# W2.4 Designing geolocation services for next generation mobile phone systems

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## 1 Introduction

Mobile telecommunication networks are in a state of transition from being primarily concerned with the exchange of voice data to allowing the exchange of a variety of information types. Currently the industry in the UK and most of Europe has reached the level of 2nd generation phones. It is predicted that over the next two years, a series of rapid technological developments will shift the telecommunications industry through “2.5 generation” (increased bandwidth and “always on” connections) to third generation (3G) in 2002. More than fifty percent of the UK population now own a mobile device and this trend of increasing ownership looks sets to continue for less developed countries with 2 billion subscribers world wide predicted by 2010 (UMTS Forum, 2000).

In parallel with change in the telecommunications industry is a shift in the portability of computers in the form of personal digital assistants (PDAs) or handheld computers. Increasingly these devices have network connections through GSM modems, infrared links and in the near future, radio links to networks. These technological steps have led to a blurring of the distinction between handheld computers and mobile phones. This trend is set to accelerate with the introduction of a host of new technologies. One such technology is location sensitivity, where devices are aware of their location in space. This has the potential to inform users about the existence and location of services that are accessible to them and will lead to the generation of vast and dynamic data sets if a history of user movements are stored. In this paper techniques for summarising data have been investigated that are information rich and less invasive of users’ individual privacy.

With mobile devices evolving into information platforms the phrase “mobile phone” is no longer an adequate representation of the present and emerging functionality in the field of mobile telecommunications. For this reason in this paper the term mobile device will be used.

## 2 Drivers for Change

A number of technological advancements and features specific to mobile telecommunications have driven the evolution of mobile devices. The main drivers for change are reviewed here.

### 2.1 Personalisation

Mobile devices are generally owned by a single individual allowing personalisation of the information sent to mobile users. Web logs and cookies have attempted to personalise desktop computers for individuals, however this can be undermined by users accessing sites through more than one machine or choosing to have their browser reject cookies.

Information services provided over mobile networks can be tailored to the individual, either explicitly, where the user fills out forms defining their interests and tastes, or implicitly, by monitoring what information an individual accesses and how they react to information sent to them. There are an increasing number of services available to mobile users and this trend looks set to continue with the advent of new technology. Personalisation can act as a filter for information searches and users are likely to value mobile information services for their ability to send timely information that is of value to them personally.

### 2.2 Location sensitivity

Mobile devices are by definition portable and this offers the opportunity to provide information relevant to the user's known location. There are a number of viable techniques for gauging the position of a mobile device and these are discussed in section 4. Knowledge of the user's location potentially offers a more relevant vehicle for Internet "push" services (where information is sent to the user without them explicitly requesting it).

There have been two separate motivating forces behind the drive to position mobile devices on either side of the Atlantic. In the US the Federal Communications Commission (FCC) Enhanced 911 (E-911) initiative has called for mobile positioning to assist the emergency services in locating callers. Motivation in Europe has focused on an appreciation of the commercial potential of location sensitive services; advertising in the form of unsolicited text messages is becoming more commonplace with location seen as a very effective means of targeting potential customers. This is a fast evolving area; the location-sensitive services industry is expected to bring in $3.9 billion by 2004 (Strategis Group).

### 2.3 Increase in bandwidth

The bandwidth of mobile communications channels is increasing in response to the need to send more information than voice data alone. The present GSM bandwidth of 9.6Kbps is dwarfed by the 115Kbps transmission rate (over twice the rate of a standard PC modem running over a terrestrial phone line) of general packet radio service (GPRS), already launched in the UK. Enhanced data rates for global evolution (EDGE) could increase bandwidth to 400Kbps before third generation services are launched in the UK in 2002 with transmission speeds of up to 2Mbps.

