Managing of Large Data Artifacts on Mobile Devices with an Ultra Sensitive GPS Devices

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Abstract. Nowadays there is decreasing number of limitations during using commercial mobile devices for data transfer, wireless connectivity or mobile device tracking. The last item is main area of this work. The model of a radio-frequency based system enhancement for user's location and tracking is developed for mobile information systems. The experimental framework prototype uses a few wireless technologies to determine indoor and outdoor position as wireless network infrastructure, global position system (GPS) etc. User location is mainly used for data prebuffering and preload by information system server to PDA or mobile device. All data on the server are saved with its artifacts as the position in the building or outdoor area and used location technology respectively. The reason for prebuffering is high speed of application response when a large amount of data is needed to transfer by server to mobile client.

Keywords: Mobile Device; Localization; Prebuffering; Response Time; GPS.

1 Introduction

Nowadays accelerates the progress of using of mobile devices and affiliated technologies dramatically and the number will be grow in the following years. It seems it will lead to the open wide application domains for PDAs (Personal Digital Assistants) and similar mobile devices that provide almost the same functionality as desktop application equivalents. The idea of such applications is based on current (and future) hi-tech devices with large scale (touch) display, large memory capabilities (with memory extension possibility) and wide spectrum of wireless network standard including bluetooth, Wi-Fi, GPS etc. Current example of device can be HTC Touch HD as a commercial device but there exists more industrial solutions.

Users of these portable devices use them all time in context of their life (e.g. moving, searching, alerting, scheduling, writing, etc.) or work. Context is relevant to the mobile user, because in a mobile environment the context is often very dynamic and the user interacts differently with the applications on his mobile device when the context is different [1]Users of these portable devices use them all time in context of their life (e.g. moving, searching, alerting, scheduling, writing, etc.). Context is relevant to the mobile user, because in a mobile environment the context is often very dynamic and the user interacts differently with the applications on his mobile device when the context is different [1].

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Recent research of context-aware computing has been restricted to location-aware computing for mobile applications using a Wi-Fi network (LBS Location Based Services). The information about basic concept and technologies of user localization such as LBS, searching for Wi-Fi AP can be found in previous article [2]. On localization basis a special framework called PDPT (Predictive Data Push Technology) was implemented. This framework can improve a usage of large data artifacts of mobile devices [3]. Continuous user position information is used to determine a predictive user direction and position. Then is possibility to link data artifacts and prebuffer data by server to mobile device in consequence. When user arrives to predicted position and the position is equal to result by PDPT core, data artifacts are stored in PDA local memory (or the loading process finishing). Time for loaded data processing and display is shorter with using of prebuffered local data. User must not wait long time after the request.

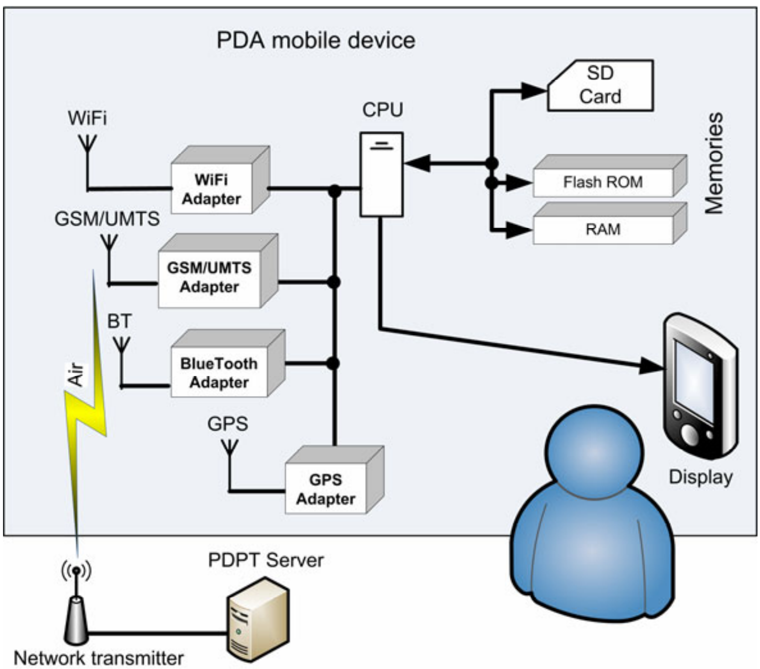

Fig. 1. Wireless networks and GPS sensor localization possibilities on mobile devices

