Extending Cyberspace: Location Based Games Using Cellular Phones

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In the current market many game developers and publishers treat the cellular phone as just another platform to which they can port a console game; they ignore the exciting new possibilities cellular phones provide via their inherent ability to maintain connectivity while on the move. One possibility is to extend the virtual world of traditional video games through location-based information, which allows users to play games that incorporate knowledge of their physical location and landscape, and then provides them with the ability to interact with both real and virtual objects within that space. However, if such games are to become pervasive and if developers want their efforts to escape the bounds of the research laboratory, they must address the nature of the cellular environment, the precision of the location-based technologies in their region, and the present and likely future capabilities of cellular handsets. To aid innovative game development we draw together many fragmented sources of information for an assessment of technologies, and implementations of cellular location-based games. Further, we discuss practical mechanisms for producing a finer degree of location granularity, both through future technology and our novel implementations of systems that augment location-sensing. The first mechanism uses Bluetooth, which is already a pervasive component of mobile phones feature sets, and can be implemented without the need for client side software. The second implements the use of a future pervasive technology, RFID tags, now that commercial cellular handsets that incorporate RFID readers have emerged.

Categories and Subject Descriptors: J. Computer Applications, J.7 Computers in Other Systems-Consumer Products.

General Terms: Design

Additional Key Words and Phrases: Location-based games, cellular phones, location-sensing

1. INTRODUCTION

Since their appearance in the early 1990s, cellular phones have become a ubiquitous consumer device with over 643 million devices sold in 2004 (and forecasts indicate that global mobile subscriptions will reach 2 billion users by the end of 2005 [Gonzalvez 2005]). This rapidly growing user base, combined with the increasing availability and range of data services on cellular networks, will undoubtedly result in the cellular phone becoming the main computing device for the majority of the population. The emergence of standardized operating systems [Coulton et al. 2004] enables software developers to produce a richer variety of software applications for the cellular phone and one principal method of personalizing this software through location-based information. Some applications may be very location-centric, with this feature becoming the core of the entire product, (for example, mapping applications and tools to find the shortest route to the closest restaurant). Other applications may provide information or advertisements

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relevant to a particular user at his or her current location, for example, suggesting a favorite type of restaurant in a town the user is visiting, along with the nearest place to park. Such location-based information is expected to have a significant influence on user behavior [Kannan et al. 2001].

Games have already been identified as a possible beneficiary of location-based information, as it will allow users to extend their game-playing outside cyberspace by incorporating interaction with the physical world. However, in this article, we will discuss only those location-based games (due to their ubiquity and true mobility) that operate on cellular phones and utilize the cellular network. As mobility is an overused term, we use the International Telecommunications Union (ITU) definition, which states that "the term mobile can be distinguished as applying to those systems designed to support terminals that are in motion when being used". In other words, unless a game on a cellular device uses a connection as part of the game, there is a strong argument that it is essentially a hand-held, portable, or nomadic game. This also means that although some innovative work on game play has been achieved using Personal Digital Assistants (PDAs) with WiFi access, such as Can You See Me Now [Benford et al. 2003], they have greater limitations in connectivity and lack the pervasive impact of devices produced on cellular phones. We agree with Kurt Uhlir [Uhlir 2005] that we "must understand the strengths complexities and weakness of location technologies" and "move past the all or nothing' belief seen in many discussions". Indeed, many of the games in this article might well be considered simple in terms of game-play, but thus far only cellular location-based games have been considered suitable for commercial deployment.

Within the cellular industry itself this new genre is not without its detractors, and indeed many are asking the same questions as cellular carriers did of stand-alone cellular games in 2000 and 2001: Will users pay to play the games? Will users want to play these games, and when will the devices and enabling technologies reach critical mass? These questions have largely been answered for the current cellular games market, which now generates 14 per cent of the 35 billon dollars generated from computer games per annum [Palmer 2005]. However, the point at which location-based technology reaches critical mass and how operators will generate revenues are difficult questions to answer, and are beyond the scope of this article. But we highlight the fact that both the infrastructure and handsets are becoming more prevalent, and the games that are already commercially available are generating significant interest among mobile phone users, and thus may answer more complex questions about whether people will want to play these games.

Providing location information is a far from straightforward, often requiring significant changes in the software and hardware of the cellular system and/or the handset, to ensure that the information is highly relevant to the user's actual position. Location information is essentially a two-stage process, in that we have to provide both the geographical position of the cellular user and the information on a particular product or service related to that location. In Section 2 we discuss current and emerging methods and systems that are able to provide the geographical location of the cellular user. The second stage of the location process is when systems take the position of the user and relate it to the information at the actual location. Although such systems are becoming available, they have not yet been incorporated in location-based games. In Section 3 we highlight both the systems that are available and how they could be utilized within games. To aid innovation and counteract many of the detractors of this genre, it is worthwhile to consider the technologies used thus far and the evolving nature of the gameplay of cellular location-based games in relation to this criticism of these detractors. It is important to recognize that game developers should utilize technology that is already pervasive [Smith et al. 2005] to maximize the potential user base. In Section V we describe a Bluetooth system that provides a finer degree of localization within the games and enables location-based gaming without the requirement for client-side software, thus permitting anyone with a Bluetooth-enabled phone to participate very easily. We then describe a very novel location-based game that uses a cellular phone with an in-built Radio Frequency Identification (RFID) reader. RFID is already expanding the interaction of objects with the Internet; we will show that it also provides significant opportunities for games. Finally, we draw our conclusions on the current state of location-based games on cellular phones and the possibilities for the future evolution of this genre.