### 2.4 New services as a result of always on connections

The move from GSM "circuit switched" connections to GPRS "packet switched" connections represents a move from a connection only established during calls to one that remains open permanently, removing the need to dial up an Internet service. This is expected to boost the speed and popularity of wireless Internet services. As a result of "always on" connections, there is a need for new systems of charging phone users. Combined with developments in e-banking mobile devices have the potential to become "electronic wallets" where calls, data downloads and online purchases are added to the phone bill.

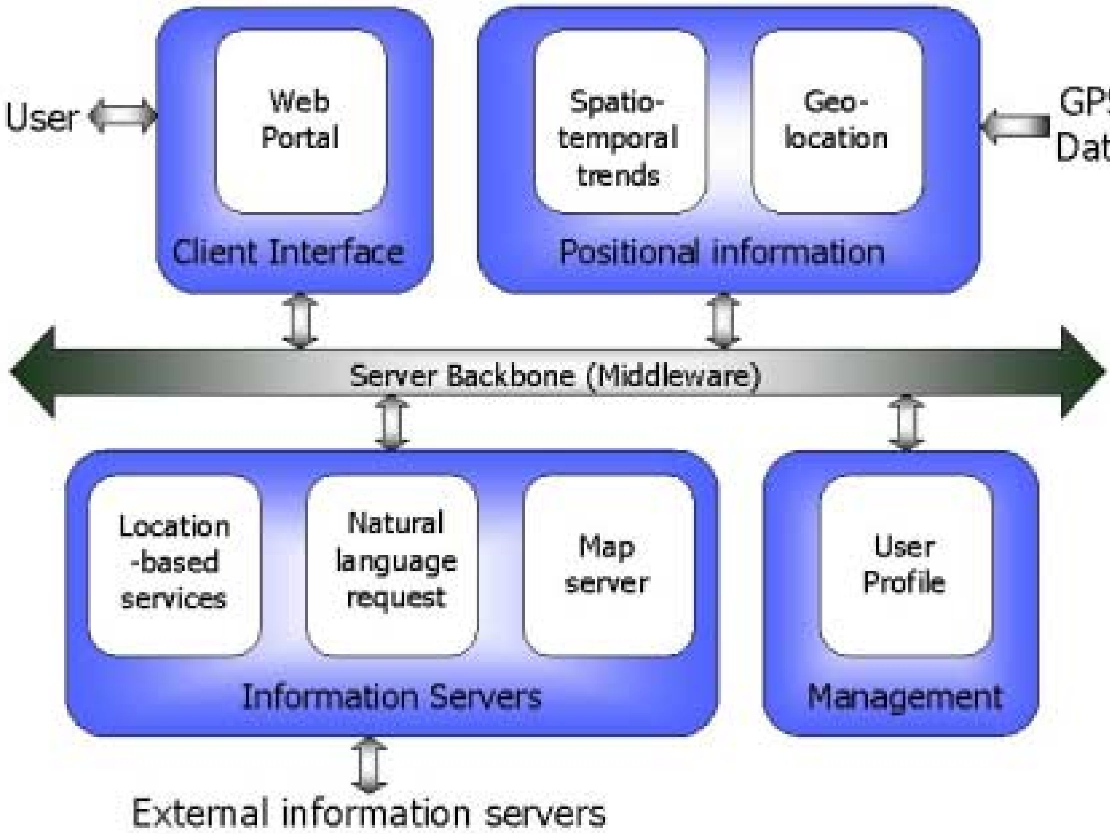
## 3 Hypergeo Project

The European Union Information Society Technologies Programme (IST) funded Hypergeo project aims to develop a prototype for the delivery of location and user sensitive information for tourists. To achieve this aim a distributed architecture has been adopted with different components focusing on specific problems associated with delivering timely and relevant information in a user friendly way. The Hypergeo system architecture consists of discrete components linked by various middleware protocols. Each component is intended to operate independently and communicate to other components through message sending. The main components are discussed below.

The web portal is the user interface to the Hypergeo service. It uses HTTP that can be accessed via a static PC or using a micro-browser on a PDA. Pages are generated dynamically to take account of the user's location, preferences and queries. The user profile stores information about the user and allows other components to access this information. Information about the user falls into three areas. Short-term information includes information about the user location and recent spatio-temporal trends. Mid-term information stores user preferences that can evolve over time. Long-term information is information on the user identity that is unlikely to change frequently.