In our case the WiFi was the starting point for framework implementation but the extension takes account of next wireless communication ways. For outdoor space there exists GSM/UTMS position utilities which can be implemented into application or GPS sensors often embedded in mobile devices either with Bluetooth wireless connection or SDIO wired GPS module etc. It is necessary to describe a position obtaining from wireless networks background in the beginning of next chapter to give a reader more information about these themes.

2 The PDPT Framework and PDPT Core

The general principle of my simple localization states that if a WiFi-enabled mobile device is close to such a stationary device – Access Point (AP) it may "ask" the provider's location position by setting up a WiFi connection. If position of the AP is known, the position of mobile device is within a range of this location provider. This range depends on type of WiFi AP. The Cisco APs are used in my test environment at Campus of Technical University of Ostrava. Measurements were performed on these APs to get signal strength (SS) characteristics and a combination of them called "super ideal characteristic" [5]. The computed equation for Super-Ideal characteristic is taken as basic equation for PDPT Core to compute the real distance from WiFi SS.

From this super ideal characteristic it is also evident the signal strength is present only to 30 meters of distance from base station. This small range is caused by using of Cisco APs. These APs has only 2 dB WiFi omnidirectional antenna. Granularity of location can be improved by triangulation of two or more visible WiFi APs. The PDA client will support the application in automatically retrieving location information from nearby location providers, and in interacting with the server. Naturally, this principle can be applied to other wireless technologies like Bluetooth, GSM or WiMAX. To let a mobile device determine its own position is needed to have a WiFi adapter still powered on. This fact provides a small limitation of use of mobile devices [4]. The test results with a possibly to use a PDA with turned on WiFi adapter for a period of about 5 hours.

2.1 Maximum User Response Time

PDPT framework is based on a model of location-aware enhancement, which we have used in created system. This technique is useful in framework to increase the real dataflow from wireless access point (server side) to PDA (client side). Primary dataflow is enlarged by data prebuffering. PDPT pushes the data from SQL database to clients PDA to be helpful when user comes at final location which was expected by PDPT Core. The benefit of PDPT consists in time delay reducing needed to display desired artifacts requested by a user from PDA. This delay may vary from a few seconds to number of minutes. Theoretical background and tests were needed to determine an average artifact size for which the PDPT technique is useful. First of all the maximum response time of an application (PDPT Client) for user was needed to be specified.

Nielsen [6] specified the maximum response time for an application to 10 seconds [7]. During this time the user was focused on the application and was willing to wait for an answer. The book is over 20 years old (published in 1994). We suppose the modern user of mobile devices is more impatient so the stated value of 10 second will be shorter. This is for me even better, because my framework is more usable. This time period (10 second) is used to calculate the maximum possible data size of a file transferred from server to client (during this period). If transfers speed wary from 80 to 160 kB/s the result file size wary from 800 to 1600 Kb [5].

The next step was an average artifact size definition. A network architecture building plan is used as sample database, which contained 100 files of average size of 470 kB. The client application can download during the 10 second period from 2 to 3 artifacts. The problem is the long time delay in displaying of artifacts in some original file types. It is needed to use only basic data formats, which can be displayed by PDA natively (bmp, jpg, wav, mpg, etc.) without any additional striking time consumption.

The final result of our real tests and consequential calculations is definition of artifact size to average value of 500 kB. The buffer size may differ from 50 to 100 MB in case of 100 to 200 artifacts.

2.2 From Data Collection to Localization

A first key step of the PDPT is a data collection phase. Information about the radio signals is recorded as a function of a user's location. The signal information is used to construct and validate models for signal propagation. Among other information, the WaveLAN NIC makes the signal strength (SS) available. SS is reported to units of dBm. Each time the broadcast packet is received the WaveLAN driver extracts the SS information from the WaveLAN firmware. Then it makes the information available to user-level applications via system calls.