2. LOCATING THE CELLULAR USER

Although we often consider the requirement for providing the location of a cellular user as a new problem, in fact all cellular phone systems effectively track a user's whereabouts at the cellular level. Each cell site has a unique id that enables the system to locate a cellular user so that it can route calls to the correct cell. To enable higher degrees of accuracy, other techniques treat location-finding as a relative exercise; in other words, the location of the cellular user must be estimated against some known framework. This framework could be the locations of the base stations of a cellular phone network or the satellites of the Global Positioning System (GPS). Each system will provide different levels of performance and capabilities, and we discuss these details in the following sections.

Cell ID. While the cell-ID has a typical location acquisition time of around 3 seconds, its accuracy depends upon the size of the cell [Trevasani et al. 2004]. Cell sizes vary depending upon the capacity requirements of a particular geographical area (for 3G systems this could range between a cell radius of 100m to 10 km). While accuracy can be extremely variable, it requires no modifications to either the cellular handset or infrastructure.

Time Difference of Arrival. To estimate location, Time of Arrival (TOA) systems measure the differences among the multiple signals arriving at a device. In order to enable a two-dimensional calculation (i.e., latitude and longitude), TOA measurements must be made with respect to signals related to at least three geographically distinct framework elements. These measurements allow us to infer either the absolute or the differential distance of signal propagation between the framework elements and the device. A system that is based on differential distance estimation is generally referred to as Time Difference of Arrival or TDOA. TDOA requires a common timing base, which is fine for synchronous cellular systems like the Code Division Multiple Access One (cdmaOne), but for non- synchronous systems such as the Global System for Mobile (GSM) other solutions are required. The accuracy of such systems can be between 50 to 250m, and is extremely susceptible to multipath accuracy problems.

Enhanced Observed Time Difference (EOTD) of Arrival. To speed GPS acquisition in both synchronous and asynchronous systems, additional network devices, called Location Measurement Units (LMUs), can be utilized. These devices measure TDOA at numerous sites and then calculate correction values. These values are collected and used to enable correction of the raw TDOA measurements. The corrections can be sent to either the cellular handset or the centralized infrastructure, as shown in Figure 1 [Anderson 2001], depending where the calculation is performed**.**

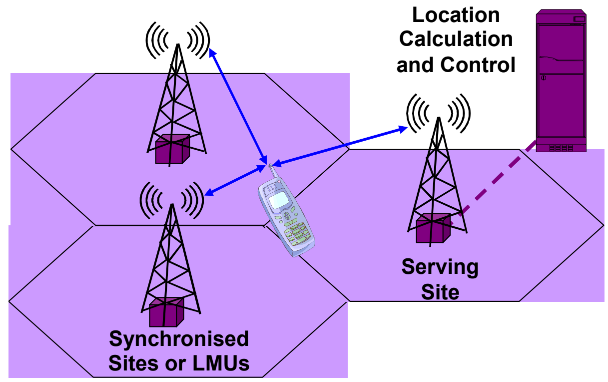

Fig. 1. The EOTD solution.

Generally, the number of LMUs will be less than the number of cell sites, and they can be located to maximize the precision of the measurement. The location measurement could normally be made in around 5 seconds and achieve an accuracy of 50 to 125m [Trevasani et al. 2004]. However, if the line of sight measurement is unavailable and/or the signal undergoes a multipath problem, system accuracy will be severely compromised. Although new hardware would have to be used, only a software update is required at the handset. Software solutions are being introduced for Version 9.0 of Symbian (in version 8.0 only the connectivity to a Bluetooth GPS is offered), and are already part of solutions offering location estimates in gpsOne for BREW [Qualcomm 2003].

GPS. GPS was originally developed by the US military for defense purposes; it is based on a system of 24 satellites that orbit the earth. A GPS receiver can triangulate its position using TOA methods as long as at least three satellites are visible. Typically, accuracy is around 2 to 10m, although higher resolutions can be achieved. The cost of GPS hardware continues to fall and GPS positioning remains a free service to consumers. Integrating GPS hardware technology into cellular phones is one of the main solutions being considered by network operators and handset manufacturers. This is evidenced by the fact that in May 2005 there were more than 150 handsets with integrated GPS hardware compared with 4 in 2001 [tinyurl.com]. However, GPS has a number of major restrictions, such as limited coverage in urban environments and inside buildings due to the requirement that cellular users be in ”view” of the satellites, and a slow location acquisition time in the region of 10 to 60 seconds. To reduce the impact of these constraints, a hybrid solution such as using cell ID as a back-up (albeit with lower accuracy) and/or network assisted GPS are being considered by the operators.

Assisted GPS. Assisted GPS systems overcome some of these limitations by using the cellular connection to transmit remotely-collected satellite navigation data from the base station to the cellular device. Using this fixed infrastructure can reduce acquisition time to less than 5 seconds, and possibly provide indoor accuracy to within 50m. However, as with the previous system, multipath and the lack of a line of sight measurement can degrade performance, and indeed A-GPS can be less accurate than GPS. Figure 2 illustrates an A-GPS location system. The main benefit for network operators to integrate

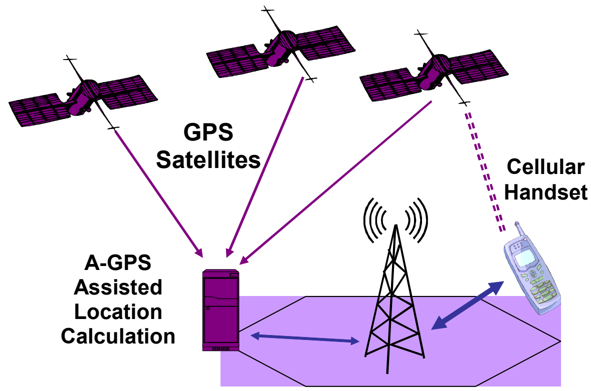

Fig. 2. Assisted-GPS.

assisted GPS is the ability to charge users for positioning information because it uses the network infrastructure.

