B05.3 Location-based services in remote areas

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1 Introduction

Many location-based service (LBS) providers are developing systems that rely on data provided over a mobile network with the limitation that where there is no coverage, there can be no service. One of the driving factors behind LBS has been personal safety, particularly locating the user in emergency situations (Reinhardt, 2001) as emphasised by the US Federal Communication Commission's enhanced-911 initiative. In remote areas, where network coverage is often limited or non-existent, services relying solely on network connections fail to inform either the emergency services or the user themselves of their location. Additionally since network positioning tends to be at its coarsest resolution in such areas, the user's position may only be known to within a few kilometres.

The trend of the last few years that has seen the blending of telephony and computing technologies looks set to continue. Such devices can now offer online and offline services with background data being stored on the device itself and timely, personalised and local enhancements delivered when a network connection is available. The increasing compatibility of GPS with such devices offers high resolution positioning. For data stored locally on the mobile device, problems of dropped connections and limited bandwidth can be avoided. Clients required to deliver such a service (location aware devices with increased memory and GSM/GPRS network connections) are available as off the shelf products and accessories. However developing solely for expensive, hi-tech devices limits the potential audience since, for the short term at least, the mass mobile phone market has been dominated by cheap or free clients with relatively limited functionality subsidised by mobile phone contracts.

Consideration of the heterogeneity of client functionality and network conditions is required to offer a generic service that will be of use in real conditions. These considerations should be included at the design stage. The challenge of delivering location-based services in remote areas with partial network coverage is to design a system that can operate in a hybrid mode. Hybrid location-based services use a combination of positioning systems and access the network when they can. Designing systems that can deliver content and services requires a consideration of three aspects of functionality; processing speed, network bandwidth and positioning accuracy. These factors influence system design concerns such as client-server architectures, security and privacy issues and business models for wireless location-based services. It is these technical considerations and design concerns that this paper will discuss.

The approach of using a smart navigation client (with increased functionality that can work both online and offline) has been adopted by a pan-European consortium working on the EU funded Webpark project. Services being trialled in the Swiss National Park, the Dutch coast and the UK offer location-based, personalised information to leisure users.

2 Client Functionality

There are three key areas of client hardware functionality that must be considered for location-based services on handheld devices (see figure 1); these are:

1. processing (including local storage capacity and display),

2. bandwidth and connection and

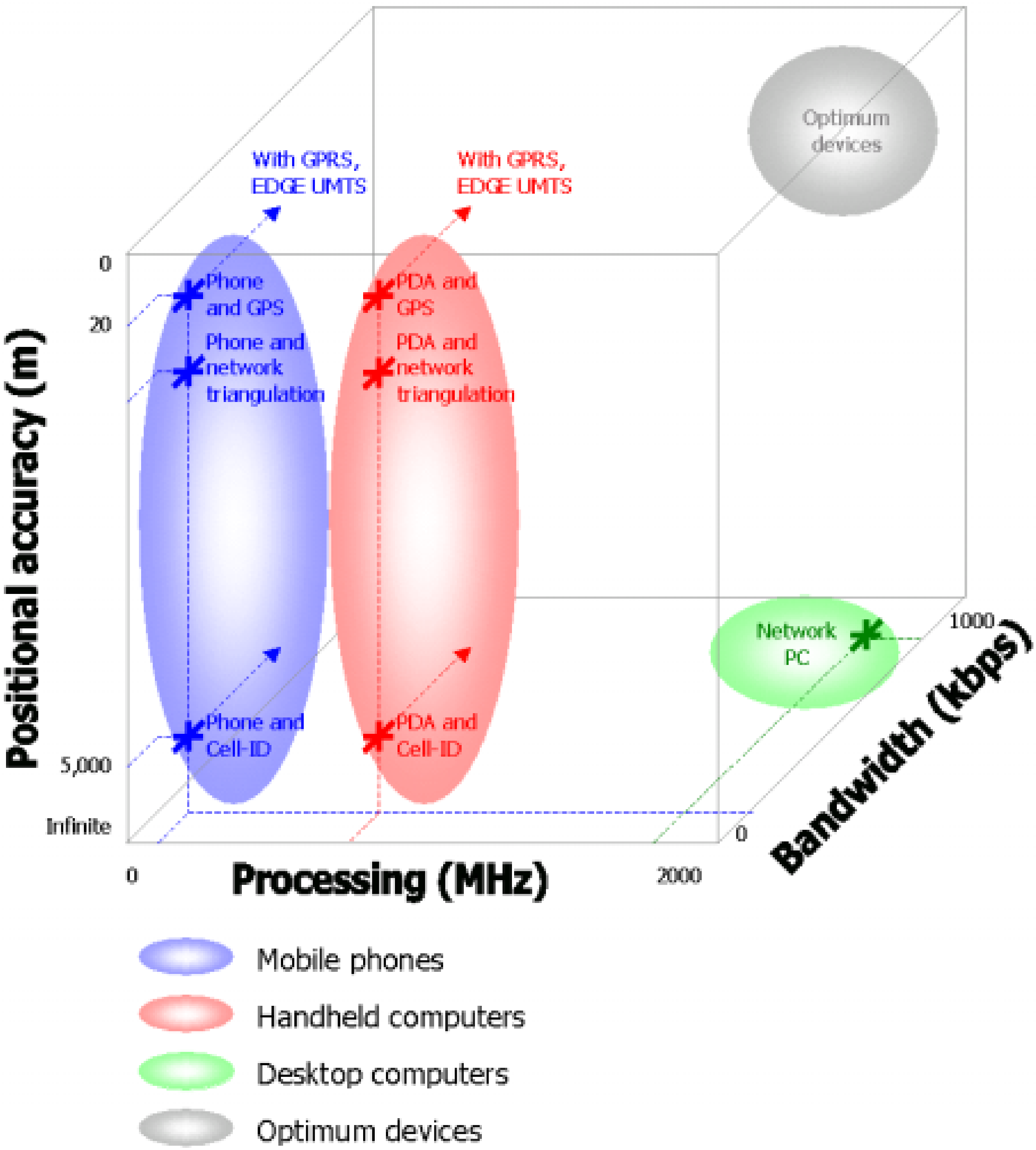
3. positioning accuracy.

The performance of a device in each of these areas dictates the services that can be provided on that client device. Making assumptions about the functionality of a client device accessing a location-based service limits its potential audience, however developing solely for the 'lowest common denominator' (a device that has limited functionality in all four areas) can result in a service that is technologically low level, lacking innovation and of limited use. A good understanding of the relationships between these three factors should dictate the choice of client-server architecture to ensure optimum use of the available resources.

Consideration of these three areas is critical for all location-based services, however, services in remote areas are a special case since the characteristics of the factors and relationship between them can be quite different. This demands alternative client-server architectures, which in turn influences the services that can be offered. The following discussion has validity for all services but pays particular attention to the case of leisure services in remote areas.

Figure 1: Three dimensional plot of client device functionality:

Processing vs Bandwidth vs Positional accuracy



2.1 Processing power

There is a continuum in the processing power of mobile devices from mobile phones with limited processing and closed platforms to handheld computers with processing capabilities on a par with the second hand laptop market (see figure 1). The most popular mobile phone devices purchased at a discounted rate and subsidised by a mobile phone contract have very little processing power and closed platforms. Displays remain small (eg 96*60 pixels) and monochrome and storage is limited to an address book and history of text messages (Nokia, 2002). The development environment is characterised by limited pre-installed applications reaching a mass audience who have little opportunity to customise the functionality (other than in a cosmetic way). For these devices wireless location-based service providers are limited to offering services via an internet or WAP browser and virtually all processing is server side.

Superseding the processing capabilities of these devices are *smartphones* with improved displays that offer increased functionality such as organisers, internet access (sometimes restricted), email and word processing capabilities that still generally come pre-installed. Processors are more powerful and there is increased storage for personal data. A wider network of developers can contribute to these systems offering more customised functionality. A number of operating systems are available (such as GEOS for the Nokia 9110) however an open, scalable operating system, Symbian, has emerged as a smartphone standard. This operating system can run on a variety of devices and allows customisation of applications on a device moving closer to a handheld computer than a legacy mobile phone.