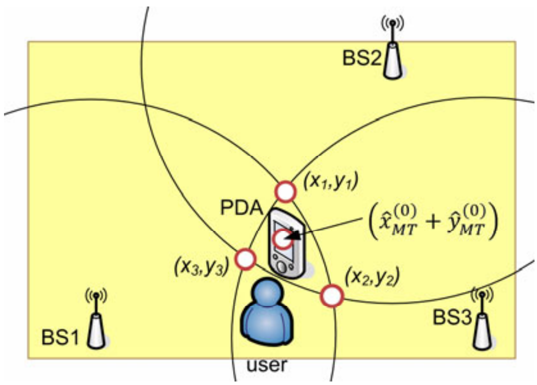

Fig. 2. Localization principle – triangulation

If the mobile device knows the position of the stationary device (transmitter), it also knows that its own position is within a range of this location provider. The typical range wary from 30 to 100 m in WiFi case, respectively 50 m in BT case or 30 km for GSM. Granularity of location can be improved by triangulation of two or more visible APs (Access Points). The PDA client currently supports the application in automatically retrieving location information from nearby WiFi location providers, and in interacting with the PDPT server. Naturally, this principle can be applied to other wireless technologies like BT, GSM, UMTS or WiMAX. The application (locator) is implemented in C# language using the MS Visual Studio .NET with .NET Compact Framework and a special OpenNETCF library enhancement. Schema on figure [Fig. 2] describes a localization process. The mobile client gets the SS info of three BSs (Base Stations) with some inaccuracy. Circles around the BSs are crossed in red points on figure. The intersection red point (centre of three) is the best computed location of mobile user. The user track is also computed from these measured SS intensity levels and stored in database for later use by PDPT Core. This idea is applicable in case of WiFi as well as BT and GSM networks.

In previous research, we focused only to use of WiFi networks while the other wireless possibilities remained without a proper notice. Now an enhancement of Locator component of PDPT framework [Fig. 4] is made to allow operate with BT and GSM networks.

BT

In BT network case, the position of BT APs must be known to allow the position determination. To collect BT APs position info in outdoor environment, the GPS can be used. For indoor area, the GIS (Geographic Information System) software with buildings map must be used to measure exact position of BT AP against to local environment. To manage with BT hardware of mobile device another library InTheHand 32Feet.NET is used.

GSM

GSM network is not local network but a cellular network. The problem is in position information of GSM BTSs (Base Transceiver Stations). The operator doesn't provide any such information. One of possible solutions is based on unofficial BTSs lists which can be found on internet. The lists are typically available in HTML, TXT or CSV formats. The medium rate for BTs with GPS position information is about 90 % of all BTs in European countries. In case of PDPT Framework, the list must be converted to PDPT server database – GSM_BTS table [Fig. 3].

In all three described cases of nearby BSs scanning, the data are saved to Locator Table in PDPT server DB [Fig. 3]. Data are processed from Locator Table throw the PDPT Core to Position Table. The processing techniques depend on selected wireless network. WiFi and BT network provide all visible APs nearby the user. From list of these APs is computed actual position (by triangulation [Fig. 2]).

Mobile devices with windows mobile operation system do not provide any GSM info to .NET Compact Framework. Even any special framework as in previous two cases is not known for me until now. Only possibility is in use of RIL (Radio Interface Layer) library. This library is divided into two separate components, a RIL Driver and a RIL Proxy. The RIL Driver processes radio commands and events. The RIL Proxy performs arbitration between multiple clients for access to the single RIL driver. When a module calls the RIL to get the signal strength, the function call immediately returns a response identifier. The RIL uses the function response callback to convey signal strength information to the module.

The GSM network provide only one BS info in each search cycle. This BS has the highest signal strength. The more BTSs info is collected by a several iteration cycles. During 10 cycles (per 10 seconds) the 4 BTS info is obtained on average.