Users' geographical locations are sent periodically by mobile users' devices and their profiles are updated with this information. This makes the user's present position available to all components in the Hypergeo system. In addition a track log history is stored but this information is degraded for the privacy of the user. It is intended that this logging of the user's position should be a transparent process where users can see the history and resolution of stored information and delete the log if they desire. Users' locational trends are extracted to preserve positional information whilst deleting the data itself. A number of techniques are proposed to achieve this aim including generalised templates of regularly repeated routes and spatio-temporal “envelopes. In addition this component aims to make assumptions about user activity and potential future locations from their recent history.

*Figure 1: Hypergeo system architecture*




In addition to knowing the user’s location, the location of services must also be known to the hypergeo service. This is achieved by the construction of a flexible hierarchy of location contexts from the broadest scope definition (e.g. Europe) to contexts at street level. Services are located within a context to allow the services closest to a user to be returned. The appropriate level of the hierarchy can be queried depending upon the user’s mobility and the number of results returned.

The natural language request component facilitates document searching. Its role is to formulate queries from terms entered by users through the client interface, query documents and display results to the user. The component works in pull mode (i.e. in response to a user request) and aims to record user feedback by storing query results.

The map server component delivers underlying geographical information within a certain region of interest to other components as a result of requests. This information can be used for map display to the user or for geographical information context used in the extraction of user spatio-temporal trends.

## 4 Acquisition and analysis of positional information

The role of City University in the Hypergeo project focuses on the acquisition and analysis of positional information. Various techniques allow the position of the user to be determined (geolocation) and this information returned to a central server. Once this information is received it can be analysed, transformed and stored; the approach taken for this second stage is spatio-temporal data mining.

## 4.1 Geolocation

In order to offer location based services the user location must first be established. There are many viable positioning techniques which can be divided into either client side techniques, where determining the user position takes place on the handheld device carried by the user, or server/network techniques, where the user position is determined on a central server.

### *4.1.1 Client side solutions*

The global positioning system (GPS) is a satellite-based navigation system. A GPS chip in a mobile device can be used to position the device to within roughly 20 metres making it the most accurate geolocation device available at the moment. Disadvantages of this system are that the device requires line of sight to satellites to function hence will not work indoors, in tunnels, or extreme "urban canyons" where an insufficient portion of the sky can be seen. It also requires that additional hardware be added to the handheld device including a bulky aerial.

Using the enhanced observed time difference (E-OTD) approach, a mobile device can calculate its distance from a base transceiver station from the observed time difference between the transmission and arrival of information "bursts". Using bursts from three or more base transceiver stations allows triangulation and an estimation of the user's position to 200 metres accuracy or better. The technique can be either a client or a server side solution. When client side, the mobile device requires further information such as the location of the transceiver stations.

### *4.1.2 Server/Network based solutions*

Network positioning systems exploit the existing network infrastructure developed specifically for mobile phones to gauge the location of the user and communicate this information via the mobile network. Some systems require adjustments to the GSM network whilst others can exploit the network as it stands. Whilst the accuracy of the network positioning may seem poor compared to GPS positioning, it has the major advantage of working inside buildings.

The cell global identity (CGI) identifies within which network cell the mobile client is located. Using this method alone therefore accuracy is limited by the size of network cell. Using timing advance (TA) information (time difference between transmission and arrival of information) provides an estimate of distance from the base station accurate to about 500 metres, however the technique employs no directional information therefore the user could be located anywhere in a circular band (or a section of a circular band) around the base station. Further research into this technique suggests that it has the potential to achieve accuracy of around 100-200 metres on the ground. Despite the coarse resolution of positional information the technique has the advantage that it can be employed on existing network infrastructures.