With personal digital assistants (PDAs) (or handheld computers) the emphasis is much more on the device as a computer with mobile connectivity as an addition (either inbuilt or via a mobile phone and modem). A variety of operating systems such as PalmOS, Windows CE (Pocket PC) and Linux are available that can be customised with user specified applications supplied by a large number of developers. Processors can be as fast as 400MHz (Compaq, 2002) and displays are high-resolution colour. Independent client side processing allows more complex client-server architectures to be implemented; location-based service providers can develop applications that run locally with server back-up as required (eg for recent timely information or to download additional information not stored locally) rather than a web-based service.

The development potential for a platform increases with the sophistication of the operating system, however a more sophisticated solution replying upon locally installed applications and client side processing massively decreases the target audience for a service. Mature services should aim to provide a system that is scalable to allow a range of functionality in the client device from the limited access for the bulk of (mobile phone) users to a full sophisticated system for mobile users with a connected PDA.

2.2 Bandwidth

An evolutionary increase in network bandwidth (the volume of data that can be sent to and from a mobile client across a network) is underway, the culmination of which (at present) is seen as high bandwidth third generation (3G) systems (GSM World, 2000). Greater bandwidth *may* allow richer data sources and more complex client–server architectures for mobile computing however there is a downside associated with availability and cost. A crucial factor for wireless computing in remote areas is strategies for coping where no mobile network connection exists and whether the proposed increases in bandwidth will have any impact in areas of low population density.

Current GSM networks, which have been the standard for Europe for the last 10 years, allow the transfer of a maximum of 9.6 kilobytes of data per second (kbps). This is slow compared with fixed line connections for desktop computers but sufficient for voice and limited data transfer (eg text messages and low resolution imagery). It has the advantage of relative ubiquity; it is the standard network across Europe for client terminals and coverage can be found in many of Europe's more remote locations where population densities are low. It is these areas that will be the last to see the introduction of higher bandwidth networks, if network operators consider it economically viable to upgrade the network at all (Morawek and Öczelik, 2000). However, there are some remote areas such as national parks and other protected areas where the transit of high-income leisure travellers has motivated investment in the network- and these offer the greatest opportunity for the development of distinctive location-based services.

A key step in network evolution from second generation (eg GSM) networks to third generation networks is GPRS (general packet radio service) whose key advantages are increased bandwidth and an 'always on' connection that will eliminate the 'dial-up' time slowing data transfers via GSM networks (GSM World, 2000). Downloading web content, checking email and higher level services are also possible on GSM networks however the experience should be faster and easier via GPRS at (theoretical) network speeds of 172.2 kbps. This theoretical maximum will not be a reality for most users who will be limited to one, two or three of the eight available time slots offering connection speeds similar to fixed line modem connections. GPRS offers the potential for increases in network capacity but if delivered across existing networks then busy networks (already operating at capacity) will not see dramatic increases in bandwidth, although the existing bandwidth will be shared more efficiently. A GPRS service now exists in most European countries including the UK but mass consumer take-up has been slow.

The next stepping stone is EDGE (Enhanced Data for GSM Evolution) offering faster connection rates still but the key development is likely to be the third generation or Universal Mobile Telecommunication System (UMTS) networks, the licenses for which mobile telecommunications companies in the UK collectively paid £22.5bn (GSMBox, 2000). Once available (likely to be 2004) it is hope that this solution will offer massive bandwidths measured in megabytes per second and permanent connections making download speeds negligible compared present networks. It is likely to be many years before UMTS makes any impact upon remote areas; there are plans for existing networks to coexist alongside new technology for many years as a backup and for legacy phone users. Aside from the costs associated with developing a new network, remote areas are usually a much lower priority than urban centres and crucially for UMTS, the network cells offering high bandwidth are considerably smaller (pico or micro cells). Some remote areas are likely to be serviced at the same rates as GSM for the lifetime of third generation networks (Morawek and Öczelik, 2000) however the information needs of travellers is likely to result in special attention being paid to national parks and remote leisure areas.

2.3 Positioning Accuracy

Positioning solutions for mobile devices can be divided into satellite-based solutions and terrestrial (network-based) solutions. Each has strengths and weaknesses however the global nature of satellite based solutions make their performance more predictable since they are not limited by the characteristics of a single local network.