The important info from BTSs is Signal Strength and Time Advance (TA). SS is refreshed every several seconds (in every scan) whereas TA is provided only during

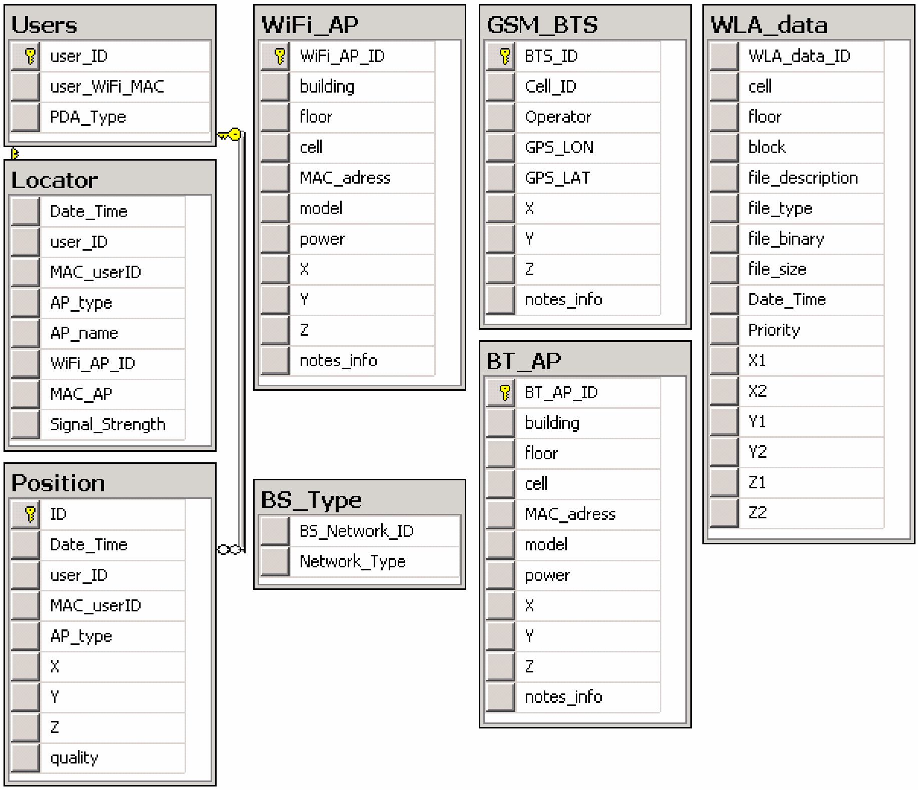

Fig. 3. PDPT server DB (Data Base) - New database architecture

some type of communication with selected BTS (e.g. request to talk, move to another area - Location Area Code (LAC)). The list of these BTSs with info is further processed as in previous case for WiFi and BT networks. Only change is in usage of TA if it is accessible.

GPS

Another possibility to get the user position in outdoor space is GPS (Global Positioning System) [8]. GPS provide a position by LONgitude and LATitude (X and Y). Only simple conversion is needed to transform a GPS coordinates to S-JTSK, which is used in PDPT Framework.

A GPS receiver calculates its position by precisely timing the signals sent by the GPS satellites above Earth. Each satellite continually transmits messages containing the time the message was sent, precise orbital information and the general system health and rough orbits of all GPS satellites. The receiver measures the transit time of each message and computes the distance to each satellite. Geometric trilateration is used to combine these distances with the location of the satellites to determine the receiver's location. GPS unit is able to calculate derived information as direction and speed in many cases. In our case it can be useful for better prediction of user direction for more dynamic response. For more precise information about localization there is more than three satellites necessary. Therefore receivers use four or more satellites to solve for all three axis and time value, which is used to correct the receiver's clock. Most GPS applications use the computed location only and effectively hide the very accurately computed time, it is used in a specialized applications as time synchronization for outdoor transitional process measurement [13].

Although four satellites are required for normal operation, fewer apply in special cases. If one variable is already known (for example, a ship or plane may have known elevation), a receiver can determine its position using only three satellites. In PDPT framework there is no mandatory to use more than three satellites too.

For error analysis we have to calculate with more sources as a signal arrival time measurement (mainly used for localization calculation), athmospheric effects (ionospheres and tropospheres errors), multipath effects and so on.