All GPS solutions are complex, in that they require both new handsets and additional infrastructure, and are likely to be severely detrimental to handset power consumption.

On a final note it is worth highlighting that the European Space Agency (ESA), a commercial alternative to GPS, is scheduled to come on-line in 2008, and will potentially offer higher degrees of accuracy, particularly for areas in extreme latitudes. Also, advances in GPS chip technology could allow faster and more accurate location acquisition from weak satellite signals. For example, Infineon describes a device that it claims can detect a GPS signal that is 1000 times weaker than a normal "open sky" signal outdoors [Friedrich 2004].

Implied Location Solutions. Implied solutions are systems where the cellular phone user can interact with objects or systems that have a known location relative to the cellular infrastructure. Thus a user's particular location can be implied by his/her interaction with the objects or systems. At the system level this could be the interaction with WLAN cells or Bluetooth piconets. WLAN cells have a relatively small coverage area, up to 100m, and as some cellular phones already include WiFi functionality, it could be used to provide a general location area; alternatively, there have been proposals to use signal strength and the interaction between different access points to obtain greater accuracy [Lin et al. 2005]. However, the use of signal strength has a number of significant limitations, which make its use outside of a very defined environment, such as a research laboratory, impractical. The limitations are as follows:

(i) The frequencies used for Wifi mean that the environment is subject to multipath problems; signal strengths can vary over very small distances, and without complex ray-tracing techniques, time-consuming localized measurements become necessary.
(ii) As the players of games will often be moving at speed, they will introduce frequency-selective fading, which will introduce errors in mapping.
(iii) Any change in the environment, such as people and objects, will also affect mapping accuracy.

(iv) Wifi is highly subject to interference in the ISM band due to competing technologies such as Bluetooth.
(v) The geometry of the position of WiFi access points can greatly affect accuracy.
(vi) Wifi is evolving to introduce multiple-input multiple-output techniques, which will increase the multipath components.

Indeed, these are some of the reasons why signal strength for estimating location has never been seriously considered in the cellular phone environment and why we would recommend its use only to provide a general location or as a communications channel.

Bluetooth offers a similar approach for general location identification, although within a smaller area than WiFi. With its high penetration of the consumer market, greater robustness against interference; and low power requirements Bluetooth is much more suitable for cellular phones than WiFi Bluetooth will be discussed further in Section 5.

In terms of interaction with objects to determine a user's location, there are two main possibilities: two-dimensional bar codes and RFID tags. Two dimensional bar codes come in a variety of forms: Quick Response (QR) codes; Semacodes [semacode.org]; and Colorcodes [Goncalves 2005], all of which can contain an internet address, which when scanned prompts the phone to load the relevant page. In Japan, QR codes have become commonplace on business cards to allow people to easily upload contact details onto phones, or in some cases, allow blogging of pictures associated with physical locations [hwww.tokyo-picturesque.com]. All these codes utilize cellular phones with in-built cameras to take an image of the code, which is either decoded on the phone with specialist software, or transferred to an Internet service for decoding. RFID tags are devices that can transmit a radio frequency signal that contains information about the object to a suitable reader. RFID-enabled phones are predicted to occupy 50% of the market by 2009, that fact, coupled with its very low power operation, make it a suitable candidate for games, as we shall see via the innovative game presented in Section 6.

3. PROVIDING LOCATION-BASED INFORMATION

In the previous section we discussed how cellular phones can be located in a particular geographical area; in this section we will discuss systems that provide useful information associated with that location. Although (as we shall see in Section 4) current location-based games do not take advantage of such systems, this information could prove vital for the operation of location-based applications; from finding the nearest sports bar to locating a particular object in a treasure hunt game. Regardless of the service being created, all location-based applications have a rather similar basic architecture, as shown in Figure 3 [Spinney 2003].

For many applications, including some location-based games, a logical way to represent data may be as a symbol on a map (there are now a number of companies that specialize in the provision of map data for cellular devices [www.tigertelematics.com, www.navteq.com, www.mapinfo.com]). While maps may be the obvious way to represent the location of cellular users, more sophisticated services will need to interpret the raw positional data and proximity to other cellular users. To enable this interpretation, a number of data formats and standards have emerged; in the following sections we describe some of the more notable examples.

