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LocFusion API – Programming Interface for Accurate Multi-Source Mobile Terminal Positioning

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***Abstract*—The aim of this paper is to present a prototype LocNet API programming interface for indoor positioning systems and a prototype LocFusion API interface enabling joint use of terminal positioning data from mobile operator's GMLC and the LocNet API. The use of data from complementary information sources can improve the accuracy of user terminal positioning in large buildings, where coverage of satellite systems is weak.**

***Index Terms*—Location Services (LCS), Application Programming Interface (API), Open Middleware, Mash-Up Services**

I. Introduction

THE ABILITY to determine the geographical position of a wireless terminal allows telecom operators to implement new Location Based Services (LBS) [1], [2], [3], [4]. Mobile operators can provide their subscribers with a variety of information related to their actual geographic location, e.g. the nearby points of interest such as ATMs, hotels, restaurants, gas stations, traffic information, etc.

Terminal localization techniques used in contemporary mobile communications networks vary in accuracy offered, implementation complexity and cost. The simplest positioning methods, such as Cell-ID or received signal strength (RSS) based, are usually easy to implement in existing networks and do not require any modifications to the user terminals. The accuracy offered by these methods strongly depends on the size of the cells as well as on radio wave propagation conditions. In typical scenarios, the positioning accuracy varies from a few hundreds to tens of meters. Much better positioning accuracy may be achieved with the use of satellite positioning systems, such as the popular GPS. Satellite systems allow to determine user location with an accuracy of up to a few meters. However, the use of satellite receivers for accurate positioning of mobile terminals in indoor environment or in densely built up city centers is difficult or impossible. Thus, due to the weak coverage, satellite systems are not useful in areas with a large concentration of users (i.e. where such services are needed) [5]. These limitations of contemporary positioning systems contribute to the search for alternative high accuracy and availability methods suitable for complex environments.

One of the possibilities to increase accuracy of positioning in indoor areas is to use dedicated local positioning systems [6] along with contemporary Gateway Mobile Location Centre (GMLC) service. An attempt to integrate local indoor positioning systems with UMTS network architecture was described in [7]. The authors proposed integration of local indoor positioning networks (Assistant Location Networks) directly into core network.

In this paper we present a prototype LocFusion API. This programming interface allows joint use of information obtained from the GMLC of the network operator and from an indoor positioning system. In the prototype implementation, the access to the GMLC data is provided by Orange Labs Poland with the use of TerminalLocation API Telco 2.0 interface [8]. The information from local positioning systems is available through the proposed LocNet API interface.

The remainder of this article is organized as follows:

- Section II presents the basic concept and principles of operation of LocNet API prototype. LocNet API allows to access the results returned by local indoor positioning systems extending the range of satellite based localization services.
- The architecture, the operation, and the implementation of LocFusion API prototype are described in section III. LocFusion API allows joint use of location information from the operator's GMLC and the LocNet API.
- Section IV provides possible usage scenarios for LocFusion API.
- Section V summarizes the paper.

II. LocNet API

LocNet API is a universal programming interface used to communicate with compatible local indoor positioning systems. The interface retrieves the coordinates (x, y, z) describing the user's location inside the building along with supplementary position related information, e.g. description of the zone of the building, floor number etc. The interface specifies only communication protocol and does not impose implementation of any particular positioning methods and algorithms. Thus, the LocNet API can be used with many different classes of positioning systems.

The prototype implementations of LocNet API described in the paper were tested with two different positioning systems: LocNet indoor positioning and tracking system developed and maintained by Lodz University of Technology [9], [10], and LocNet-PW terminal positioning system developed by Warsaw

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University of Technology and Orange Labs Poland. Both systems used throughout the tests employ GSM and/or Wi-Fi received signal strength (RSS) measurements [11] to estimate the actual position of the terminal [12]. However, the two systems employ various classes of positioning algorithms and are implemented with the use of different server technologies.

To enable interaction between local positioning servers and LocNet API, the servers should be capable to accept LocNet API compatible requests and return positioning results in LocNet API compatible data format.

LocNet API application server is responsible for registration and management of local positioning servers providing terminal location information. This is achieved with the use of a database storing information on LocNet locations (i.e. sites where local positioning systems are available) and corresponding configuration parameters.

LocNet API application servers also triggers GSM/Wi-Fi RSS measurements required to estimate actual terminal position. To achieve that, the server communicates with user terminals. To support the RSS measurements, a dedicated LocNet Android application was developed. The application designed for Android based mobile devices performs GSM/UMTS/Wi-Fi signal strength measurements and passes the results back to the server. After successful initialization, LocNet Android application runs in the background. The application can be activated with the use of SMS message sent by LocNet API. After activation, the application starts the measurement procedure and sends the results back to the LocNet API. RSSI measurement results are sent in JSON format.