The uplink time of arrival (UL TOA) method uses positional information from several base station transceivers and requires minor modification to the network infrastructure in the form of locational measurement units (LMUs) at base stations. These are devoted to receiving information from mobile clients about how long information from base stations took to reach the mobile device. Calculations are performed away from the client at a dedicated server in the mobile network; hence the system works for existing mobile terminals. Accuracy of between 50 to 150 metres can be achieved although recently companies have been claiming results as accurate as 5.6 metres (Cell-Loc, 2000).

### *4.1.3 Hybrid methods*

Network assisted GPS overcomes the coverage problems associated with GPS (i.e. that it is unable to function without line of sight to the satellites) by combining network information with GPS information. This requires a modification to the network with location measurement units (LMUs) added to selected base transceiver stations. This system offers accuracy of around 10 to 20 metres with arguably the main advantage being the increased coverage.

## 4.2 Spatio-temporal data mining

The ability to define the absolute physical location of users leads to a huge volume of data being collected and stored. Due to the vastness of this data set, and for reasons of personal privacy, it is arguably inappropriate to store all the positional information for individual users. Techniques for summarising data have been investigated that are information rich and less invasive of users' individual privacy.

Simply knowing a user's position in space is of limited use. In addition to their location it helps to have positional history in the form of summaries of their previous movement and geographical information context in the form of underlying land use maps and transport networks. By combining these different sources of information, higher level information can be attained such as assumptions about transport types and user behaviour.

### *4.2.1 Behaviour modelling using user's positional data only*

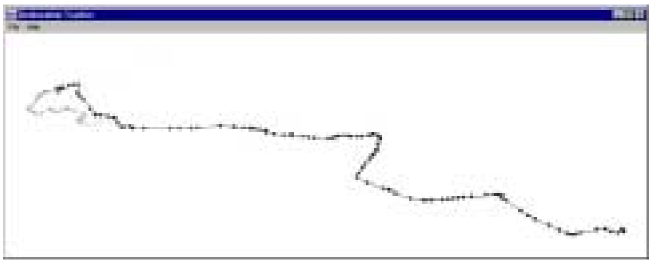
A number of techniques show potential in deriving user behaviour from analysis of user track history without comparison with underlying data sets. Here the user's present location, recent track history and a degraded longer-term location history are used to find trends in the data.

Certain behaviours are associated with certain speeds however classes tend to have large overlaps using this parameter alone. Transport behaviour in particular has a hierarchy where walking is the slowest with further possible distinctions between general transport classes. This parameter alone provides unreliable estimates of user behaviour.

Measuring the sinuosity of the user's track offers some potential in identifying user behaviour. For example, shopping behaviour tends to reveal a very sinuous track with a great deal of backtracking, stopping and starting. At the other extreme train and plane journeys tend to be smooth lines travelling predominantly in a single direction (see figure 2).

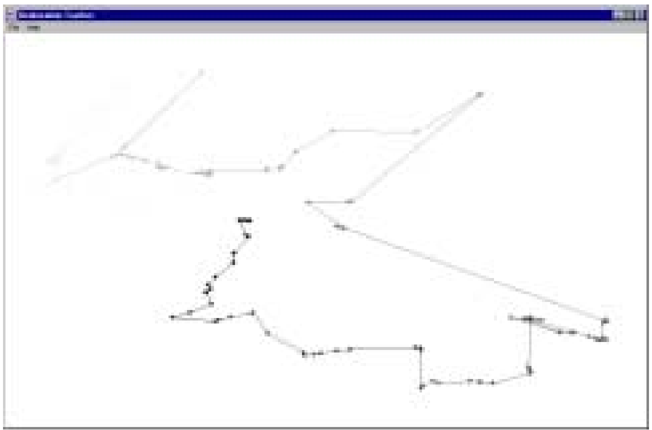
*Figure 2: Track logs associated with different transportation types*

*Track log. Motorbike journey through London*



The time elapsed is represented by the greyscale shading of the points. The earliest points are white and latest black.

