GEOMESSAGING AND MOBILE MAP IMAGING IN PERSONAL NAVIGATION

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ABSTRACT

Nowadays it is possible to identify and visualize your location using only a mobile terminal, such as a cellular phone or a pocket computer. The applications of mobile location services are very diverse, and most providers offer only technology rather than business or a ready solution. Yet operators must see at least one compelling end-user service that can be built upon such a technical foundation. Here we present such a service based on GeoMessaging and Mobile Map Imaging, which is ready for immediate adoption. GeoMessaging adds location information to the messages sent by people using SMS, WAP or e-mail services, and puts special emphasis on user-created location-related content. GeoMessaging promotes advanced person-to-person communication, improves logistic efficiency and produces immediate revenue for operators and service providers. Mobile map imaging provides users with the view of geographic map for the immediate area at the user's location. Map Image Storage System integrates the image representation paradigm, state-of-art compression technology, and storage system architecture.

1. INTRODUCTION

Have you ever looked at a map and wished you could pinpoint your exact location? Ever found a great spot and wanted to remember where it is? Or ever tried to point your friends to this fabulous place? Have you ever tried to locate your colleagues or the loved ones? Or being found yourself in an unknown surrounding with no clue about location, tried to call a taxi or road service to this place?

Nowadays it is quite possible to identify own location on the Earth using GPS receiver [Kaplan, 1996]. GPS is the acronym for *Global Positioning System* referring to the network of U.S. Department of Defense satellites circling the earth and continuously transmitting coded information about their locations. Built with military applications in mind, GPS was made available for civilian use in 1980. Typical GPS unit is able to show location information in a variety of ways, from simply telling the coordinates and relative location to location waypoints on the map, which is either embedded into the device or downloaded from a PC. Applications of GPS are very diverse, from navigation and tracking to more complex land surveying, or to recreational use. With some calculations, it is possible not only to determine speed and direction of going, but also to show and keep tracking one's position on a map, look up street addresses and provide detailed routing directions.

The use of conventional GPS is limited to the area with the clear sky view and only if sufficient energy source is provided. Therefore GPS became popular generally in airborne and naval navigation. The mobile phones step forward in this direction by adding two-way communication channel. Using the two-way information exchange, a variety of added value location based services can be developed. The mobile phones also provide a cheaper and faster way of determining the location at the cost of accuracy; although this can be solved if/when networks are upgraded to be able to triangulate the exact location [Drane, 1998; Dye, 1999]. If GPS receiver is integrated into a mobile phone, the location can be determined with higher precision, and in the area not serviced by the mobile network.

The *pocket computers* (PDA) go even further. With the use of various software and hardware plug-ins available on the market these can be easily turned into anything imaginable, provided the computational resources are sufficient. Higher processing power and memory resources allow for larger amount and higher quality of map images to be stored and facilitate interfacing the system with end users [Gellersen, 2000].

Most *Mobile Location Services* (MLS) providers offer technology, rather than business. Technology to locate mobile terminals, to search for services in proximity, or to find one's way in unfamiliar surroundings. Yet, operators should see at least one compelling end-user service that can be built upon such a technical foundation. In this paper we present the concept of *GeoMessaging* that is communication with location awareness. With the use of GeoMessaging it is possibly not only to determine your own location but also exchange it with the others, and it is not a limit. GeoMessaging puts special emphasis on user-created services, when users contribute with their own location related content. More complex scenarios can be therefore designed in the context of time and spatial information: from simple locating of a fishing party in proximity to complex searches of events occurring in a particular place and time. GeoMessaging can be further expanded and integrated in the framework of Digital Earth.

Society is gathering an enormous amount of digital information about the Earth and its inhabitants. This information is stored around the world and is not easily accessible or utilized in conjunction with other types of data. Although some of this data is historical and political, most of it refers to a specific geographic location (is *geo-referenced*). *Digital Earth* provides an interoperable environment to access and employ the vast amount of geo-referenced data [Crockett, 1998]. The user will be able to find and explore this data, and interactively overlay it with visual geographical information, such as maps or satellite views. It will serve for better decision-making, geo-information management, increasing knowledge and scientific discovery and dissemination to support a sustainable human world.