III. LocFusion API

The main goal of the LocFusion API interface is to allow joint use of terminal location data from different, complementary sources [13]. LocFusion API permits co-operation with local indoor positioning systems through LocNet API and with the GSM/UMTS network Gateway Mobile Location Centre (GMLC) via RESTful API exposed by PLMN operator. The possibility of common use of the location information from different sources makes it possible to determine more accurate information on the probable location of the user terminal.

LocFusion API enables to determine the user's location information in one of the two modes. Basic operation mode involves determining the user's location based on the results of the received signal strength measurements collected at a single point of the building. The other mode involves the possibility of determining the position of the terminal based on a sequence of signal strength measurements collected along the path describing the movement of the user [14].

LocFusion API interface makes it possible to easily incorporate additional sources of positioning information, such as RFID, dedicated WLAN systems using other communication protocols (ZigBee, 6LoWPAN), inertial sensors, etc.

A. API Architecture

The system is composed of three main modules: local positioning networks coupled with local positioning server, dedicated application server that manages all local positioning networks and exposes their features via web-based API, and main application server that manages all of the elements and communicates with the user. A database of sites where wireless local positioning networks are deployed is managed and supervised by LocNet API application server. The server also provides indoor positioning data for the API. An important part of the prototype system is Telco 2.0 Web Gateway that is used to incorporate external GMLC into the system. The architecture of the proposed solution is presented in Fig. 1.

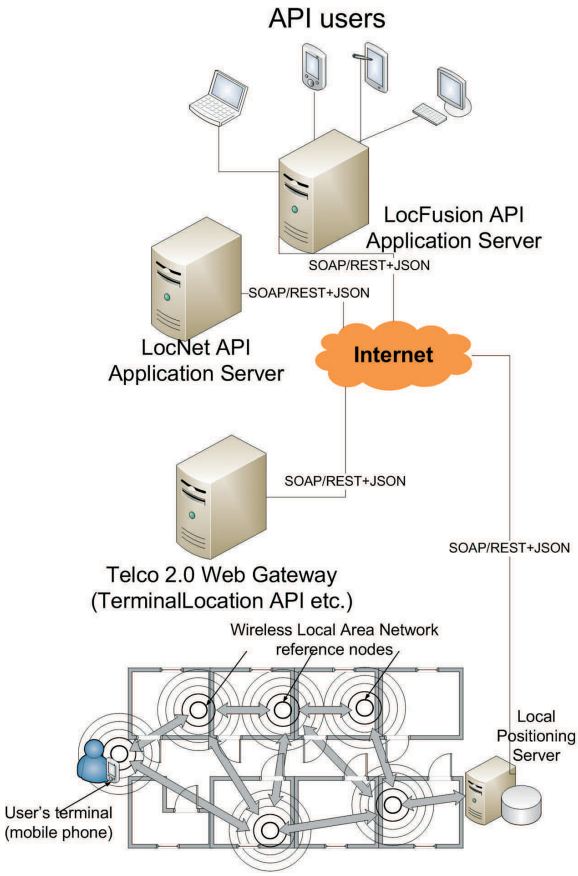

Fig. 1. LocFusion architecture.

Main application server is also responsible for managing security policy of the LocFusion system, especially for user authorization and maintaining legal affairs of estimating user's position in PLMN.

B. Software Architecture

LocFusion API has a modular software architecture. Every module can be developed separately and independently of each other until interfaces interoperability is kept. Moreover, at functional level LocFusion software is layer-organized as shown in Fig. 2.

Modular software architecture permits to expose certain positioning modes over the northbound interface. For prototype implementation three different API modes have been

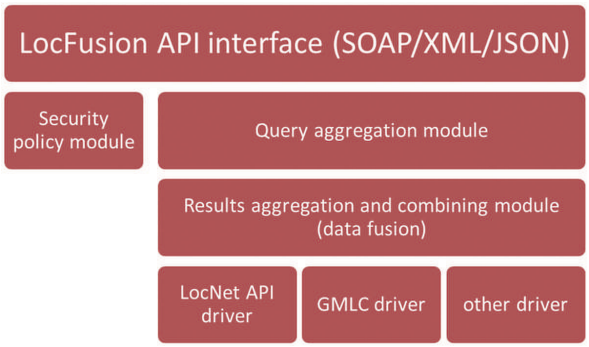

Fig. 2. LocFusion Software Architecture Functional Diagram.

implemented:

1) Single position estimation:
   - With remote call address (callback) – in this mode request identifier is returned immediately while entire terminal position is passed to provided callback address as soon as it is available,
   - At single HTTP transaction – in this mode HTTP response is sent to the user directly with estimated position. Server response contains only position estimator, request identifier is not passed to the end-user.
2) Multiple position estimation:
   - With remote call address (callback) – in this mode request identifier is returned immediately while entire terminal position is passed to provided callback address as soon as it is available. Terminal position is estimated periodically, the period between each two estimations is provided within request along with the total number of position estimations.