Multipath effects is GPS signal affection by multipath issues, where the radio signals reflect off surrounding terrain; buildings, canyon walls, hard ground, etc. These delayed signals can cause inaccuracy. Long delay multipath effects is possible to discard more easily then short delay. Multiple effects are much less severe in moving objects. When the GPS antenna is moving, the false solutions using reflected signals quickly fail to converge and only the direct signals result in stable solutions. Because we consider to use GPS outdoor but within build-up area it is essential correct GPS receiver information.

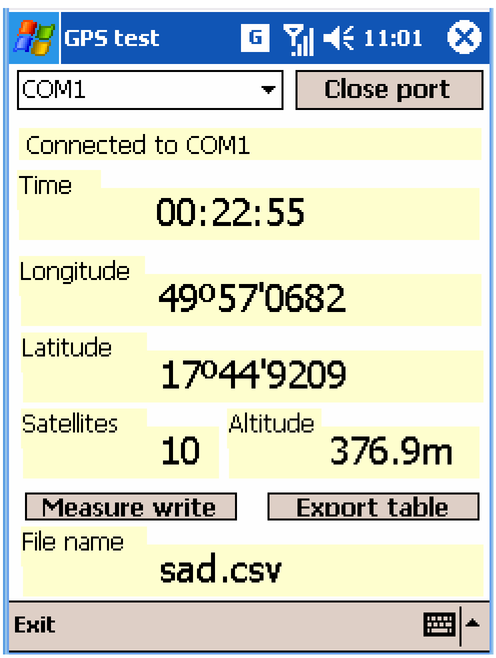

Fig. 4. GPS test application for PDA

Due free using of this technology by civilians there exists many mobile devices dedicated to a special areas, especially commercial applications in the tourist or car navigation. This means closed set of applications. But in new types of personal mobile devices we can find embedded GPS modules (or we can connect external GPS) and extend original PDPT framework with new capabilities of GPS.

Basic implementation of GPS software module for PDPT core was implemented with NMEA (National Marine Electronics Association) protocol decoder. By the $GPGGA (Global Positioning System Fix Data) sentence information string we get information about clock, latitude, longitude, number of satellites etc. This data can be stored in framework database and assigned to artifacts [Fig. 4]. A part of NMEA message received by used GPS module:

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$GPRMC,191843.000,A,4957.0673,N,01744.9146,E,0.00,220.70,010709,,,A*61
$GPVTG,220.70,T,,M,0.00,N,0.0,K,A*0A
$GPGGA,191844.000,4957.0673,N,01744.9146,E,1,09,1.0,381.8,M,42.8,M,0.0,0000*76
$GPRMC,191844.000,A,4957.0673,N,01744.9146,E,0.00,220.70,010709,,,A*66
```

In accordance with following table 1 we can obtain all required information.

Table 1. Table of data conversion by NMEA string to required values

Sequence	Example	Format and notes
1	191844.000	hhmmss.sss (UTC time in calculated position)
2	4957.0673	ddmm.mmmm (Latitude)
3	N	c (North/South indicator)
4	01744.9146	dddmm.mmmm (Longitude)
5	E	c (East/West indicator)
6	1	d (Quality indicator, 1 – successful, 0 – impossible to determine the position)
7	09	dd (Number of visible satellites)
8	1.0	d.d (Horizontal dilution of precision)
9	381.8	d.d (Antenna altitude above/below mean sea level (geoid))
10	M	c (meters – unit for antenna altitude)
11	42.8	d.d (Geoidal separation)
12	M	c (meters – unit for geoidal separation)
13	0.0	d.d (Age in seconds since last update from different reference station)
14	0000	dddd (Different reference station ID#)
15	*76	*xx (Control checksum)

For indoor environments there is possibility to use GPS receivers and repeaters instead of using WiFi network or its combination [Fig. 5].

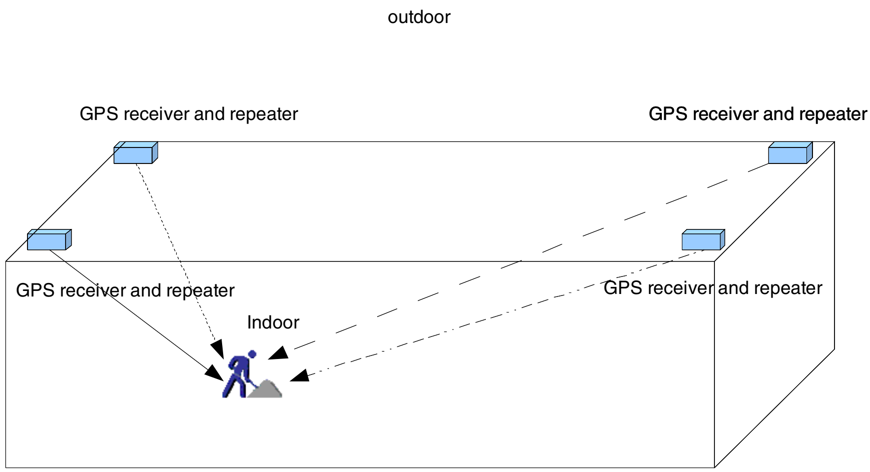

Fig. 5. Using GPS repeater indoor

2.3 The PDPT Framework Design

The PDPT framework design is based on the server-client architecture. The PDPT framework server is created as a web service to act as a bridge between MS SQL Server (other database server eventually) and PDPT PDA Clients [Fig. 6].

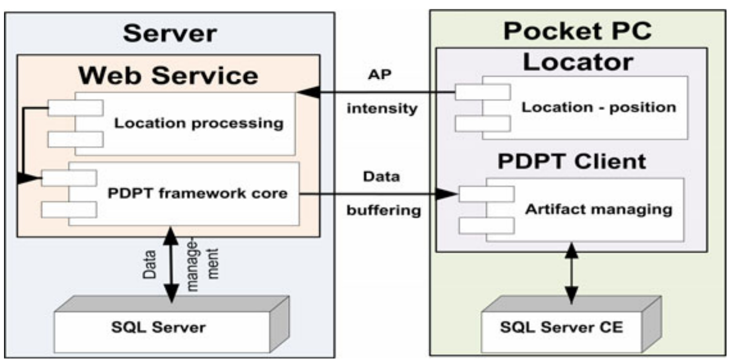

Fig. 6. PDPT architecture – UML design

Client PDA has location sensor component, which continuously sends the information about nearby AP's intensity to the PDPT Framework Core. This component processes the user's location information and it makes a decision to which part of MS SQL Server database needs to be replicated to client's SQL Server CE database [9][10]. The PDPT Core decisions constitute the most important part of PDPT framework, because the kernel must continually compute the position of the user and track, and predict his future movement. After doing this prediction the appropriate data are prebuffered to client's database for the future possible requirements. This data represent artifacts list of PDA buffer imaginary image.

2.4 PDPT Core - Area Definition

The PDPT buffering and predictive PDPT buffering principle is relatively simple. Firstly the client must activate the PDPT on PDPT Client. This client creates a list of artifacts (PDA buffer image), which are contained in his mobile SQL Server CE database. Server create own list of artifacts (imaginary image of PDA buffer) based on area definition for actual user position and compare it with real PDA buffer image.

The area can be defined as an object where the user position is in the object centre. The cuboid is used as the object in present time for initial PDPT buffering. The PDPT Core will continue with comparing of both images. In case of some difference, the rest artifacts ale prebuffered to PDA buffer. When all artifacts for current user position are in PDA buffer, there is no difference between images. In such case the PDPT Core is going to make a predicted user position. On base of this new user position it makes a new predictive enlarged imaginary image of PDA buffer. The new cuboid has a center in direction of predicted user moving and includes a cuboid area for current user position. The PDPT Core compares the both new images and it will continue with buffering of artifacts until they are same [11].