The technologies that shall be developed in the Digital Earth framework include storing, indexing, and retrieving the data, multi-resolution data representation, broadband communication networks, data and metadata standards and exchange protocols, certification and authorization mechanisms, and new visualization methods. *Mobile imaging* application provides user with the view of geographic map for the immediate area at the user’s location. Images (maps in particular) facilitate the interpretation of spatial location and provide an easy way for navigation and direction. The imagery data requires a lot of storage space. Only a single copy of Earth’s land imagery will exceed petabyte (10^{15} bytes). Specific of portable and mobile terminals and their constraints require development or special adoption of existing techniques. Image availability and quality, and short access times are the primary concern. High compression rates, as well as fast decoding and transmission are therefore among main requirements.

The constraints of mobile terminals and the requirements for mobile imaging systems are discussed here. We present a few scenarios, in which the images can be used for navigation in mobile environments. We also introduce the *Map Image Storage System* (MISS). The system integrates the image representation paradigm, state-of-art compression technology, and system architecture. It allows for interactive operations with the map images in mobile environments. It can be used on either server (operator or service provider) or client sides, and be integrated in any of the presented scenarios.

2. PERSONAL NAVIGATION

The new personal mobile location and navigation services, two of the most significant future applications of the mobile communication technology, open up a whole new world for mobile phone users [Markkula, 2001]. It will be possible to request a wide range of information about daily needs. Parents can locate their children, employers can, if desired, track and locate their employees and follow the route of sent items, thus saving money and increasing efficiency. In case of emergency the origin of received calls and messages can be located and thus, help can be sent to the right place. Although there are various approaches for locating the mobile phone, they can be classified into two categories. The phone can either be located with the help of the cellular system's signals or the phone can be integrated with a GPS receiver, which takes care of the location function.

2.2 Mobile Location

The simplest method for locating a mobile phone is based on cell identification, and is known as *Cell Global Identity*, which is often accompanied by *Timing Advance* information [Drane 1998]. The method is based on the information that is already built into the network. It works on a legacy mobile phones, and is very inexpensive to implement. The major drawback is that accuracy is directly dependent on cell radius, which can be very large especially in rural areas.

Another techniques would measure the propagation time of the signal between several base stations and the mobile terminal in order to triangulate the location. A problem of this approach is the accurate time synchronization that is required between the base stations in order to obtain useful time delay estimates. There are two alternatives depending on where the calculation has taken place. The network-centric approach is known as *Time Of Arrival* (TOA) technique, and the terminal-centric approach is known as *Enhanced Observed Time Difference* (E-OTD) technique [Reed, 1998; Sage, 2001]. Both techniques require installation of additional receivers in the network, and the latter one requires development of new phones with additional processing power and memory. The multi-path propagation problem also decreases the accuracy in an urban environment.

Another technique (which is a strictly a software solution) is based on signal attenuation measurements. If the signal levels from three different base stations that are known, the location of the mobile terminal can be determined as the unique intersection point of the three circles [Hellebrandt, 1999]. Although signal level contours are no longer circles in urban environment, the signal measurement campaign shall be performed once the service is established. An advantage of this technique is that in the GSM system, every phone measures the signal levels from up to seven stations at 0.48-second intervals to facilitate handover. With the software added to the mobile phone, this information can be used for location purposes.

To conclude, the accuracy of techniques discussed here is within the 50-200 meters, and is sufficient for most types of location-based applications, in which the proximity information is often sufficient.

2.1 Global Positioning System

GPS network comprises 24 satellites circling the Earth on high orbit and several ground control stations [Kaplan, 1996]. Satellites send very low power radio signal with coded information about