In each mode at least two parameters have to be provided in order to perform user positioning: valid authorization key (API-key) and phone number. Each API-key is then verified in Security Policy Module against phone number to verify whether positioning permission has been granted by the user. In particular, terminal can be localized only if user granted permission for MSISDN to be localized.

C. LocFusion Query Processing And Aggregation Algorithm

In many positioning system applications developers and designers focus on accurate positioning in means of estimating absolute geographical location of the end user. This approach is the most convenient way to mark position in outdoor scenarios, hence it is easy to integrate with GIS systems.

On the other hand, indoor positioning does not rely on absolute location identifiers since in-building descriptors (e.g. “office room 312” or “conference room”) can be more convenient to utilize. Moreover, when 3D positioning is considered accurate and reliable altitude identification is necessary. When considering outdoor positioning absolute altitude above the sea level is the most popular. For indoor positioning the most applicable altitude identification could be floor index

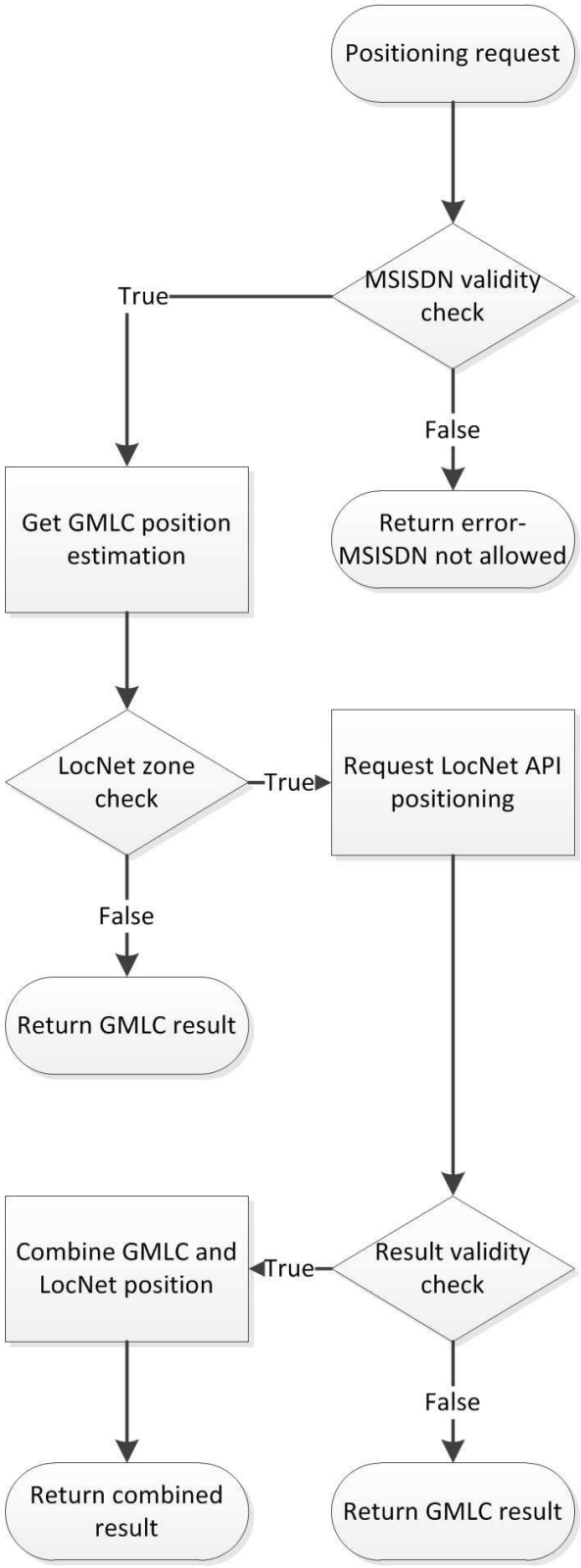

Fig. 3. Query processing algorithm.

