Location-Based Services
The State of the Art

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ABSTRACT
The convergence of the Internet and wireless telecommunications has opened the way for a plethora of data services for the mobile handset user. One potential area of mobile (m-) commerce development is in location-based services (LBS). Using a range of positioning techniques, operators can offer entirely new services and improvements on current ones. Popular examples cited include emergency caller location, asset tracking, navigation, location-based information or geographically sensitive billing. This paper examines the technologies, applications and strategic issues associated with the commercialization of LBS. The paper concludes with some predictions on the role of LBS in m-commerce.

Keywords: location-based services, wireless, mobile commerce.

INTRODUCTION
In their own right, the Internet and mobile phone have witnessed extraordinary market penetration. By the end of September 2002, there were an estimated 605.6 million Internet users worldwide (Nua, 2003). In June 2002, the global number of mobile phone users reached one billion for the first time (eMarketer, 2002). Together, the convergence of these technologies promises to bring further services. Worldwide, revenues from mobile (m-) commerce—i.e. transactions over wireless telecommunications networks—are expected to exceed $25 billion by 2006 (Frost and Sullivan, 2002).

In the emerging m-commerce economy, the knowledge of the position of a given service subscriber making a call is gaining particular interest among mobile operators who can, in turn, provide innovative location-based services (LBS). Such ideas are not new: basic tracking services and automated vehicle location (AVL) have existed since the 1980s. However, until recently, the specialized location-based industry survived as a niche market to both high-end businesses (such as trucking and freight) and well-to-do customers (via...
automobiles such as Lexus and BMW). Typically, high-priced devices required subscriptions to special location services, suppressing demand (Frost and Sullivan, 2003).

Full commercialization of LBS has only become possible in the last few years. In particular, recent technological advancements, regulatory change, and industry trends have begun to provide an environment that is conducive. As a result, the door has been opened to a vast array of commercial applications, including those for emergency services, asset tracking, navigation, location-sensitive billing, and location-based information services. Indeed, according to the Strategy Analytics (2003), LBS could be worth an estimated $8 billion by 2008.

Recently, the terrorist attack of September 11 has highlighted the value of LBS technology. In response to the emergency, cellular networks were heavily used both by the public and rescue workers. Of particular note was the jury-rigged automatic location systems used in New York as part of the rescue effort. Undoubtedly, the September 11 attacks have helped focus attention on the importance of a system that locates emergency callers.

The purpose of this paper is to examine the emerging LBS phenomenon. In particular, the following sections chart the technologies, applications, and strategic issues associated with this emerging wave of e-services. To conclude, the paper presents a summary and some predictions regarding the future of LBS.

**LOCATION TECHNOLOGIES FOR MOBILE COMMERCE**

One or more location methods can be used to determine the position of user equipment for LBS. Location techniques operate in two steps—signal measurements and location estimate computation based on the measurements—which may be carried out by the user equipment or the telecommunications network (Mitchell and Whitmore, 2003). Subsequently, positioning techniques can be categorized into several varieties, each with its advantages and disadvantages. The main types are cell-location, advanced network-based, and satellite-based positioning. Three of the main categories of positioning methods are shown in Table 1, in order of increasing accuracy.

**Cell-Location Positioning Techniques**

This technique works by identification of the cell of the network in which the handset is operating (the “cell of origin”). Cell of origin (COO), sometimes called Cell-id, is the main technology widely deployed in wireless networks today. It requires no modification to handsets or networks since it uses the mobile network base station as the location of the caller. However, although locating the caller is fast—typically around three seconds—accuracy is limited. Positioning accuracy depends on the size of the cell and techniques used for enhancing location calculation, such as user self-locating (whereby end-users use landmarks and addresses to improve their positioning precision) and propagation time.
measurements. Position down to 150 metres in urban areas is not uncommon, growing significantly outside major areas of population.

