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Tests of Smartphone Localization Accuracy Using W3C API and Cell-Id

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***Abstract*—Location based services (LBS) are considered very relevant for the users of mobile networks. All local events and facts related to area nearby seem to be more important that others which happen in remote places. Localization data is used in all types of services: weather, traffic, tourist info, etc. One of its most important (and regulated by law) applications is providing persons location in case of emergency.**

This paper presents results of field tests related to assessment of accuracy of two most commonly used localization methods: Cell-Id and W3C Geolocalization. The tests were conducted in the form of test drives along some of the most important roads in Poland. Position of the test vehicle obtained using analyzed methods was logged and compred to localization obtained from the Global Positioning System (GPS).

Data collected during test drives was processed and statistical information about localization accuracy was calculated. Results obtained for different methods were compared and conclusions about localization quality are provided.

The paper also describes test environment and data model which were used during work being reported.

I. Introduction

RECENT surge in number of smartphones used worldwide causes increased interest in development of applications dedicated for advanced mobile phones. There are many types of applications available which can be either bought or downloaded for free. Depending on user's current needs he or she can select from company's application shop (e.g. Google Play, Samsung Apps, iTunes) what suits him best. Typically, after having used application for some time user is expected to assess the application and share his/her opinion for the benefit of its developers and future users.

Smartphones are considered to be personal devices which are almost always carried by their owners and used in all kinds of places and situations. This means that *portability* is one of their key features and all services and content which are based on their localization are more relevant than generally available, non-localization dependent, information.

Valuable and popular services are available not only in the form of applications. To provide a complete offer, application developer very often prepares a version which can be used in a web browser run on a mobile phone. Such services are typically written using HTML5 and Javascript which gives great flexibility in preparing user interface which can be very similar to interface prepared for native application.

This paper focuses on assessment of localization algorithms available to developers of browser based services.

II. Localization Methods

There are different sources of device localization available for the application and service developers. The best accuracy can be obtained using positioning systems based on signals emitted by satellites (e.g. GPS, GLONASS, Galileo) [10], [4]. However, it is not always possible to use this method of localization (due to lack of satellite signal, limitations of device battery capacity or simply lack of required signal receiver in the device). In such cases localization can be obtained from a cellular network or through algorithms provided by operating system vendor.

A. W3C Gelocalization API

This API [9] was proposed by World Wide Web Consortium (W3C) [2] as the uniform way to access mobile device location from the Web browser. It is currently implemented in all popular browsers. The API defines programmatical access to localization data. Taking available information as input data, dedicated algorithms are able to calculate position of the mobile device and asses accuracy of such calculations. The most commonly used data sources include: Wi-Fi connection parameters, device's IP address used for mobile communication, list of sensed GSM/CDMA cells, radio communication signal strength.

Location providers continuously collect data from mobile devices being used worldwide and improve quality of localization accuracy. However, because they do not control configuration of the infrastructure which is used for mobile communication, any major change in it may cause drop in the quality of information obtained through the API.

B. Cell-Id based localization

Localization based on Cell-Id is one of the most commonly methods used by land mobile networks. Its popularity comes from the fact that it relies on the mechanisms already in place which are required for basic voice and data communication.

Implementation of Cell-Id localization requires relatively low investment in network infrastructure. Usually, deployment of a Gateway Mobile Location Center (GMLC) is the key part of projects aiming to launch such capabilities in the mobile network.

In this method, a geographical location (a pair of coordinates) is assigned to every cell in the network. Location error depends on the size of a cell and can vary from tens of meters to c.a. 20-30 kilometers.

Localization accuracy is related to the size of the cell which serves the mobile device. Previous work [5], [8], [12], [11] showed that cell sizes depend on the type of the area. Smaller cells are found in city centers which is in accordance with network capacity requirements. In the rural areas, bigger cell sizes are used to ensure network coverage.

Other, more accurate, localization methods are also available: Time of Arrival, Enhanced Observed Time Difference [7], [6]. They rely on information coming from more than one network towers (base stations). Using information about signal strength and/or time parameters of communication between the device and the base station, it is possible to calculate user location with smaller error. This, however, requires additional infrastructure which is not available in many networks.

III. Data Model

Let *a localization* of an object be defined as a pair $p = \langle x, y\rangle \in \Re^2$, where x and y are called *coordinates* of object's location. Distance between two objects will be denoted as $d : \Re^2 \times \Re^2 \mapsto \Re^+ \cup \{0\}$.