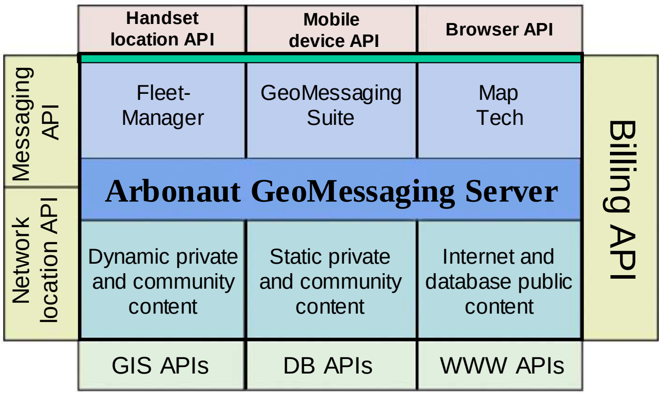

Figure 1. Diagram of the GeoMessaging Platform.

their location and time, which is used to triangulate the three-dimensional position (latitude, longitude and altitude) of the receiver. The signal travels “line of sight”, meaning that GPS cannot be used if there is no clear view of the sky, e.g. inside buildings, close to high structures, under heavy foliage, and underwater. Civilian GPS receivers are also prone to potential position errors caused by various signal deteriorations. It may also take at least several minutes to determine the location, if GPS has been not used within some period of time. GPS receivers also consume a lot of energy and drain battery within a few hours of operation.

The accuracy of civilian GPS varies from 6 to 100 meters. The accuracy and satellite locking time can be further improved using assistance of terrestrial reference stations located at precisely known locations (*Assisted* or *Differential* GPS). These stations determine the satellite position and signal error components, and provide the corrected information to the receiver in real time using radio or cellular networks. This approach provides pinpoint accuracy but increases cost of the receivers and the network infrastructure.

3. GEOMESSAGING

GeoMessaging is communication with location awareness. *GeoMessages* are notes that users send to one another with a spatial context. It allows users to deliver their location to peer groups, so that they can locate their contacts. GeoMessaging is based on SMS (*Short Message Service*) messages or WAP (*Wireless Application Protocol*) services, with amendments, which include: (1) Geo-coded location documents, (2) Geo-coded location messages, and (3) GeoSearch. It uses the support of personal navigation services, whenever available. If necessary GeoMessaging allows for user-input location, and the position of interest can be represented as a street address.

GeoMessages are collected in private *GeoNotebooks*, shared between a group of dedicated users, or in an Open GeoNotebook that is accessible for public. Incoming messages are stored in the Inbox, and all sent messages, whether sent through the Web or with a mobile terminal, are stored in the Outbox. GeoNotebook serves to search information in the context of location and time. For example it is possible to search the personal surroundings of your current location with keywords and to find matching points of interest. In this way, users act as the active providers of the content for location-based services.

GeoMessaging Suite is a unique and easy to use application platform for mobile location messaging. Suite supports cross-media messages, such as messaging between phones, email, and asset tracking devices. It consists of SMS, WAP and Web-interfaces, and converts location into a format appropriate for each terminal. Suite also has many other features, such as functions to compose, send, and store GeoMessages across different carrier media.

4. DIGITAL EARTH

The concept of geo-referencing employed in GeoMessaging could be expanded further and understood in the framework of *Digital* Earth. Digital Earth is a multi-agency collaboration in between U.S., E.U., China, Canada, and Israel, leaded by American *National Aeronautics and Space Administration* (NASA). A primary goal of Digital Earth is to provide an easy access to geo-referenced information about the Earth and its inhabitants [Crockett, 1998]. Digital Earth is not only a rich geo-oriented three-dimensional interface to the information about the Earth but includes a way to obtain this information, framework in which it is published, a new market for data and software services, a set of standards, and technology challenges.

Digital Earth provides an interoperable environment to access and employ the vast amount of electronic data. The users will be able to find and explore the information by zooming it from global to local views, roaming through the space and time, and asking for additional information on particular features. Although some of the data for the Digital Earth would be in the public domain, it might also become a digital marketplace for companies selling a vast array of commercial imagery and value-added information services. Applications range in education, decision support, resource management, problem solving for citizens and communities, etc. A typical scenario includes accessing various geo-spatial data and overlay it to visualize the topic. For example, in case of emergency, the satellite and aerial views of the area, map image, building plans, weather on location and other permanent information can be retrieved and displayed. The public will determine the extent to which particular applications develop.