| Location Service (LS) Category | Explanation | Typical Methods of Positioning | Accuracy | Response Time | Key Limitations | Cost & Market Requirements |
|--------------------------------|-------------|--------------------------------|----------|---------------|-----------------|---------------------------|
| Category LS1: (Basic service level) | Location of all handsets with at least cell accuracy | Cell of Origin (COO) or Cell-ID, including Service Area Identity (SAI), LocWAP and enhanced Cell-ID. May also include enhancements with propagation time measurements | Low. Depends on cell size and enhancements; typically 150m to 10,000m | Very Fast. Typically around 3 seconds. | Very limited accuracy in areas with low cell radius | Low cost. No modifications needed to networks or handsets |
| Category LS2: (Enhanced service level) | Location of all new handsets with reasonable cost and improved accuracy | Estimated Time of Arrival (EOTD) for GSM, and its variations such as Advanced Forward Link Triangulation (AF-LT) and Idle Period Downlink (IP-DL) for CDMA and WCDMA respectively | Medium. Typically around 50m to 125m | Fast. EOTD takes around 5 seconds. | Dependent on visibility of base stations for signal measurement and number of location measuring units (LMUs) | Moderate cost. Software modified handsets needed for positioning |
| Category LS3: (Extended service level) | Location of new handsets with high accuracy and higher costs than LS2 | Global Positioning System (GPS) and Assisted Global Positioning System (GPS) | High. Outside buildings, approx. 10-20m; inside buildings, approx. 50m | Variable. GPS takes around 10-60 seconds and AGPS 5 seconds | Signal degradation and reduced accuracy in certain environments, e.g., inside buildings or "urban canyons" | High cost. New handsets needed for positioning |

**Table 1.** Three categories of mobile location methods

**Advanced Network-Based Positioning Techniques**

Advanced network-based techniques rely on the measurement of signals from nearby base stations via the user's equipment. The position of the user is derived by triangulation, using techniques such as Enhanced Observed Time Difference (E-OTD) and Observed Time Difference of Arrival (OTDOA). The E-OTD method works on the Global System for Mobile Communications (GSM) network. Variations of E-OTD such as Advanced Forward Link Triangulation (AF-LT) and Idle Period Downlink (IP-DL) have been developed for Code Vision Multiple Access (CDMA) and Wide-band CDMA (WCDMA) networks. The positional information is based on relative times of arrival of
signals at the handset and fixed receivers as sent by base stations. Location receivers or reference beacons (referred to as Location Measuring Units or LMUs) are overlaid on the cellular network at a number of geographically-dispersed sites. Location is then calculated using the time differences of arrival of the signal from each base station at the specially-enabled handset and LMU (via time stamps and intersecting hyperbolic lines). E-OTD is typically accurate to approximately 50 to 125 metres, with a response time of around 5 seconds. In a manner similar to E-OTD, OTDOA location works by calculating the time difference of the arrival of a signal from a mobile device and three network base stations. The large cost of network synchronization affords only small improvements over COO in urban areas, and the response time is much higher at around 10 seconds.

**Satellite-Based Positioning Techniques**

In some cases, a global navigation satellite system such as the Global Positioning System (GPS) can be used to enhance the accuracy of radio positioning. GPS has been available for general use since the early 1990s. Operating in the L-band frequencies GPS can be used anywhere in the world. The system's satellites transmit navigation messages that contain their orbital elements, clocks, and statuses, which a GPS receiver uses to determine its position and thus its roaming velocity (Tseng et al., 2001). Determining the receiver's longitude and latitude requires three satellites, and adding a fourth can determine the user's altitude. In May 2000, the US Army derestricted outdoor positioning to a sufficiently high resolution for advanced use—currently 10 to 20 metres.

Stand-alone GPS has the key problems of a relatively long time to first fix, usually 10 to 60 seconds, and difficulty in fixing a location within buildings. It also fails in radio shadows and requires considerable cost, complexity, and battery consumption in handsets (Djuknic and Richron, 2001).

