing of large amount of queries from the multiple user applications.

Diagram 7 shows the dependency of the mean execution time of data updating and extraction algorithms on the telematics map grid spacing. It is seen that algorithms execution time quadratically depends on grid spacing, which relates to quadratic dependency of number of grid nodes on its spacing and linear dependence of query execution time on the number of nodes. Irrelational increase in query execution time in case of 30 meters grid spacing is explained by the deny of the database query optimizer to use indexes due to relatively small number of records in the regular grid table. Data processing time in this case will noticeably decrease with the larger geographical area.

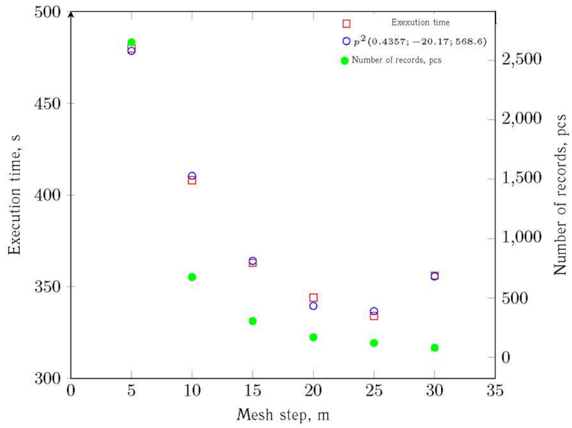

Figure 7: Dependency of execution times of the queries on the number of database records.

4 CONCLUSION AND SUBSEQUENT WORK

This paper describes the experiments with the prototype of the multiprotocol node in part of implementation of the technology of wireless networks data management within the telematics map with the use of relational DBMS and high-level programming language. The implemented algorithms of data gathering, updating, and extraction shown the operability of the prototype as a whole.

Conducted research of execution times has proved the applicability of technology of telematics map data updating and extraction at a rate of 2 Hz.

While the total write cycle time averages at 0.5 seconds, the algorithm only requires 3.6 ms average in case of data updating and 1.45 ms average in case of data extraction, which does not exceed 12% of total cycle time. These results allow to confidently talk about possibility to increase the rate of map data updates or connect multiple additional user applications to the telematics map.

As a subsequent work we consider to analyze the operational quality of algorithms of signal level values approximation in the grid nodes and a research on synchronous and asynchronous mechanisms of database replication between the local telematics map and the cloud service.

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