2.5 PDPT Framework Data Artifact Management

The PDPT Server SQL database manages the information (artifacts) in the context of their location in building environment. This context information is same as location information about user track. The PDPT Core selecting the data to be copied from PDPT server to PDA client by context information (position info). Each database artifacts must be saved in database along the position information, to which it belongs. The new software application called "Data Artifacts Manager" was created to manage the artifacts in WLA database (localization oriented database). User can set the priority, location, and other metadata of the artifact. The Manager allows creating a new artifact from multimedia file (image, video, sound, etc.), and work with existing artifacts [5]. The needs of interface to operate with APs info arose out of the developing process of PDPT Framework. The enhancement of Artifact manager was created on that ground. Now the Artifact Manager contains a new tab "Base Stations Manager" to operate with APs or BSs of selected networks. This manager is connected directly to PDPT Server database, to tables WiFi_AP, BT_AP, GSM_BTS.

2.6 The PDPT Client Application

The PDPT Client application realizes thick client to the server side and an extension by PDPT and Locator modules. Figure [Fig. 7] shows three screenshots from the mobile client. The first one [Fig. 8a] shows the Locator module with selected GSM scanning. The info text box "Locator AP ret." Provide info about last founded GSM BTSs and number of recognized BTSs (BTSs with GPS position). In current case the 6 BTSs was founded and 5 of them was recognized by PDPT Framework. Figure [Fig. 8b] shows the classical view of the data artifact presentation from MS SQL CE database to user (in this case the image of Ethernet plan of the current area). The

PDPT tab [Fig. 8c] presents a way to tune the settings of PDPT Framework. The middle section shows the logging info about the prebuffering process. The right side means measure the time of one artifact loading ("part time") and full time of prebuffering in millisecond resolution. More screens and details of PDPT Client can be found in chapters 2.7 and 2.8 [5].

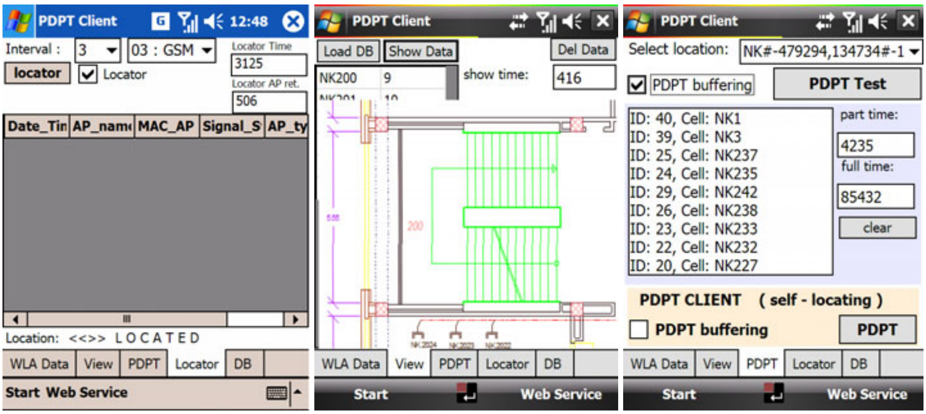

Fig. 7. PDPT Client – Left one figure 7a – Locator component with GSM scanning. Middle one figure 7b – View of normal client data representation. Right one figure 7c - The PDPT options screen allow to start and control the PDPT buffering.

3 Conclusions

This work is focused on the real usage of the developed PDPT framework on a wide range of wireless mobile devices and its main issue at increased data transfer rate. For testing purpose, few mobile devices were selected with different hardware and software capabilities. The high success rate found in the test data surpassed our expectations. This rate varies from 84 to 96 % [5].

The PDPT prebuffering techniques can improve the using of medium or large artifacts on wireless mobile devices connected to information systems. The localization part of PDPT framework is currently used in another project of biotelemetrical system for home care named Guardian to make a patient's life safer [12]. Another utilization of PDPT consists in use of others wireless networks like BT, GSM/UMTS, WiMAX, or in GPS. This idea can be used inside the information systems like botanical or zoological gardens where the GPS navigation can be used in outdoor. Some improvements of Locator module or Artifact Manager are described as well as improved architecture of PDPT server database. The larger area of PDPT utilization can improve importance of PDPT Framework in wireless mobile systems.

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