Using GPS in addition to a wireless network, often referred to as assisted-GPS (AGPS), can provide significant extra benefits. Embedding a GPS receiver into the user's handset can directly provide positioning fixes in less than 5 seconds; the network may assist the user equipment by reducing the power consumed of the handset, by optimizing the start-up and acquisition time, and by increasing the sensitivity of the GPS device (Lavroff, 2000). AGPS can also be used indoors, where it is accurate to within 50 metres. In the future, technologies such as Bluetooth and IEEE 802.11 may enable assisted location positioning within buildings and "hot-spots" to even higher resolutions, suggested at around 10 metres (Nokia, 2003).

Overall, the various positioning technologies are complementary and there is no single universal solution. Where both accuracy and coverage are important, hybrid technologies may provide an optimum solution. Cellular and advanced network-based technologies can be used to fill in the gaps in coverage from satellite-based systems, like GPS. The basic
positioning accuracy category is focused on market penetration, and should be available for all phones, enabling a fast time-to-market. The intermediate category will have a software impact on handsets, while the high accuracy category will have a hardware impact on handsets. All three levels of accuracy will exist in parallel in the future (Nokia, 2003).

**EMERGING LOCATION-BASED SERVICES**

The kinds of location-based technologies described above enable many advanced forms of consumer data services based on the position of the user. Typically, services can be categorized into four main areas, as demonstrated by Table 2. Let us examine each of these areas in turn.

**Safety**

The prime driver for the implementation of LBS infrastructure in the United States is safety. Emergency and rescue services have a vital need to know the current location of any host that sends an emergency message. The United States government mandated that providers of personal communication systems must add location-identification capability to their emergency 911 (E911) services (Rockwell, 2003). Specifically, the original mandate stated that handset-based solutions must locate an emergency caller to within 50 meters for 67% of calls and within 150 meters for 95% of calls. Alternatively, carriers implementing network-based location technology must achieve location accuracy of 100 meters for 67% of calls and 300 meters for 95% of calls. Carriers must also undertake reasonable efforts to achieve 100% penetration of handsets allowing location services by 31 December 2004 (Lavroff, 2000). Europe has no such mandate, but the European Commission is considering a less vigorous version of E911 as part of its regulatory telecommunications framework and enhanced 112 initiative (WLIA, 2003a).

| Area of Use         | Application                  | Purpose                                      |
|---------------------|------------------------------|----------------------------------------------|
| Safety              | Emergency services           | Obtain help from emergency services          |
|                     | Roadside assistance          | Obtain breakdown assistance                  |
| Navigation and tracking | Vehicle navigation         | Reach a destination                          |
|                     | Fleet management             | Manage fleet resources                       |
|                     | Asset tracking               | Locate and direct assets                     |
|                     | People tracking              | Locate and direct people                     |
| Transactions        | Location-sensitive billing   | Competitive pricing                          |
|                     | Zone-based traffic calming   | Automatic pricing of road usage              |
|                     | Cross-selling                | Sales of products and services               |
| Information         | Locational advertising       | Targeted advertisement                       |
|                     | Public infostation           | Provide public information                   |
|                     | Geographic messaging         | Localized information and alerts             |
|                     | Yellow pages                 | Find proximity of something specific         |

Table 2: Key areas of application of location-based services
The same technology used for E911 services also has value for other, related aspects of personal safety, particularly roadside assistance. In the event of an emergency breakdown or accident, the consumer’s mobile device could be used to assist in getting roadside assistance to the right location.

**Navigation and Tracking**

Navigation and tracking form a core segment of the emerging LBS market. In the United States, the average person spends 500 hours per year in an automobile. Interestingly, though, only 100,000 of the 146 million registered cars in the United States and 20 percent of fleet trucks are equipped for telematics, i.e., LBS for automobiles. With the widespread deployment of services, the telematics market could expand considerably in the next few years.