Spatial Databases. Spatial data is metadata that can be used to characterize the location of a particular object and describe how that object relates to other entities in the

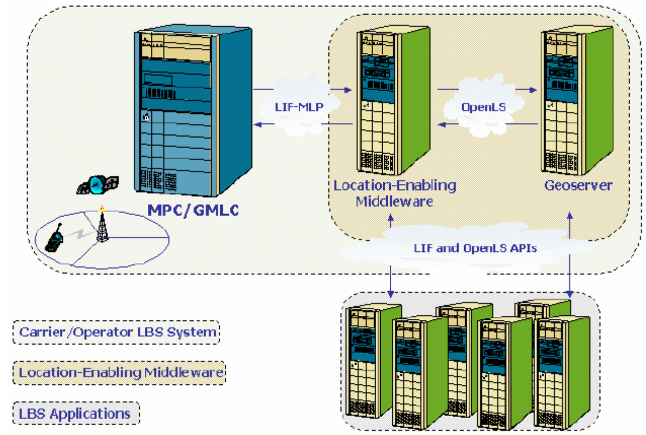

Fig. 3. Basic architecture of a location-based application.

overall space in which they coexist. Access to and provision of this metadata is via spatial databases. One of the most prevalent databases is Oracle Spatial, a component of Oracle 10g [Loney 2004], which enables the storage of spatial information and its quick and efficient retrieval. It not only provides a schema to store and index geometric data types, but also facilitates their efficient and swift recovery.

XML. Most of the XML standards associated with location information were developed by the Geographical Information Systems (GIS) industry. These XML standards address two types of geographical information, i.e., static and dynamic information. Static information can be the actual geography of the area like mountains, rivers, towns, while dynamic information could be a moving object such as a vehicle or a person and the events associated with these objects. To represent the two types of data, the following subsets of XML have been defined.

- *Geography Mark-up Language (GML)*
  GML is used to describe the geographical features; it was developed by the OpenGIS (OGC) consortium. GML is the most widely supported open specification for representation of geospatial data. It facilitates the delivery of geographic information as distinct features and provides control as to how they are displayed. GML provides mechanisms to correspond to relationships between geo-spatial objects in a manner that each one of these relationships is unique. Each user's view of geospatial information will be unique for that particular user [Lake 2001].
- *Point of Interest Exchange (POIX)*
  POIX is used to describe a particular position of an object and information related to that position, irrespective of whether the object is stationary or in motion. For instance, a POIX could handle both a moving vehicle and a sports bar as a point of interest. Although it is used to portray information related to a position, POIX cannot describe additional information, for example, opening times at the sports bar.
- *NaVigation Mark-up Language (NVML)*

NVML is an XML format to represent locations as points of interest along a certain route. Originally developed by Fujitsu for data exchange between navigation systems, it not only describes a route from current position to a destination point, but also finds the nearest shop or restaurant from a given position. Apart from route descriptions, NVML can also be used to provide tour schedules and transportation routes.

Location-based games could utilize one or more of these languages to enhance the game experience for the user. For example, in a treasure hunt game, GML could be used to lay out the map and provide the user with information on his/her current location; POIX could be used to provide information about different landmarks. A game player could use this information in order to, for example, solve a game clue or unlock a game feature. NVML could then provide information on how to get to a specified location from the user's current position. The more a game player interacts with his surroundings, the more interactive the gameplay can become, and the gameplay itself can be personalized to each individual player's location.

4. EXISTING LOCATION-BASED GAMES

According to US industry analysts, location-based services will be worth approximately $2 billion by 2009 [Saunder et al. 2004]. Although there has been a lot of publicity in Europe and the US about location-based applications and games, it is still considered a fringe activity. There are a number of reasons for this: first, it is an immature industry that is particularly susceptible to the fragmentation of mobile standards second, the mobile gaming sector is becoming dominated by branded titles and a large amount of original IP is being ignored [Ruskola 2005]. Although this article cannot easily answer questions about generating revenue, it does highlight that infrastructure and handset support is growing all the time, and that some games are being developed that are generating high levels of public interest.

At the Game Developers Conference in March 2005, at the 3D, Multiplayer and Location Based Games Conference in April 2005, and at E3 in May 2005,and numerous on-line discussions, many traditional game developers and executives expressed doubts about location-based games. Specific game development concerns include thefollowing:

(i) within games, movement is mostly designed as a necessity;
(ii) games cannot simply be consumed; to entertain, they constantly need the players to act;
(iii) games often require other users to function;
(iv) location-based games are not able to introduce a story;
(v) the ability of location-based games to handle player network latency in fast-moving games.

Before we consider these concerns in detail, we consider an extensive, although undoubtedly incomplete list, of many major cellular location-based games that have appeared so far. We will examine these games in terms of game play and the technologies utilized (which we highlight in Table I). We also provide a useful reference on the evolution of these games and highlight the fact that this will often be dictated by the availability of handsets to the general public.

Botfighters and Botfighters2. Botfighters is a search and destroy combat game, generally regarded as the first location-based cellular phone game, launched in 2000 using Cell ID [www.botfighters.com]. In the first version of Botfighters, players sent an SMS to find the location of another player and if that player was in the vicinity, they could shoot the other player's robot by sending another SMS message. While gaining some recognition, Botfighters' use of SMS and its crude location accuracy means that it suffers from delay and to limited levels of social interaction as players physically distributed over large areas**.** Botfighters 2 attempts to remedy this situation by using a J2ME client and GPRS connectivity to upgrade game play to incorporate collaborative gameplay, character upgrading, trading weapons and bonus material, as well as AI-controlled opponents. Despite its aspiration to become a Massively Multiplayer Online Role Playing Game (MMORPG), a greater degree of location accuracy and social interaction is undoubtedly required to attain this goal. While collaborative gameplay is a useful addition, Botfighters 2 does rely on a critical mass of players, and network latency becomes apparent when players operate in close proximity.

Gunslingers and Gunslingers 2. In terms of technology and gameplay, Gunslingers 2 [guns.mikoishi.com], is the same as Botfighters, and is currently available only in Hong Kong, and suffers from the same limitations as Botfighters.