Many different coordinate systems are used worldwide. Humanity since centuries needed the ways to represent parts of the Earth surface (modeled as an ellipsoid) as a subsets of a plane (the maps). Nowadays, the projection which is used in GPS (known as WGS84) is a de facto standard in the Internet. In WGS84 *geographic* coordinates i.e. latitude and longitude of a point are provided. Because of that, in order to avoid systematic error in calculations of the objects' distance, coordinates have to be translated to a Cartesian coordinate system. PUWG2000 which is a Polish standard of geodetic coordinates was used during calculations reported in this paper.

Let localization event l be a triple $l = \langle t, p, a\rangle$, where $t \in \Re^+ \cup \{0\}$ is a timestamp of the event, p is object's location at time t and $a \in \Re^+$ is a measure of localization accuracy.

Let $L = \{l_1, l_2, \ldots, l_N\}$ denote *localization event stream* defined as a finite sequence of N localization events ordered according to timestamp values.

L models information about object's location at some points in time. Based on L it is possible to estimate object's location $p'(t, L)$ at any point in time. During calculation of $p'(t, L)$ it is assumed that:

- the object was located at p_1 for all $t < t_1$,
- for $t_k, t_{k+1} \in \langle t_1, t_N\rangle$ the object was moving with constant velocity along line segment $\overline{p_k p_{k+1}}$,
- the object was located at p_N for all $t > t_N$.

During the tests the following localization data was collected:

- L^{GPS}- vehicle track logged by GPS device (Garmin eTrex Vista),
- L^{Orange}- geolocalization using Cell-Id in Orange Polska,
- L^{iPhone}- sequence of localization events of iPhone device,
- L^{Android}- W3C Geolocalization API events obtained for Android device.

The goal of the test was to compare different localization methods. The basic measure of localization quality is a localization error $e \in \Re^+ \cup \{0\}$. It is defined as the distance between point being a result of analyzed localization method and a point $p^{\text{GPS}} = p'(t, L^{\text{GPS}})$ i.e. object's localization according to GPS receiver.

Let $E = \{e_1, e_2, \ldots, e_N\}$ be a localization error stream defined as a finite sequence of localization errors. For each L a localization error stream can be calculated, providing that a reference localization event stream $L^{\text{GPS}}$is available.

In order to compare different localization methods, the basic statistics were calculated for E^{Orange}, E^{iPhone}, E^{Android}which denote localization error streams calculated for L^{Orange}, L^{iPhone}, L^{Android}respectively. The results of these calculations are presented in the following sections of this report.

IV. Test Environment Configuration

The tests were performed in the form of test-drives during which localization of the vehicle was monitored using methods which were to be compared. Additionally a GPS receiver was put onboard of the test vehicle. It was used for logging of the vehicle location with maximum available accuracy and frequency.

During the tests the following devices were used: iPhone 3GS (iOS), ZTE SanFrancisco (Android), and Garmin eTrex Vista GPS receiver. Smartphones were equipped with subscription of Orange Polska mobile network.

The Fig. 1 shows main components of the test environment and main communication channels between them. iPhone and Android smartphones communicate with W3C API servers to receive device localization. When localization is calculated and returned to the device it sends a request to log it in the test application. Devices' localization is concurrently monitored by mobile network through Gateway Mobile Location Centre (GMLC). Position of the vehicle is logged by GPS device.

For the purpose of the test a dedicated web page was designed, developed, and exposed in the Internet. Its role was to trigger calls to W3C Gelocalization API on any device which opened it in the Web browser. Result of the localization API calls was logged in a database which was located on a Web server.

V. Test results

The test drive took place in January 2013. Its route is shown in Fig. 2. The tests covered some of the most popular roads in Poland. Test drive started in Warsaw and then proceeded through Czestochowa, Krakow, Nowy Targ, Kielce, Radom and ended in Warsaw.

A. Maps

After completion of the test-drive, data were processed and visualized using open source Quantum GIS [3] software. Sample maps showing data collected during tests-drives are presented in the Fig. 3, Fig. 4, and Fig. 5.

Places which are results of localization procedures are marked with dots. Dashed line segments connect locations obtained through different methods and actual device's position.