Location technologies can play an important part in logistics. Taxis are being equipped with automatic vehicle location devices, allowing the fleet dispatch system to automatically select the taxi closest to the pickup location. Similarly, fleet management systems are helping freight companies to monitor the status of deliveries and other logistics activities (Varshney and Vetter, 2002). It is even conceivable to know all inventory in transit, or “rolling” inventory, allowing an efficient method of selecting a source of components based on their known location. By knowing the location of rolling inventory, times between transaction, manufacture and delivery can be further reduced.

In Israel, mobile operator Orange offers a wireless workforce application, using CT Motion’s Cellebrity platform, which includes location technology based on EOTD. Orange can offer companies the ability to monitor the movements of their workforce throughout the country to an accuracy of up to 100 meters. The central coordinator, or dispatcher, can see where each of the workers is on a map of the country and so can allocate tasks more efficiently (Wieland, 2000).

Tourists are a key customer segment requiring location-based information, since they are most often found in unfamiliar geographic areas. Some services, such as Bluesigns, are aimed at these consumers (http://www.tcial.com/bluesigns/). Bluesigns works by the tourist phoning the Bluesigns tourist information center via a telephone access number. During the tourist’s call, location is determined and location-sensitive information is generated from a database. Location can be determined either by GPS or verbal communication with an operator at the tourist information center. Based on the customer’s location, the tourist can be guided along highways to a particular destination, such as a petrol station, restaurant, hotel, or tourist attraction.

Similarly, Webraska—a mapping and navigation company—offers a number of services through mobile operators such as KPN (Holland), AirTel (Spain), SFR (France), and Proximus (Belgium). Based on COO technology, the service requires users to type in
abbreviations of their location (e.g., L-O-N for London, then B-A-K for Baker Street) before the network can locate roughly where they are and provide location-specific information such as directions (Wieland, 2000).

**Transactions**

The main thrust of transaction LBS is billing based on the customer's location. For example, a number of countries, such as Singapore, use road pricing as part of their traffic calming and environmental policy. Payments are made electronically through a special, in-car device on entry into a particular geographic area requiring payment. If secure payment mechanisms become generally available through the mobile phone, e.g., secure electronic cash, this could present a convenient replacement for these proprietary, traditional systems.

Location-sensitive transaction opens the way to new forms of price differentiation based on the location of the user. On one level, BellSouth Wireless Data is offering "distressed items" such as discounted last-minute tickets to Broadway shows for people that are near enough to pick them up before curtain, a form of price discrimination. On another level, individuals could be charged and taxed according to geographic region, such as a state or a country, or proximity to outlets selling goods that the consumer wishes to purchase.

Location-based cross-selling is another possible stream of transaction revenue. For example, the mobile user who has just seen a film at the cinema could immediately be offered a CD or DVD of the soundtrack or film. Similarly, in addition to charging for information requests, such as a query for a restaurant address, service providers could earn additional revenue by asking subscribers whether, for another ten cents, they would like directions to the restaurant. Ultimately, retailers, such as restaurants, could share in service costs to encourage customer interest.

In terms of payment systems, the mobile Internet has some way to go towards maturity. However, a number of solutions are underway. For example, in Finland, Sonera’s Pay-by-GSM enables the user to dial a number to receive a charge to a prepaid phone or for a deduction from a mobile account. Similarly, Visa, Nokia and Merita-Nordbanken recently piloted the dual subscriber identification module (SIM) concept for Nokia phones, where a second SIM is a Visa credit, debit, and bankcard.

**Information**

The roaming user can be provided with information, alerts or even advertisements based on the user's locale. Typically, advertisements depend on location. For example, a particular sale may interest only people within a certain distance of a merchant’s store. Thus, the sender will only need to transmit the advertisement to users within a set distance.
(Tseng et al., 2001). In Japan, such ideas have crystallized via digital couponing, which is popular on the iMode service, offering discounted products and services to subscribers within a certain radius of participating merchants.

Similar to advertising, geographic messaging is another useful application of location technologies. For example, an alert could inform the user of a security threat in a certain part of the city, such as a train station, stadium or shopping mall. Other types of public localized information can also be broadcast in a particular area; for example, a public “infostation” could provide such information as the opening times of a public library, movie theater listings, city phone directories, the schedule of bus services, or the availability of parking spaces.