Mogi. Mogi is *a* treasure hunt game where players using cellular phones collect objects. The game is based around a J2ME application that currently can only be played on eight handsets from network operator KDDI in Japan. The aim of the game is to accumulate as many points as possible by collecting virtual treasure items that have been spread randomly over a virtual map of Tokyo. Items can be collected once the user reaches within 400 meters of the virtual item and players can meet other players to trade items. The location tracking is provided by either GPS or Cell ID, and the developers recommend that GPS should only be used when looking for a particular item or players in a small area. Cell ID is used to get a general bearing [www.mogimogi.com], most likely to reduce the heavy battery consumption that long periods of GPS operation require. The gameplay is predominantly single person, although players can trade with others to complete their collection and attain a high score [Hall 2005]. In its current form, Mogi is confined to the streets of Tokyo, and is unlikely to work in large rural areas due to situations like "closest player 978km" being an unexciting proposition.

UnderCover and UnderCover 2: Merc Wars. UnderCover and its sequel UnderCover 2: Merc Wars are designed to be MMORPGs based on Cell ID. Although the technology is similar to that of Botfighters, the developers have introduced greater social interaction in the second version by allowing players to enhance their experience by visiting real cities in over 44 countries [www.undercover2.com] by completing missions, looking for friends, enemies, and landmarks in real streets. The developers of the game are also trying to encourage commercial partnerships, ranging from: sponsored shelters or hide-outs where players are safe from enemies to product-placement advertising like branded bonus packs. The game is available only to Java-enabled phones, but future versions are being developed to support Brew and I-mode.

Swordfish and TorpedoBay. Swordfish is a location-based fishing game where players use their cellular phones to find and catch virtual fish [www.blisterent.com]. Swordfish uses A-GPS to find the user's current location and that of the virtual fish. A player's general movement in his or her local area will bring the player into the vicinity of the fish, and the player can then move to a particular location to try and catch the fish.

The positions are all relative, in that they do not have to be in a particular city or area to play the game. Although, the positional accuracy has been improved over Cell-ID, the game has no social element, and is likely to suffer from the same power consumption problem as Mogi. TorpedoBay utilizes the same technology, but is essentially a multilayer game in a similar vein as the old Battleships games, but using street maps. This is a newly released game and we were unable to comment on latency issues.

ConQwest. ConQwest is a team-based treasure hunt game, which uses implied positioning from semacode tags; it is sponsored by Qwest Wireless in the USA to promote its camera phones. . As the players' position is implied, the game area must be set-up prior to the game by placing semacode stickers at defined locations around the selected urban landscape. Each sticker is given a relative value, the players collect the stickers by taking pictures with their phone cameras. The first team to collect $5000 worth of semacodes wins. The set-up requirement is undoubtedly a limitation, although this is largely compensated for by the finer degree of localization and physical interaction within that space. The game has been played by teams, generally drawn from local schools in the USA (based on the success of the first game, a second series of sponsored games is taking place across the USA [www.conqwest2005.com]). In many respects the problem of player drop-outs has been solved, as the game is an event; but this does limit its ability to be played among large numbers of the public. Because the gameplay is a treasure hunt, latency is not a major factor.

The Journey II. Although maintaining the crude location accuracy of other Cell ID games, the Journey II is an attempt to introduce more narrative into an adventure game. Players solve mysteries by progressing through the story and going to actual physical locations as indicated by the story [journey.mopius.com]. Instead of changing the gameplay on the basis of the player's location, the game builds a virtual game environment as soon as it realizes that the player has moved. For example, at the start of the game the player's real home can be the office, and when asked to go to another location, such as a park, the player has to move in the real world. As soon as the game detects a change in Cell ID, it prompts the player that he or she has reached the new location (the park), which in reality could be any location in the physical world. This in turn creates a virtual world as the story unfolds and the player moves back and forth through the game world until the mystery is solved.

Songs of the North. Songs of North is a research prototype that attempts to inject more story into a Cell ID location-based game, which is inspired by Finnish mythology, specifically by the epic Kalevala [gamelab.uta.fi:8080]. In essence, the game is a treasure hunt whose story revolves around a machine that is able to recreate everything previously destroyed by war whose pieces are scattered around the world. The interesting thing about this application is that its developers did not focus on the small screen but attempted to immerse the player in an audio world where wolves howl and eagles screech [Lankoski et al. 2004].

Treasure Hunt. Treasure Hunt [themobile.com] uses GPS to get location information, which allows players try to find a virtual treasure by discovering different clues hidden at various locations. A novel feature is that at the start of every game players are given a picture or video clue followed by a number of multiple-choice answers. Users have to pick the correct answer to unveil the location of the next clue. The user then navigates around the virtual world picking up items and new clues. Gameplay unfolds depending on the answers; wrong answers can lead to a weaker clue and vice versa, thus making the gameplay different for each user.

I like Frank The interesting aspect of I like Frank is that it is a mixed reality gaming concept that combines online and cellular gaming with location-based information. This aspect could be viewed as equivalent to the Dungeon master in the old Dungeons and Dragons games; the game itself is another treasure hunt game. It was played in March 2004 by people on the streets of Adelaide, Australia, in conjunction with online gamers who could interact with them through a virtual representation of the city. The game has its origins in a game developed using a mixture of PDAs, Wifi, GPS, and walkie talkies [Berford etal 2003]. Similarly to Conquest, it is an event-based game, and hence the drop-out problem is solved. The style of gameplay compensates for network latency.