5. MOBILE MAP IMAGING

Real-time cartography imaging application provides user with the view of geographic map for the requested area in real time [Kraak, 2000]. Map images are presented at the user's location or retrieved via network. Mobile map imaging expands into this, by adding the user mobility to the game. In this scenario, the user equipped with wireless mobile terminal, which might be a mobile phone or a pocket PC, receives the real-time map image updates.

The development of real-time imaging had begun in the latest eighties, when the world decided to convert waste amount of paper documents into a digital format. The digital format has many advantages: economical storage, easy search, reproduction without loss of quality, and quicker delivery. The complexity of the systems dealing with vector data or capable for automatic transfer of the document image into the textual or vector form has prevented their successful use in every document imaging application. Even though nowadays server-side databases tend to have vector representation of the map data, the maps are still delivered to the end user in a simple raster format.

Mobile terminals by they technical specifications remind the personal computers at the beginning of last decade. Technological constraints are similar, when the demands of user followed by technical revolution are nevertheless the same. New technologies shall be developed or the existing ones shall be adopted. Mobile imaging discusses the way of representation and delivery of graphical information to the mobile terminals, in particular map image content used for navigation services.

5.1 Mobile map imaging scenarios

Here we consider four various approaches to delivering map images to the mobile user:

a. *Server-side approach*:

In this approach an image (a view on the map in the particular moment of time) is prepared on the server and served to the client in a compatible image form. This approach supports legacy handsets capable of displaying graphic information (i.e. WAP enabled mobile phones). It does not

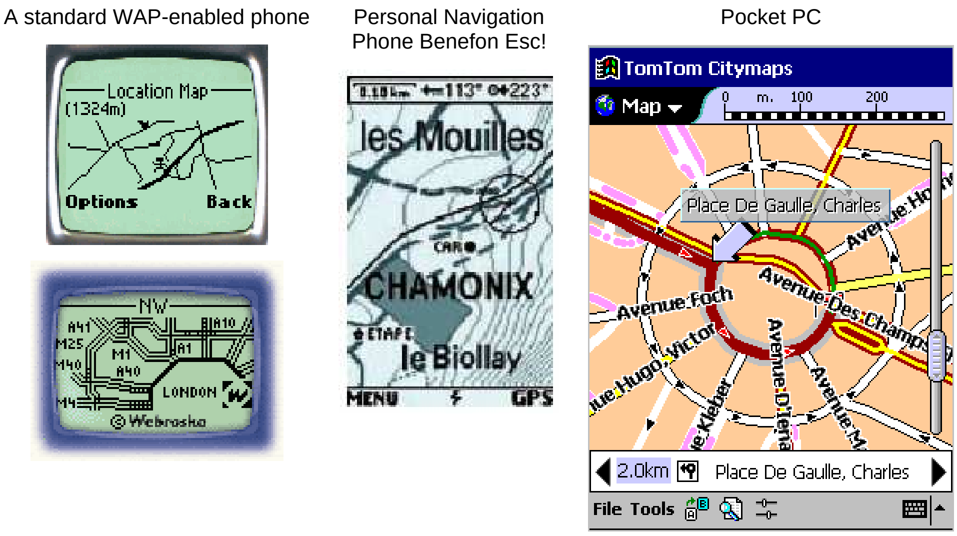

Figure 2. Sample screen view of typical mobile imaging applications.

support moving map feature. A new view of the map corresponding to a different location will require a new request and new image retrieval. The image quality is also limited. The situation can be improved if the terminal has some capability to run software (for example terminal running J2ME platform) [Riggs, 2001]. Additional features can be then implemented for improved interactivity, e.g. retrieval of larger map view than the display size for smooth map panning, etc.

b. *Client-side approach*:

In this approach the compressed images are stored in the memory of user's terminal. This approach is more suitable for a portable computer than a mobile device, because of larger memory resources (necessary for store the complete map data of the region), higher processing power and richer user interface. Alternatively, the images can be loaded into the device from a more powerful home computer connected to Internet. The rich interface and map-browsing features can be also embedded in the firmware in the way it is done in the Personal Navigation Phone Benefon Esc!, a GPS-enabled mobile phone. With the use of either location technology (e.g. AGPS), the communication between the mobile terminal and the service provider will be limited for augmentation data and GeoMessages.