One of the most basic LBS offered by mobile operators is the mobile Yellow Pages. Indeed, many European operators are reluctant or unable to go beyond this sort of service, offered, for example, by Sonera, diAx, and Telia. In this type of service, the roaming user asks the question: “what’s near me?” For example, items such as locations of restaurants, shops, public transport, or nearby ATMs may be useful to the user as the user moves through an unfamiliar city. Weather or traffic information can also prove useful; Bell Mobility’s Book4golf service allows the user to locate a North American golf course, book a tee time, and get a location-specific weather forecast. An extension of the “what’s around” type of service is the “who’s around” service. Such an application determines who currently occupies a specific geographic area. Most recently, this has been used for mobile dating services.

**ESTABLISHING A TECHNOLOGY PLATFORM FOR LBS**

One important strategic issue is the selection of an appropriate technology for a particular service, both in terms of location positioning infrastructure and speed of network. Most LBS, except those for safety and navigation, can begin with cell-level accuracy and the current second generation of networks. However, for mass acceptance, the technological platform for specific LBS must go beyond this. To this end, Table 3 shows a variety of LBS applications and indicates some of the appropriate platforms. Typically, packet-switched networks, such as the Global Packet Radio Service (GPRS) or CDMA2000 1x, are more suitable for applications where short, intermittent bursts of data are required, e.g., navigation, tracking, or intermittent messaging. Other applications can use any network, although the requirements for network speed in areas such Yellow Pages and cross-selling will rise with consumer demand for multimedia.

Accuracy depends on the criticality of location in an application. This is highest where the exact location of an individual’s handset needs to be known, e.g., emergency services or navigation. More general requirements for zonal targeting reduce the required accuracy.
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Table 3: Typical technology requirements for location services

| Application                          | Typical accuracy requirement (typical technology) | Typical network type (typical technology) |
|--------------------------------------|--------------------------------------------------|------------------------------------------|
| Emergency services                   | High (AGPS)                                      | Any                                      |
| Roadside assistance                  | Medium (EOTD)                                    | Any                                      |
| Vehicle navigation                   | High (AGPS)                                      | Packet (GPRS+)                           |
| Fleet management                     | High/Medium (AGPS/EOTD)                          | Packet (GPRS+)                           |
| Asset tracking, e.g., packages       | Low (COO)                                        | Packet (GPRS+)                           |
| People tracking, e.g., workers       | Medium/Low (EOTD/COO)                            | Packet (GPRS+)                           |
| Location-sensitive billing           | Medium/Low (EOTD/COO)                            | Any                                      |
| Zone-based traffic calming           | Medium (EOTD)                                    | Any                                      |
| Cross-selling                        | High/Medium (AGPS/EOTD)                          | Any                                      |
| Locational advertising               | Medium/Low (EOTD/COO)                            | Packet (GPRS+)                           |
| Public infostation                   | Medium/Low (EOTD/COO)                            | Packet (GPRS+)                           |
| Geographic messaging                 | Medium/Low (EOTD/COO)                            | Packet (GPRS+)                           |
| Yellow pages                         | Medium/Low (EOTD/COO)                            | Any                                      |

PRIVACY AND STANDARDS

Although considerable progress is being made in the commercialization of LBS, such systems are still very much at an embryonic stage of development. Further advancement of location-based commerce (L-commerce) requires overcoming a significant number of obstacles in technology, markets, and policy. Even before companies begin to examine whether customers are willing to pay for these new services, they need to establish a technological, legal, and ethical platform for service provision (O’Connor and Godar, 2003). Key areas of discussion among industry players are privacy and technology standards.