RayGun. RayGun allows players to track and kill virtual ghosts via their cellular phones whose phone-screen layouts are similar to traditional radar screens [www.glofun.com]. Similarly to Swordfish, but using GPS rather than A-GPS, a player's position is tracked relative to the virtual position of the ghosts, which can then be killed by walking or running towards them. In terms of playability, the GPS resolution on the phone is three meters and the time interval to acquire new position data from satellites is around one second. This means it takes approximately four seconds of movement before RayGun can update its radar. In the US this game is currently available to Nextel customers; it runs on a choice of two Motorola handsets.

Tron. Tron is a multiplayer game for mobile phones that are based on a variation on the arcade classic. Tron players move in real space; and GPS is used to track and locate users. Players race across the game grid leaving trails to block their opponent's path. Players can pick bonus materials that allow them to get shields and break through a trail left by opponents [datenmafia.org]. As the gameplay depends on player interaction, the precision provided by the GPS may produce too fine a degree of accuracy, since GPS-enabled cellular phones are unlikely to be the norm. Further, because this game is multiplayer, and if it is to succeed, only the players will need to handle player drop-outs.

Decay Watch. Decay Watch is another treasure hunt style game, using Cell-ID or GPS, where players eliminate decay in cities by searching out and location-tagging decay, identified as graffiti, littered beaches, run-down buildings, etc. [Christopherson 2004]. The most interesting aspect of the game is that it features mobile bogging and mobile chat between players; it was released in partnership with an existing online gaming community [/www.superdudes.net]. Although the gameplay in its current form is limited, the social interaction may prove attractive to non-traditional game players.

Frequency 1550. Despite the obvious applicability of this genre for engaging students in educational purposes, Frequency 1550 appears to be the first game developed for this audience. The game is aimed at 11 to 12-year-old students, to be played at one of Amsterdam's medieval city gates. The game uses GPS to locate the players (interestingly, from a technological perspective, the GPS is not located on the phone itself, rather the phone communicates with a GPS receiver over Bluetooth). Students play the role of pilgrims coming to Amsterdam in 1550 to visit the special relic associated with The Miracle of Amsterdam. The relic has been lost and the players are then involved in a treasure hunt to retrieve it [www.waag.org]. Although this is a multiplayer game, it is basically played as a treasure hunt event, and therefore circumvents latency issues.

Colors. Colors is a single or multiplayer GPS game for the Gizmondo gaming device [http://www.gizmondo.com]. While Gizmondo does not have an integrated phone, it does use cellular General Packet Radio Service (GPRS) connectivity, which is why it is included in this discussion. The objective of the single-player is to shoot his or her way through 50 different game missions centered around gang culture in a real-world

Table I. Summary of Location-Based Games

Game	Location technology	Location (May 2005)	Platform	Single &/or Multiplayer	Available from
Botfighters 1 & Botfighters 2	Cell ID	Sweden, Russia, China	SMS / J2ME	S & M	2000 & 2005
Gunslingers 1 & Gunslingers 2	Cell-ID & GPS	Singapore	SMS/ J2ME	S & M	2003
Mogi	GPS	Japan	J2ME	S & M	2003
Undercover 1 & Undercover 2	Cell ID	Hong Kong Portugal	J2ME,	S & M	2003
Swordfish	A-GPS	Canada/ USA	J2ME	S	2004/ 2005
Torpedo Bay	A-GPS	Canada/ USA	J2ME	S & M	2005
Conqwest	Semacodes	USA	WAP	M	2004
The Journey	Cell ID	Austria	Symbian OS / UIQ	S	2004
Songs of the North	Cell ID	Trials in Finland	J2ME	M	Concept only!
Treasure Hunt	GPS	USA			2004
I Like Frank	Cell ID*	Adelaide	J2ME	M	2004
RayGun	GPS	USA	J2ME	S	2005
Tron	GPS	Trials in Austria	J2ME	M	Expected Q4 2005
Frequency 1550	GPS	Amsterda m	J2ME*	M	2005
Agaju: The Sacred Path	GPS	UK USA (2006)	Windows CE	S & M	2005
Colors	GPS		Windows CE	S & M	2004

environment. An interesting addition to what essentially is another action game is that in multiplayer Colors, players can stake a claim to a real neighborhood by setting up geo-fencing points. Players then receive messages alerting them to other people's presence in their area, which allows interactive multiplayer gaming.

Agaju: The Sacred Path. Agaju: The Sacred Path is another Gizmondo game, this time using both GPS and its Gyroscopic Camera technology [Venetia 2005]. The Gyroscope introduces the physical movement, i.e., left or right, of the device itself into the gameplay. The camera is also used to make the game responsive to certain symbols, which will come physically packaged with the game on pieces of paper. If one of the symbols is held up in front of the device when in camera mode, a tiny character appears with which the players can interact. GPS and GPRS will be used as part of the gameplay, and the UK version will have specific places that gamers will need to move to or point their cameras at. The game itself is not expected to be released in the UK until the end of 2005. While the game has some innovative aspects, it is questionable that gyroscopes will be used in ordinary cellular phones.

Having posed the concerns of the industry and examined many of the cellular location-based games, we now respond to those concerns. The first is indicative of how traditional console game developers view the cellular phone as a constrained console platform rather than a mobile device. This is unfortunate, as the cellular phone can allow greater levels of interaction in both social and spatial dimensions, and so open up new possibilities for gaming. As we have seen, the second concern over the requirement for player interaction is a valid one in that all the location-based games developed thus far are action- based, although the concept of location seems to lend itself well to the action and shoot-em-up genres. However, location -based games are at a very early stage in their evolution, and new cellular system capabilities and phone features are likely to significantly speed their future development. As we saw in our discussion of current implementations of these games, the third concern about requiring additional players is often, but not always, true. Indeed, the reason many people play games or sports is that they wish to enjoy the experience with others; this could be considered a positive.