c. *Client-server approach, shift on the server*:

The following two scenarios employ dynamic "over the air" map loading, and the ability to utilize the downloaded information for the further use. The server-centric approach employs the client capable for image decoding and HTTP communications (e.g. high-end "communicator" style phones, or PDAs). When it occurs that the map data existing on the terminal (either preloaded or preserved from previous trip) does not cover the requested area, the client will request the new data from the server. The server will extract the data for the requested image's fragment from its database and serve it back in the compressed form. Client will add this new (compressed) data to the existing (also compressed) data, and proceed with the data locally present.

d. *Client-server approach, shift on the client*:

Although this approach is similar to the previous one, it produces much less load on the server, but sets requirements for the client's memory resources. In this terminal-centric approach, the client has a preloaded map index table, which, in fact, can be large. The index is used for requesting from the server the parts of the compressed image file corresponding (parts) to the desired image fragments. The server can be implemented as a simple HTTP server. Both, server and client must operate with the image data stored in the same compressed format, though.

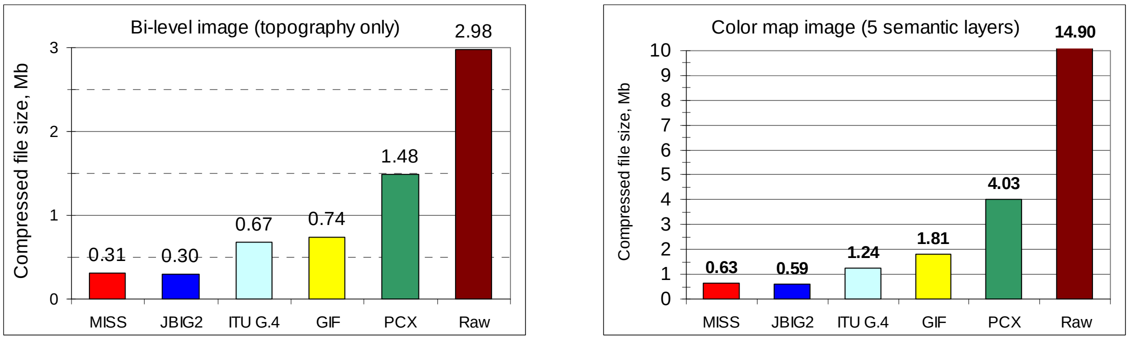

Figure 3. Storage size of reference image using various compression techniques.

5.2 Requirements for mobile imaging

With a flashback into the past, the processing power of the computers in early nineties represents the technical level of the mobile terminals at present. The primary constraints are the processing power, memory resources, network bandwidth and display size. Although the first two parameters are always increasing, the difference from desktop computers will remain yet for a long time.

Table 1. Processing power of personal computers in nineties, and modern mobile terminals.

	PC from early 90s, mobile phone	PC from mid 90s, PDA
Processor speed	1-10 MIPS	50-100 MIPS
RAM	< 1 Mb	16-32 Mb
Storage space (HD)	< 4 Mb	~ 100 Mb
Display size	320×200	640×480
Network speed	< 9.6 Kb/s	14.4 – 56 Kb/s

To understand how the compression is important for storing image data, we draw the following example. A typical topographic image representing a single map-sheet will have dimensions of approximately 5000×5000 pixels. The following diagrams show the sizes of the image file in the raw and compressed form for the black-and-white and color representations. The JBIG2 and MISS columns on the picture correspond to the latest state-of-the-art techniques of the same name.

The requirement for a typical storage system employed in mobile environment can be summarized to (1) *high compression rates*, which improves transmission and saves on storage, (2) *fast decoding*, which facilitates interactive operation and lessens the processor power constraint, (3) *spatial access*, which stands for direct retrieval and "on the fly" decoding of the image fragment [Samet, 1989].

As we have noted, typical display size and resolution of a typical mobile terminal is much lesser than the original raster image and thus, only a small fragment of the entire image may be viewed at a time. If spatial access is supported, an image may be interactively browsed on the terminal. When the image is scrolled, a new part of data is retrieved and decompressed on the fly. In this way, spatial access eliminates time delays caused by image decompression and transfer. The thumbnail image or lower scale map can serve to locate the desired part of the image of higher scale.