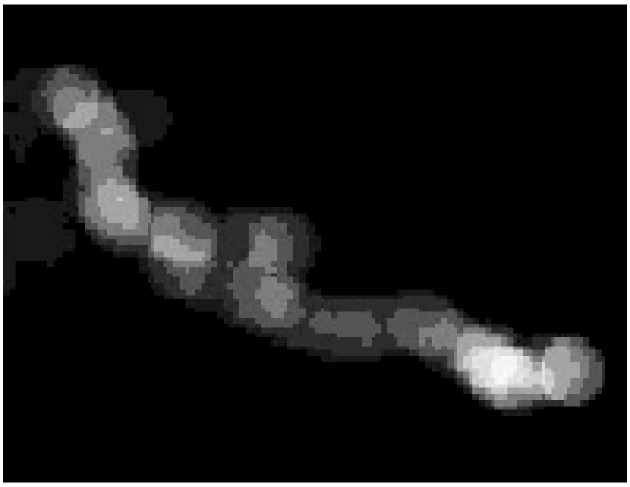
*Track log. Sightseeing in Amsterdam*



A drawback of the GPS system (that devices only function with direct line of sight to three or more satellites) could be turned to an advantage by monitoring these switch on/off events to see if they correspond to certain behaviour types. The loss of signal corresponds to users going indoors, into tunnels or urban canyons. Switch off events help identify nodes such as home and work locations and may be particularly useful for detecting journeys on underground transport systems.

Density surfaces of aggregated points indicate key nodes that are unique to a user. Initial results show home and work locations standing out well. Moving to a new location with a "fresh canvas" should allow new nodes such as a hotel, to be identified quickly.

*Figure 3: Density surface showing a user's journey to work.*



The home location (bottom right), work location (top left) and a number of *en route* transport nodes can be identified.

### *Behaviour modelling with underlying context*

By querying the user location and summarised positional information against underlying geographical information, more information about user behaviour may be revealed. The type and resolution of the geographical information used has a strong bearing on the analysis that can be performed.

Track logs can be compared to transport networks to establish the type of transport a user may be employing. Speed may also help to identify the transport type. This is of significance since the transport being employed affects information needs, accessibility and the scale at which searches should be performed.

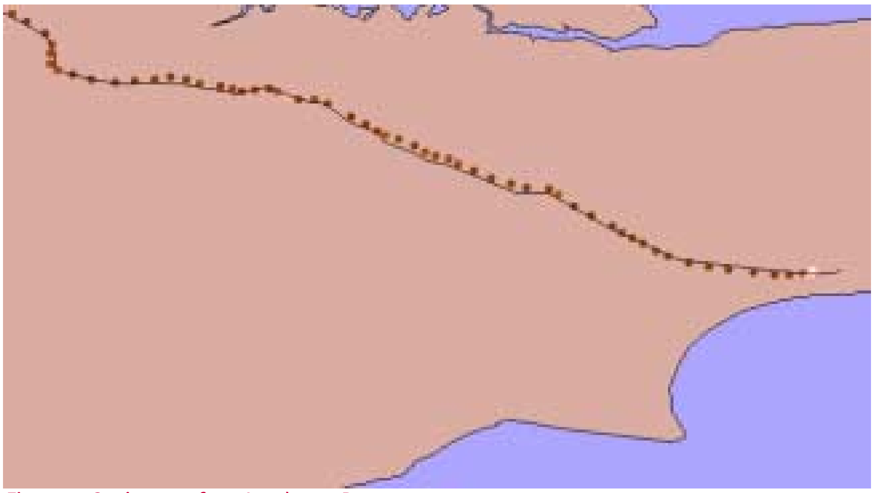


*Figure 4: Car journey from London to Dover*

A track log following the M20 through Kent. Shading represents speed from light (slow) to dark (fast).