The location industry is currently in the ridiculous and destructive situation that every location finding system and positioning vendor has a different proprietary location-finding technology. Such fragmentation severely hinders the opportunities for broad market growth of location services and introduces problems of interoperability. Recently, a number of companies have come together to form industry associations aimed at establishing standards and discussing other important industry-wide issues. In September 2000, Nokia, Ericsson, and Motorola announced the formation of the Location Interoperability Forum (LIF), a forum to establish global interoperability standards for mobile positioning systems and solutions (http://www.openmobilealliance.com/lif/). LIF members represent a mix of network operators, equipment manufacturers, and service providers responsible for deploying equipment. Prominent members include Cambridge Positioning Systems, CellPoint, and Airflash. The cooperation of such key players in the location industry is likely to provide a strong platform for future service development. While a single technology is unlikely to dominate, a framework for the development of complementary and hybrid interoperability solutions is likely to emerge.
In December 2000, eight leading companies involved in the wireless location industry in the US, Canada, and Europe—Cell-Loc, SignalSoft, GoAmerica Communications, Cambridge Positioning Systems, Zero Knowledge Systems, Indexonly Technologies, iProx, and ViaVis Mobile Solutions—established another industry group, the Wireless Location Industry Association (WLIA) (http://www.wliaonline.com/). WLIA will interface with government, administrative, and regulatory bodies on behalf of the industry and create a forum to develop self-regulating policies, network, and share information among members in the industry. It will also provide references and information about the industry to the public and policymakers, both in the United States and elsewhere.

High on the agenda for the WLIA is the issue of privacy, which promises to be a considerable challenge on wireless devices (WLIA, 2003b). In the United States, the Fair Location Information Practices (FLIP) dictate that companies must: (1) inform customers about collection practices; (2) give the customer choice regarding any uses of the information; (3) allow for access to the data so that customers can ensure that it is correct; (4) maintain the data securely; and (5) comply with enforcement and auditing of the FLIP policies. Recent attempts to introduce further wireless privacy policies, such as the Wireless Telephone Spam Protection Act (aimed particularly at unsolicited wireless advertising), could further limit the use of location-based technology to market mobile users (Greening, 2003). Overcoming such significant hurdles in the United States in order to reach the commercial market will prove difficult. In Europe, no comparable policies exist yet, but they are currently under discussion at the European Commission.

SUMMARY AND CONCLUSIONS

This paper has examined the technologies, applications, and strategic issues surrounding the development of commercial LBS. The growth and convergence of the Internet and low-cost wireless services has created a significant impetus for operators to create new revenue streams from value-added, differentiated LBS. As we have seen, a variety of technologies based on the handset, mobile network, and satellite positioning systems are available, such as COO, EOTD, and AGPS. These have created the platform for a plethora of services in areas such as safety, navigation and tracking, information, and location-based transactions. Of these, safety is the key market driver, where policy in the United States has mandated emergency service caller location. Advertising, roadside assistance, fleet management, people tracking, road pricing, and location-based products are some of the other possible LBS under development.

Notwithstanding, cellular LBS are still in the early stages of development. Further commercialization requires overcoming a significant number of obstacles in technology, markets, and policy. Even before companies begin to examine whether customers are willing to pay for these new services, they need to establish a technological and legal platform for service provision. Key areas of discussion among industry players are privacy,
which has particularly strong regulation in the United States, and technology standards, which are incredibly fragmented. The creation of two global, self-regulating industry bodies in 2000—the LIF, focusing on technical standards, and the WLIA, focusing on commercial and regulatory aspects such as privacy—may provide some much needed guidance on these issues.

If such obstacles can be overcome, the strategic benefits of LBS are potentially enormous, not just in improving efficiency and effectiveness of current services, but in developing new services and transforming core aspects of business. The next wave of mobile telecommunications networks will enable even more sophisticated LBS. Network standards such as GPRS, now available in most developed markets, are eminently suitable for LBS. Beyond GPRS, third generation (3G) network standards, such as the Universal Mobile Telephone System (UMTS) in Europe, offer greater flexibility; with speeds of up to 2 Megabits per second, UMTS offers the ability to have simultaneous voice and data calls. With such infrastructure in place, the massive range of possibilities for new and improved services is beyond even current thinking.

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