A major drawback of prevalent image compression methods is the low compression rates [Arps, 1994]. At least twice-higher compression rates comparing to the prevailing algorithms can be already achieved using state-of-art compression techniques [Haskell, 1998]. The high complexity of these techniques set high demands to the processing power, and prevented from their application in personal computers of the last decade and also prevent from application in modern mobile environments.

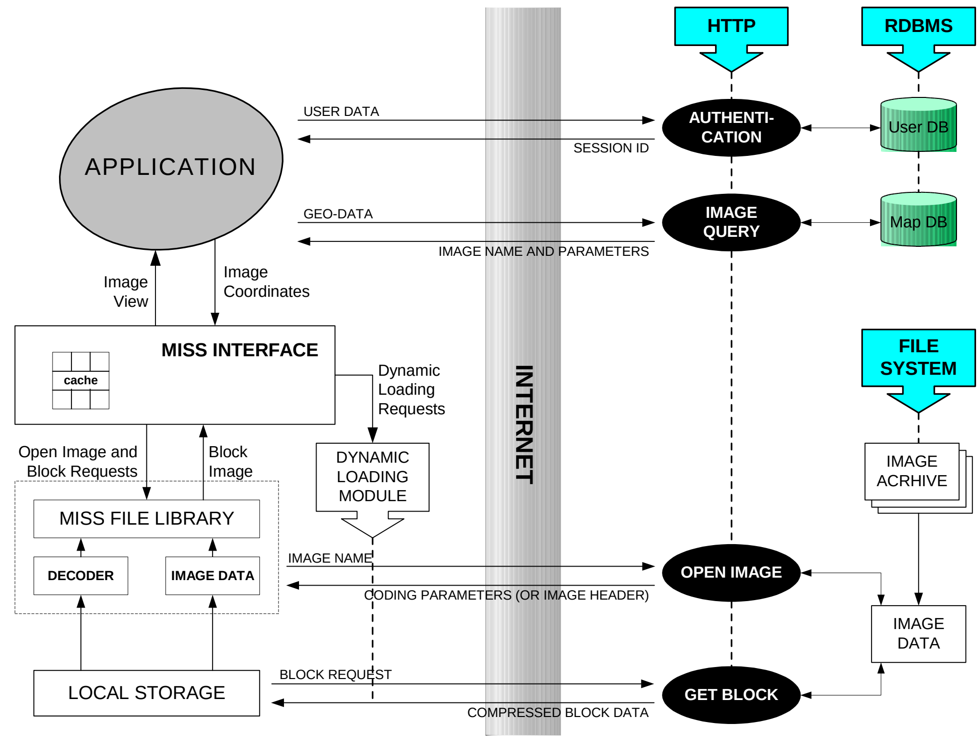

Figure 4. Architecture of the Map Image Storage System.

Another disadvantage of state-of-art techniques is that entire image or a major part of it must be entirely transmitted to the client before it can be decoded and presented to the user. Also decoding of the image fragment alone may not always be possible. As it has been previously indicated, the partitioning of the image into the fragments cannot be easily achieved [Ageenko, 2000a]. Using supposition that mobile terminal may not have sufficient resources to hold entirely map image, and high-speed channel (and fast processor) is not available to transmit (decode) the entire image is real-time, the operations with remotely located images would not be possible.

5.3 Map Image Storage System

Map Image Storage System (MISS) includes system architecture (shown in Figure 4), map image representation paradigm and a sort of algorithms for image compression and processing on both the server and client sides. The MISS system supports the following properties: (1) state-of-art compression, (2) multi-scale representation for map zooming, and (3) fast image scrolling (panning) ability, via the spatial access feature.

The system allows for the use of identical image representations on both, server and client sides. The information exchange can be arranged using a standard (e.g. HTTP) protocol, so that any device with a physical or wireless Internet connection can perform it. In this way MISS can be used in any of the scenarios discussed in the Sec. 5.1, including the very latter one.