At present the de facto standard global navigation satellite system is the US military Global Positioning System (GPS) using NAVSTAR satellites (Börjesson et al, 1999). It can offer positioning accuracy of 20 metres, 95 percent of the time (Nakamura, 1997) however the signals from satellites are too weak to penetrate masonry or any considerable depth of solid material so coverage is reduced in vehicles and virtually non-existent within buildings. Acquiring a positional fix is not instantaneous and can take several minutes (Hayday, 2002; Navman, 2002); for built-up areas in particular “urban canyons” can limit impede GPS coverage, however, in open rural areas where the view of the sky is less interrupted GPS typically performs better. Another development for satellite-based systems is the European scheme Galileo, which aims to provide a more accurate alternative from 2008 that unlike GPS, will not be a cost-free service (Thurston, 2001). The main advantage of satellite-based systems is that they have global coverage and hence operate in remote areas of zero population density (including polar regions, deserts, oceans) as long as the view of the sky is relatively unobscured; terrestrial solutions can only position users where network coverage exists. In addition a mobile device with GPS receiver will operate anywhere regardless of the network operator (if a network exists) and so does not have to account for the variety of positioning technologies available through terrestrial networks.

Terrestrial solutions relying upon the mobile network infrastructure can employ a variety of techniques of varying granularity to position users. The calculation of the location can take place on either the handset or the network and this forms a neat distinction between different approaches (Swedberg, 1999). Of the network based approaches, the simplest and least accurate is the Cell of Origin (COO) or Cell Identity (Cell ID) technique which reports which network cell the device is in and is required for call routing. No information on precision or accuracy is reported; since mobile cells can range from tens of metres to tens of kilometres in size this technique cannot provide reliable results. Wireless location-based services in remote areas should assume poor accuracy since the size of network cells is roughly inversely proportional to population density (up to a maximum of about 35 km); more cells are required to deal with dense network traffic in built up areas.

Whilst cell of origin *must* be known to the network (even if not readily accessibly to location-based service providers) more accurate network-based solutions require network modification and so are not ubiquitous. The Angle of Arrival method (AOA) improves the cell of origin technique by estimating the direction of the mobile device from a specific antenna. The Time of Arrival Method (TOA) method measures the time for signals to travel from several antennae to the device to triangulate an estimated position and, uncharacteristically for terrestrial techniques, performs better in remote settings than built-up areas where claimed optimum accuracy is around 50 metres (Swedberg, 1999). A ground truthing exercise can provide a map of Radio Frequency (RF) characteristics for a network cell and the incoming signals from a device compared to this to offer an estimate of location (US Wireless, 2002). Whilst accurate, producing the map of frequency characteristics is expensive and the technique is less reliable in remote settings than in built-up environments where distinct patterns associated with the urban infrastructure emerge.

Positioning techniques where calculation takes place on the handset hold the advantage of not requiring network modifications. The GPS satellite system can be regarded as a handset approach, however, it is really distinct from the category since it operates entirely independently any mobile telecommunications network. Enhanced Observed Time Difference (E-OTD) is the same triangulation technique as Time of Arrival with similar levels of accuracy however processing occurs on client device. A variety of techniques, such as cell of origin, can be performed using a SIM toolkit, however without further intelligence in the device or network or a hybrid approach, the accuracy will be limited to the techniques described above (Christensen, 2001). One hybrid solution is assisted-GPS in which the terrestrial solution provides a server-side 'rough-fix' for the GPS, which may be useful in remote areas.

The implication for location-based services in remote areas is that satellite based solutions potentially offer a more generic, reliable and accurate solution than terrestrial solutions which where the resolution of the positional fix may be poor with unreported accuracy information or be unable to provide positional fixes in remote areas. For safety information, such as providing a route back to shelter from an unknown remote location, the terrestrial solution will fail to provide the user's location and mapping information if relying solely upon a network connection. The satellite-based solution using cached information can offer directions to safety in remote areas where no mobile network coverage is available.

3 Client-server architecture

The relationships between processing speed, network bandwidth and positional accuracy should help to define the client-server architecture for a service. Assumptions about any of these considerations may lead to a lack of service on some devices or in some areas. Alternative strategies should be considered to deal with different clients devices, a range of bandwidths and different levels of accuracy in client positioning in order to reach as large an audience as possible.