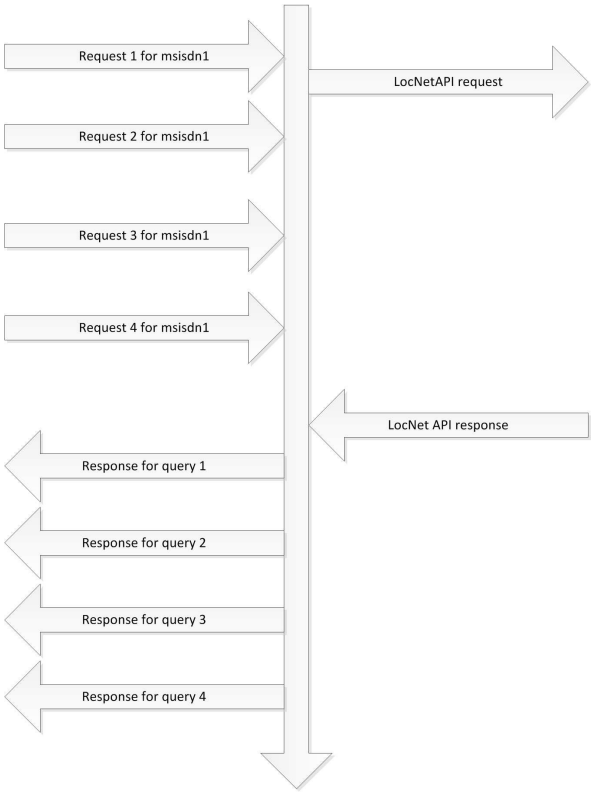

Fig. 4. Query aggregation flow diagram.

(e.g. ground floor, 1st floor etc.), hence it is more convenient building altitude identification rather than absolute values above the ground or sea level.

Therefore, LocFusion API is designed to provide additional descriptors for indoor position including floor index or name, zone within a building (e.g. "north wing"), room or office number or its name (e.g. "kitchen" or "office room 312") and site-related information (if available), including site features etc.

Moreover, contemporary absolute geographical position is calculated and returned for API backward compatibility. Absolute coordinates are also be the only result if no additional indoor positioning could be invoked.

Therefore every valid positioning request is internally processed with the use of an algorithm presented in Fig. 3. In order to increase API efficiency and to minimize LocNet API calls internal API request aggregation module has been implemented. Main feature of this module is to collect all valid positioning request for certain mobile subscriber and satisfy all the requests with single LocNet API call and thus single terminal call. Aggregation module operation idea is presented in Fig. 4.

IV. Usage Scenarios

LocFusion API might be seamlessly incorporated in a number of Location Based Services (LBS) but it is primarily designed to increase positioning accuracy inside the buildings. Therefore, possible use scenarios include but are not limited to monitoring and navigating the elderly or disabled people indoor, services allowing parents to localize their child, monitoring the trace of the employees (e.g. couriers or security guards).

The ability to determine reliable user position inside building makes it possible to aid elderly or visually impaired people in navigating inside public buildings like offices, hospitals or shopping centers. In this case LocFusion API might serve as reliable and accurate network-based user location source. Moreover provided context- related information might be used directly to inform users on their current location.

There are already developed applications that use positioning capabilities of the mobile network (offered by GMLC) to help parents in finding their child. These services offer rough location estimation and thus do not make possible to find a child for example inside big shopping center. In this case LocFusion API might provide both: rough location outside building (as accurate as the one offered by GMLC) and accurate context-related position inside the building. It is worth to mention that returned results include description of the building area (like "left wing corridor", "3rd floor") which makes them easy to use in finding people indoor.

LocFusion API makes it possible to send periodic position updates to the remote service and thus allows to implement a variety of tracking and monitoring LBS directly on the basis of the API. Possible use of the API includes monitoring and tracking of the employees that should follow a desired trace like couriers, security guards etc. It is also possible to use LocFusion API for Machine-To-Machine (M2M) applications, mainly for tracking of important and precious equipment (machines, electronic devices etc.) coupled with GSM module.

V. Summary

This article presented the prototype Application Programming interfaces that allows joint use of the dedicated indoor positioning system and GMLC in order to improve accuracy and usability of the location information. Modular system architecture and detailed description of the key components has been provided as well as detailed summary of developed query processing algorithms. The article also provides description of the possible use of LocFusion API.

Future works on the API includes evaluation of API performance in both computing and network usage aspects. It is also planned to undertake experiments to analyze positioning error when LocFusion API is used for tracking services.

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