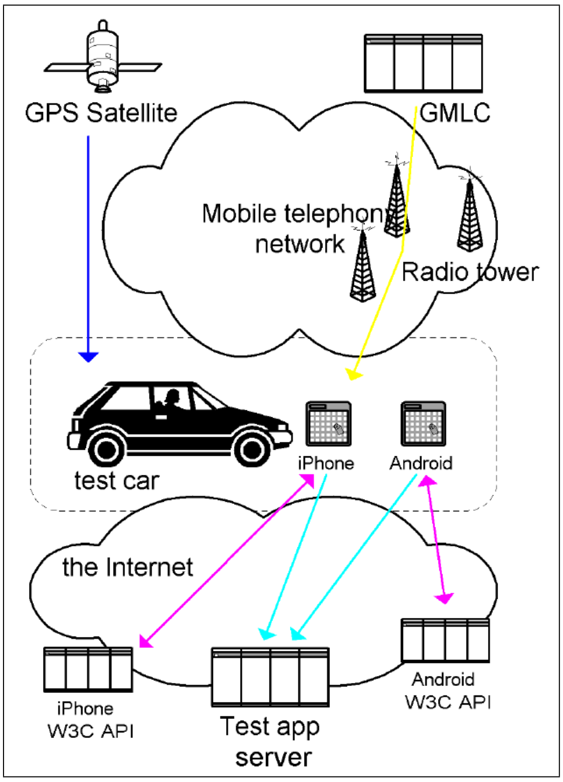

Fig. 1. Test data collection environment

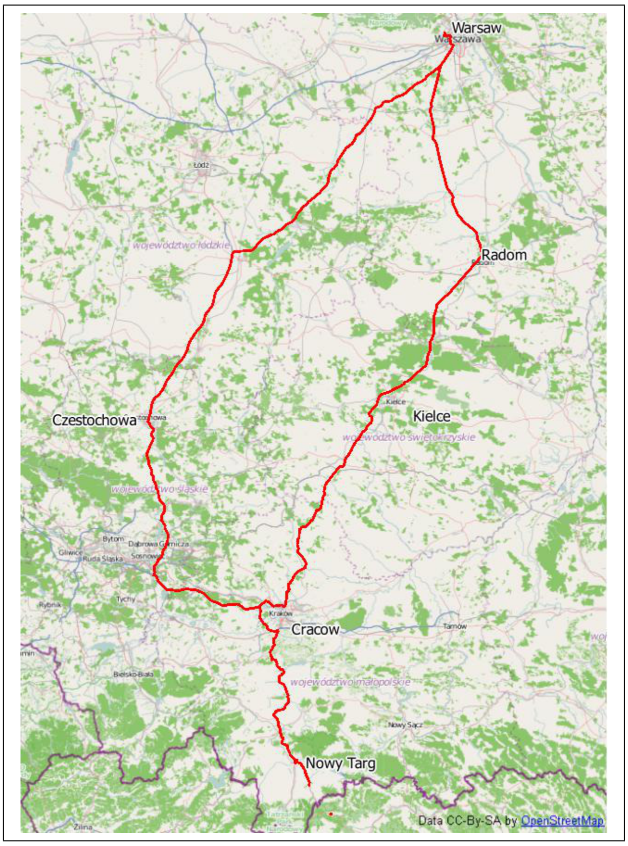

Fig. 2. Test drive routes

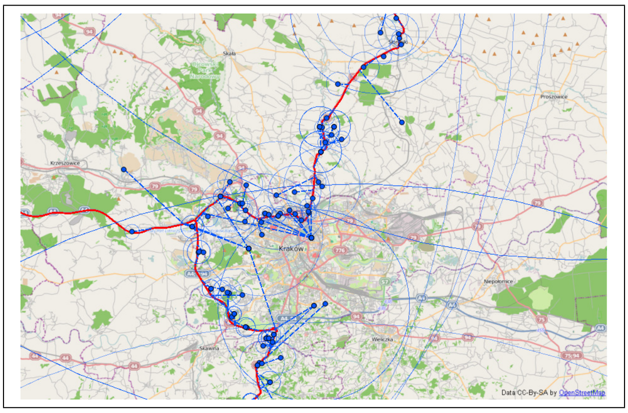

Fig. 3. iPhone location events in Cracow area

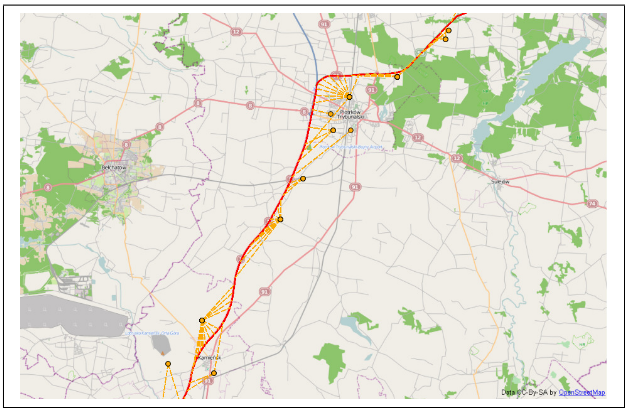

Fig. 4. Cell-Id (Orange Polska) localization events

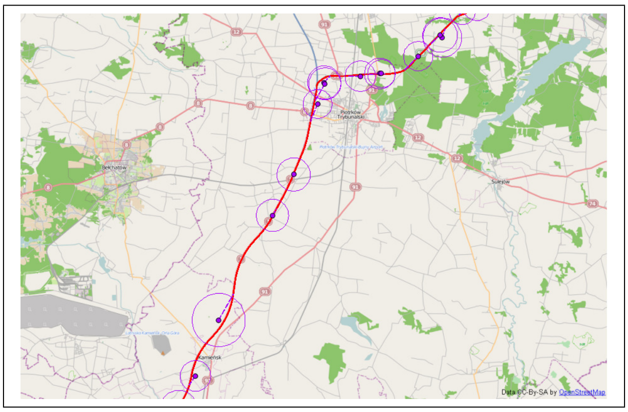

Fig. 5. Android localizations near Piotrkow Trybunalski

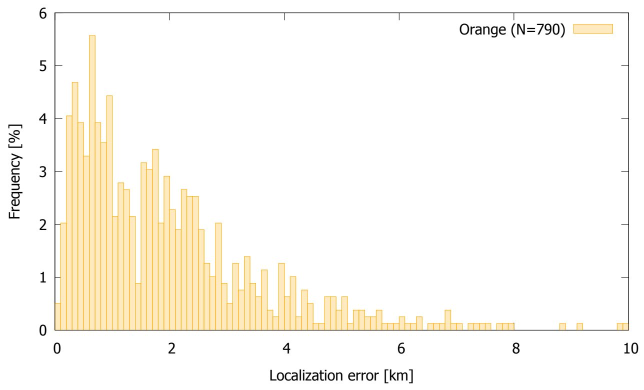

Fig. 6. Cell-Id location error distribution

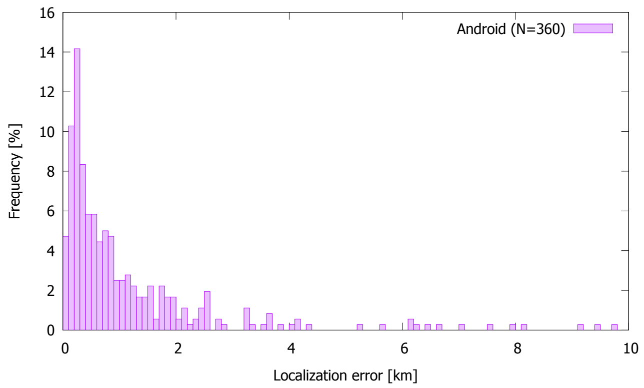

Fig. 7. Android location error distribution

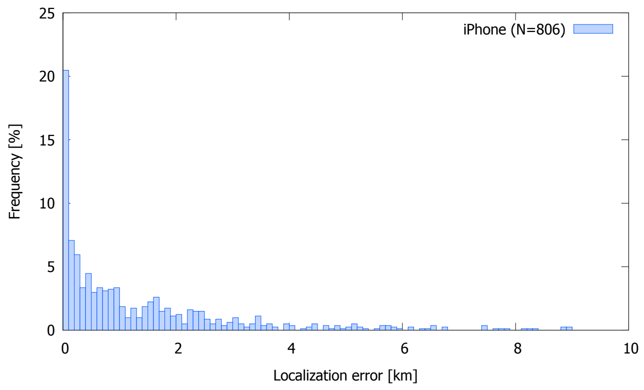

Fig. 8. iPhone location error distribution

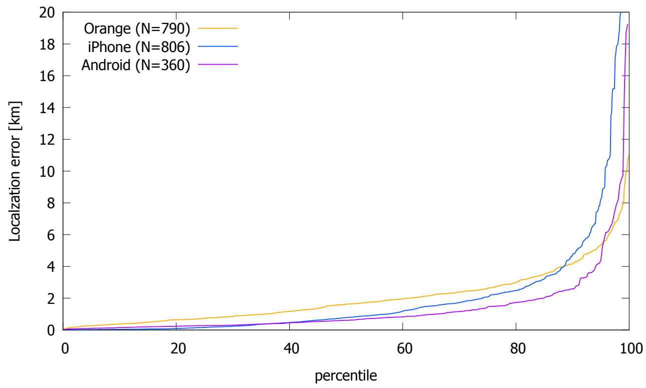

Fig. 9. Error value - cumulative distribution

Circles represent accuracy of localization as returned by W3C Geolocation API.

From the analysis of graphical data it can be concluded that in most of the cases W3C API localization is much more accurate than one based on Cell-Id. However, for some events W3C API localization error (examples can be seen in Fig. 3), is several times higher and is comparable to localization errors found in Cell-Id method.