Devices with limited processing power (such as traditional phones) rely heavily on a server-side network architecture since the client is not capable of running more sophisticated functionality. Consequently the bandwidth (and crucially the existence of a network connection) becomes increasingly important since services rely on requests to the server and returning of results rather than local processing. More powerful devices can perform more tasks locally and continue to operate to some degree without a network connection. This becomes important in remote areas where presently network connections may be sporadic or non-existent, and in the future where bandwidth may be less than in built-up areas.

Developers must consider this discrepancy during the design stage or risk losing favour with two key market areas; rural populations and visitors to remote areas. Tourism and leisure has become a standard test-bed for location-services since it is associated with a user visiting a new area and hence having a strong need for information (Davies et al, 1999). The mobile telecommunications industry, for whom coverage is associated with user's *fixed* home locations, should consider that wireless location-based services are inherently *mobile* and not dictated solely by the user's home address (where a higher bandwidth fixed line is likely to be the connection of choice).

More powerful devices with an open development environment are also generally more expandable and can find a greater number of solutions to positioning the device. Closed devices with limited processing capability rely on the positioning solution provided by the network operator. More powerful devices can take advantage of the satellite systems that can provide more accurate positional fixes and retain fixes in areas without network coverage. Mature services should aim to provide a scalable system that can provide a range of functionality.

For more sophisticated devices caching data locally and working offline can allow a wireless location-based service to continue to work even where there is no network coverage. With accurate positioning and cached local data users can chart their progress on route maps or receive directions for returning to shelter if lost in poor visibility. Services designed for limited clients may be confined to broadcasting text alerts (eg a severe weather warning) to all or selected users in a region.

4 Security/Privacy

While the foregoing technical considerations provide constraints on the technical provision of the proposed solutions, issues such as security and privacy hold the key to take-up of the services. The 'use-case' for location-based services in remote areas is the user who uses the mobile device as a safety backup or as a mobile information appliance. However, effective responses to such 'geographic information needs' require (geographic) context for the user's request such as the user's (recent) movement history and appropriate personalisation information (Raper 2001). Without such information the service cannot aspire to any 'intelligent' characteristics based on knowledge discovery. Here then is a conundrum: the service providers will need to make a case to potential users for engagement with the service in order to give the service a chance to make its responses adequately relevant to the user. Yet such engagement might well require permission to track the user and to store such tracking information, which is a prima facie privacy issue.

Given current sensitivities to data privacy this conundrum may seem like a 'catch-22'. However, in reality it shows the way ahead for location-based services: service providers will have to define circumstances where holding locational personalisation makes sense in the context of the service, and they will have to develop privacy policies and tools to match. If they do not then the services will remain at the level of isolated responses to isolated requests, and there is not much potential in that. The authors are working on the EU Webpark project (http://www.webparkservices.info) that is developing tools to address these challenges.

5 Business Models

Offering a range of services requires new business models to be considered. One criticism of the move from dial-up to always-on connections has been that the user will not understand what they are paying for and more complex client-server models will exacerbate this. One success in mobile data communication has been micropayments associated with news alerts and the short message service where rather than subscriptions fees, a user pays a specific amount for an isolated transaction. New location-based services built upon the development of geographic personalisation can enhance the ability of the service provider to target services hence this well understood model continues to offer utility.

A further feature of the location-based service business model is that the content is likely to be a blend of framework information (Timpf, 2001) that is 'sponsored' and premium information that requires a micropayment. This idea of a ‘demo’, ’evaluation’ or ‘free’ application as a lead into a paying service is well understood in the software market and the difference between online and offline services and data could become a standard for location-based services. There are further challenges in the design of layered services where the framework information enhances the premium information if there is good data integration. This will require the development of 'niche' applications that offer functionality requiring data services that offer the user real added value.

6 Conclusion

The development of location-based services for users in remote areas share many of the needs of location-based services elsewhere, viz. A privacy policy, personalisation, a killer app, good geographic information content and a technical architecture such as the reference platform for Open Location Services (http://www.openls.org/). However, in remote areas there is a need to develop distinctive client processing, bandwidth access and positioning solutions associated with the heterogeneity of mobile devices. Combining these design requirements will deliver the innovative services that Webpark project market research has indicated exists.

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