As for the concern that games are not able to develop stories, there is often disagreement on what constitutes a story within a game. Indeed we agree with Chris Crawford's view that a story should not merely provide some premise for action within a game but should evolve relative to a particular individual playing the game [Crawford 2005]. Therefore, many console games can also be criticized for paying limited attention to the development of a good story [Crawford 2005].We highlight the embryonic attempts already being made [journey.mopius.com] to allow game players to engage in interactive stories as a positive for the future. These concerns (as mentioned previously) may well stem from the perception of the cellular phone as a limited capability console (also there is no evidence that the vast majority of cellular phone users are desperate to play console-type games). The concerns about latency are well founded, since for very fast-moving games where players are in close proximity, there will undoubtedly be problems. However, gameplay can be adjusted to take account of this, and the use of close- range technologies such as Bluetooth could get around many of these problems. Finally, we highlight that location-based games do contribute to operator revenue,(in Sweden, Botfighters claimed EUR 10 to 100 per person in 2002. Some players spent as much as EUR 5000 overall on the game; while in Russia, during peak game periods, the company received 1 million SMS messages from gamers per weak, which is a very high figure for a company with 200,000 subscribers [ISA 2003]). Further, as the majority of location-based games launched thus far have generated a considerable amount of public interest, they may well capture the interest of less traditional gamers.

5. USING BLUETOOTH IN LOCATION-BASED GAMES

As was discussed in Section 2 many of the advanced location-positioning systems have difficulty providing user location in heavily built-up urban environments or inside buildings. Bluetooth provides a solution for these environments; we previously presented a Bluetooth system [Rashid et al. 2005] that can provide location-based information/advertisements, in Pico cells of approximately 10 meters, to cellular devices equipped with Bluetooth technology. Furthermore, unlike other systems [Aalto et al. 2004], (http://www.locatrix.com and http://www.e-lba.com) it requires no client-side software, thus allowing users to instantaneously opt-in to the service.

The system uses Object Exchange Protocol (OBEX) over Bluetooth to send the information to target devices. OBEX (which is licensed by Bluetooth Special Interest Group (SIG) from Infrared Data Association (IrDA)) has become an extremely popular protocol as it is transport-neutral, which means that it can work over almost any other transport- layer protocol. OBEX sits over the RS232 Serial Cable Emulation (RFCOMM) protocol [Brey et al. 2001] and can be used to push information related to a game onto a user's phone.

The Bluetooth treasure hunt style of game, where players move around the real world connecting to Bluetooth sites to find the next clue or objects to collect, represents a good example of how to employ this technology within a location- based game. In this type of game we have incorporated a game server to facilitate devices that roam between different locations and prevent duplication of game information, e.g., clues in a treasure hunt game via an integrated back-end database system. Figure 4 below shows the layout for two sites, each able to push messages to the users. Each Bluetooth push server launches a device discovery after a fixed interval of time. Devices discovered after each inquiry are cross-checked with the database. Only newly discovered devices are recorded in the database and a game message is sent to these devices. Devices that received the game message in the previous discovery do not receive this particular game message. If a game message is made available in the database, the next discovery will push the message to all the devices in the area. The messages themselves can be tagged to expire in the database after a certain amount of time. Within the same scenario the game can pick a random device and give the lucky recipient an extra clue or special power.

As some of the advanced location positioning systems are added to cellular phones and their infrastructure, this Bluetooth system could be used to reduce acquisition time and improve accuracy in indoor and urban environments, as shown in Figure 5. With this enhancement, a much richer range of location information can be made available to the users at a variety of locations.

When players come into close contact as part of the game, Bluetooth provides a further benefit, as it has a latency of around 20-50 milliseconds compared to the 1-5 seconds that are typically expected even on 3G cellular networks.

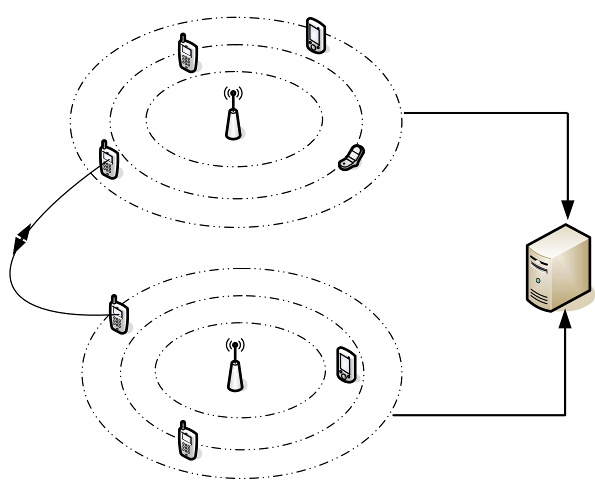

Fig. 4. Bluetooth messaging system that facilitates devices roaming between different Bluetooth cells.