### *4.2.3 Summarising Positional Data*

Spatio-temporal behaviour can be summarised into long-term or short-term information. Two approaches to summarising longer-term trends have been investigated. User defined envelopes drawn around the range of a user's visited locations for specified time periods produces an enclosing polygons. These envelopes are useful summaries of where the user spends their time and can be used as a heuristic to limit search space. Comparing these envelopes for different times of the day or different days of the week offers insight into how the user's behaviour varies with time. Polygons produced through this process could be used as data input for the other processes of spatio-temporal analysis.

By defining specific start and end points, *episodes* of behaviour may be defined which can act as templates against which to compare present user behaviour. The start or end points to episodes may be leaving or returning to the home or work location, remaining static for a period of time, or an abrupt change in speed or direction. Matching ongoing behaviour to a template in real time allows assumptions to be made about the remainder of the user's journey and offers feedback about the relative importance of that particular episode template.

Two methods of summarising short-term information have been investigated. Conjectured activity attempts to predict the users behaviour from analysis of the user's movement and comparison with underlying data sets, particularly. Fuzzy set theory could be used to account for the uncertainty inherent in categorising behaviour and could prevent (for example) results only relevant to a user in a car being sent to someone who is, in actual fact, travelling on foot.

Another approach to summarising short-term behaviour is looking ahead, predicting future locations from present behaviour and context. This category is less discrete and is likely to incorporate elements of all of the above. Envelopes, episodes and activity could be combined to predict polygons of where a user is likely to be at defined periods in the future.

### *4.2.4 Passive Relevance Feedback*

The user location will be logged after search results have been sent hence it can be seen which, if any, of the suggested locations sent in response to user queries the user chose to visit. This feedback could be invaluable in identifying the locations and services preferred by the user and in helping to develop a standard set of results queries that could be stored and dispatched immediately without the need for further processing.

### *4.2.5 Aggregated Results*

The results of individual users could be combined to provide information about how users operate and interact en masse. This will allow the heterogeneity of spatio-temporal trends to be modelled. Preferred locations and routes could be revealed assisting in developing pre-processed query results. Further aggregated trends could be the mean spatial extent associated with different time scales (mean hourly, daily or weekly spatial extent) or spatial and temporal extent associated with different user behaviours. If sufficient data were to become available, interaction between users could be studied such as seeing how users respond to congested road systems and calculating threshold values for attractions at which point the excessive volume of visitors deters others from going to that location.

## Conclusion

Advancement within and convergence between the fields of mobile telecommunications and computing is leading to new mobile devices with increased functionality including the ability to calculate their location. This is leading to the creation of large dynamic data sets. Summarising this positional information offers great potential in assisting user queries, creating a profile of user behaviour and offering feedback on results sent by the system. A number of techniques offering potential in summarising this data have been described which aim to retain information about the user whilst deleting data that could infringe an individual's privacy.

## References

BBC News, (2000), Mobiles 'owned by 50% of UK'.

http://news6.thdo.bbc.co.uk/hi/english/business/newsid_817000/817941.stm

Cell-Loc, (2000). Technology Overview. http://www.cell-loc.com/index3.html

Coalition Against Unsolicited Commercial Email, (2000). http://www.cauce.org/

Federal Communications Commission Web Site, (2000). Enhanced 911 Initiative. http://www.fcc.gov/e911/

McSwein, K., (1999). Information Revolution or Industry Hype. The effect of Broader Bandwidth on Mobile Communication. MSc Thesis. City University.

Swedberg, G. (1999), Ericsson's Mobile Location Solution. Ericsson Review No. 4, 214-221.

UMTS Forum, (2000). UMTS Brochure. http://www.umts-forum.org

Vicinity Corporation, (2000). Forget about wired...

http://www.mapblast.com/vicinity/press/news/news_03_13_00_.html

Wired News (2000), Signing Up to Be Surveilled.

http://www.wired.com/news/technology/0,1282,37559-2,00.html

The Wireless Developer Network, (2000). Phone.com Introduces the Mobile Location Server for Mobile Internet Applications - http://www.wirelessdevnet.com/news/2000/206/news8.html.