B. Localization error distribution

In Fig. 6 location error density for Cell-Id is shown in the form of a normalized histogram. The maximum number 5.6% of location events fall in to the bin representing range $\langle 0.6\text{km}, 0.7\text{km}\rangle$ of error value.

Similar histograms visualizing data related to W3C API implemented in iPhone and Android mobile phones are shown in Fig. 7 and Fig. 8.

The bins with maximum percentage of events are: $\langle 0.2\text{km}, 0.3\text{km}\rangle$ for Android phone and $\langle 0.0\text{km}, 0.1\text{km}\rangle$ for iPhone. They account for 14.2% and 20.4% of localization events respectively.

C. Comparison

Localization quality of analyzed methods is compared on chart in Fig. 9 and Fig. 10. It presents cumulative distribution of localization error for all localization methods. It can be noted that for the range from 0m until about the median, iPhone localization is much better than other two. Taking into account about 90% of measurements Cell-Id localization is worse than other two. However, when all results are analyzed, the maximum error values significantly are smaller in case of Cell-Id than in methods based on W3C API.

Summary of basic statistical information is presented in

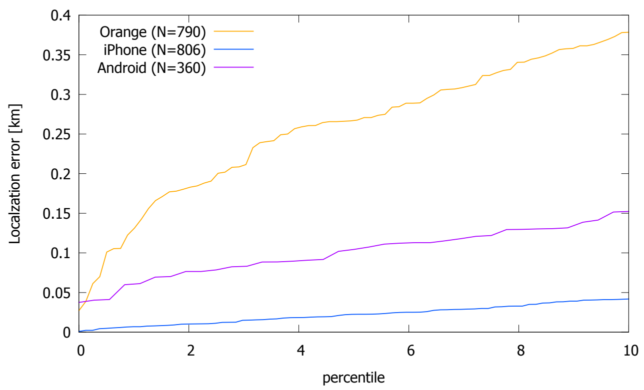

Fig. 10. Error value - cumulative distribution 0-10th percentile

TABLE I
COMPARISON OF LOCALIZATION ERROR STATISTICS. VALUES IN KM

Method	N	e_{avg}	σ	Q_1	Q_2	Q_3	e_{max}
Cell-Id	760	1.99	1.77	0.73	1.62	2.62	10.96
Android	360	1.28	2.16	0.28	0.61	1.40	19.24
iPhone	806	2.18	5.38	0.16	0.78	2.07	80.30

Table I. Taking into account average error value and standard deviation, Cell-Id seems to be the best localization method. However, there is big discrepancy in values of the first, second, and third quartiles in favor of W3C API methods.

VI. CONCLUSIONS

The set of tests showed that both W3C Geolocation API and Cell-Id methods are very good sources of location information for application developers. The quality of the W3C API implementations is very impressive, keeping in mind that API providers do not have any a priori information about spatial configuration of GSM and Wi-Fi networks.

Tests were performed with a kind of black box approach. Probably some results could be explained if geolocation algorithms used by Android and iPhone APIs were known.

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