The system uses compressed raster image format organized so that it supports the zooming and panning requirements. Furthermore, the system does not depend on any database or vector format as digitized raster maps can be easily generated are reproduced from any source format, including paper maps. Another advantage of the system is that it requires only a modest memory and computing resources in order to be real-time operational in mobile environment.

The general idea of the image representation in MISS is in (1) the separation of the image into the (a) multiple scales, (b) semantic layers, and (c) block tiles, and (2) in the use of the special encoding schemes satisfying with the above sub-division and system requirements. Semantic decomposition provides separation of the image into the simple layers containing different semantic meaning, for example: topographic data and contours, elevation lines, fields, water areas and administrative borders [Ageenko, 2001]. The user application can reproduce the map on the display by overlaying the layers, plotting each one in its own color or gray value. The semantic separation provides better compression performance in comparison to the other decomposition options, such as bit-plane or color-value separation. It also gives user a freedom of choice of the information he wants to display. In particular, only the topographic layer can be shown on cheaper terminals with monochrome display.

The compression algorithm employed in MISS is based on the forward-adaptive context-based compression technique [Ageenko, 2000a]. It alleviates the major difficulties related to state-of-art technique and makes the use of the technology feasible on the portable and mobile devices. The map image is operated on the client in a following way. The blocks of the map along the route (providing that the client location is dynamically determined used either of positioning services) are dynamically decoded (or retrieved and decoded) and used to create a picture shown on the terminal display.

The Table 2 summarizes the times necessary to perform transmission and decoding of an image fragment corresponding to the size of the display of a typical mobile terminal. Different map images were used in these settings. Monochrome representation. Four-level grayscale representation corresponds to a typical map images used in Benefon Esc! Personal Navigation Phone. Five-level semantic representation corresponds to the images in NLS Topographic Database Series 1:20 000. And monochrome images were generated from the topography layer of NLS images with the resolution reduced with a factor of 2.5. The compression efficiency (measured as *bitrate*) and decoding speed parameters were obtained empirically for the MISS system. Decoding speed is given for a reference processor running at 1 mips (*million iterations per second*) speed. For the further notice, if the "moving map" scenario is employed, there is no need to decode an entire view, but only the blocks constituting it. It increases decoding speed up to a factor of 3. The compression performance (and therefore transmission time) can be also further improved by about 30 % at the cost of higher compression complexity [Ageenko, 2000b]. It results in about 50 % longer decoding, which can be employed in high-end terminals.

Table 2. Typical image transmission and decoding times in MISS. Decoding speed is as of 1 mips processor.

TERMINAL PARAMETERS				IMAGE PARAMETERS			OBSERVED TIMES	
Phone type	Bandwidth, bit/s	Display resolution, pixels	Processor speed, mips	Image representation model	Coding bitrate, bit/pel	Reference decoding speed, pel/s	Trans-mission time, s	Decoding time, s
Basic phone	14400	128x128	4	Monochrome	0.3	4000	1	4.8
Advanced phone	49152	360x120	40	4-level grayscale	0.85	850	0.7	1.3
Advanced phone	49152	360x120	40	5-level semantic	0.19	975	0.2	1.1
PDA, Communicator	49152	up to 120000	up to 200	5-level semantic	0.19	975	0.5	0.6

6. CONCLUSION

GeoMessaging means automatically attaching location data to person-to-person messages between people using SMS, WAP or email services. It applies equally to personal and professional communication. GeoMessaging puts special emphasis on user-created mobile location services. The location related content generated by users could produce operator revenue by charging users for queries and downloads of GeoNotes. It also attracts users to send more messages, possibly for a premium paid for the location element. GeoMessaging can be adopted immediately, since it operates on existing terminals and networks.

Map images are used to interpret the user location and give visual directions. Map Image Storage System adopts state-of-art compression technology for the use in real-time and mobile environments. High compression rates, the direct access to the specified fragment of the image without the need to decode or transmit the entire image data, and ability to re-use the image date once retrieved, all these significantly improve image access time and facilitate system operation for the end-user. The requirements to processing power necessary to run MISS engine make it possible to implement the technology already on the current generation of mobile terminals.

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