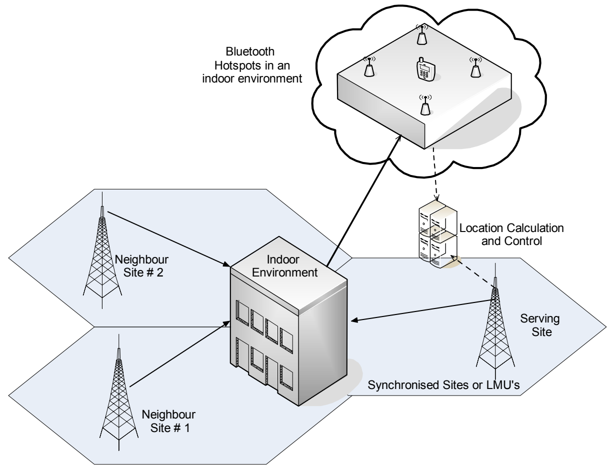

Fig. 5. Bluetooth complements EOTD for indoor environments.

6. USING RFID IN LOCATION-BASED GAMES

RFID is hailed as the next big evolution in computing, as it enables everyday objects to be connected to the Internet. RFID tags, a simple microchip and antenna, interact with radio waves from a receiver to transfer the information on the microchip. These tags are classified as either active or passive. Active tags have their own transmitter and associated power supply; passive tags do not have their own transmitter; they reflect energy from the radio waves sent from the reader. Active tags can be read from a range of 20 to 100m, while passive tags range from a few centimeters to around 5m (depending on operating frequency range).

Nokia has recently introduced a clip-on RFID reader (Nokia Xpress-on Mobile RFID Kit) for its 5140 Series 40 phone. The RFID reader can be accessed via J2ME applications running on the phone to trigger defined actions within the application. It should be noted that this phone is but the first of many, as RFID and its associated technology, Near Field Communications, are predicted to be installed on 50% of phones by 2009 [RFID Journal 2004].

To illustrate how RFID could be used for location-based games, we describe such a game, developed at Lancaster University, and about to go into major public trials (www.pac-lan.com) at Lancaster in the UK and in Finland. While this is not the first time PACMAN has inspired the development of a location-based game, these previous attempts have either used the phone to simply provide a voice link [www.pacmanhattan.com] (effectively a walkie talkie arrangement) with no means to estimate locations , or to utilize highly expensive and dedicated technology [CHEOK 2004].

The player who takes the role of the main PAC-LAN character collects game pills (using the cellular phone), in the form of yellow plastic discs fitted with stick-on 13.5 MHz RFID tags placed around the campus maze as shown in Figure 6.

Four other players take the role of the “Ghosts” who attempt to hunt down the PAC-LAN player. A Java 2 Platform Micro Edition (J2ME) application, running on a mobile

Fig. 6. RFID PACLAN game.

phone, is connected to a central server using a General Packet Radio Service (GPRS) connection. The server relays to the PAC-LAN character his points and the position of the game.

Ghosts' ,based on the pills they have eaten**.** The game pills are used by the Ghosts, not to gain points, but to obtain the PAC-LAN character's last known position and to reset their kill timers, which must be enabled to allow them to catch PAC-LAN. In this way the Ghosts must regularly interact with the server, which is then able to relay their position to the PAC-LAN character every time a Ghost collects a game pill. The Ghosts can "kill" the PAC-LAN character by detecting him/her via the RFID tags on the Ghosts' clothing (or costumes), assuming their kill timers have not run out. Once PAC-LAN is killed, the game is over. The points for the game are calculated in the form of game pills collected and time taken to do so. When PAC-LAN eats one of the red power pills, he/she is then able to kill the Ghosts, and thus gain extra points, using the same RFID detection process. "Dead" ghosts must return to the central point of the game maze where they can be reactivated into the game.

The central point of the maze is controlled by the server and a special RFID tag to ensure that the Ghosts remain immobile until released. At certain times the central point can be collected by the PAC-LAN character to obtain bonus points, as per the arcade.

CONCLUSIONS

In this article we have discussed the exciting possibilities of extending video games from the traditional realms of cyberspace to the real world through location-based games operating in a cellular environment. In Section 2, we introduced many of the possible location estimation systems developed for the handset, infrastructure software, and hardware, along with a discussion of their potential accuracy. We also show that providing location information is essentially a two-stage process, in that we have to provide both the geographical position of the cellular user and the information on a particular product or service related to that location.

Section 3 describes techniques used to supply the localized information, while acknowledging that the majority of location-based games developed thus far has not fully exploited the potential of such systems.

In Section 4 we discussed industry and developer concerns and summarized the current location-based games, highlighting both in order to address these concerns. All the location-based games discussed can be categorized into three genres: action/adventure, treasure hunt, and role-playing games. Finding other players in a shoot-em-up game can initially be exciting, but the gameplay can quickly become repetitive, and the games rely on high numbers of players with the same game in the same area. Treasure hunt games can quickly become boring when played alone, and those that create an event appear to receive greater publicity and recognition. Although some of the games being marketed are massive multiplayer online role-playing games (MMORPG), their inability to compensate for the short gameplay of cellular users may hamper the ability to immerse players in the games. Geo-fencing provides a new element to games, in that players can specify their own virtual territory based on their actual physical neighborhoods. The incorporation of community features such as mobile chat are effective because they take advantage of the social nature of the cellular phone, and are features likely to prove significant in the success of these games.

In Sections 5 and 6 we illustrate the potential of two technologies, i.e., the already pervasive Bluetooth and the likely to become pervasive RFID. We also discuss how they can be combined with cellular connectivity to create new forms of interactive location-based gaming. We also note that feature sets of cellular phones are evolving rapidly, and hence developers will be presented with new and exciting possibilities for some time to come.

For now, location-based cellular gaming is a niche market, which often depends on players owning specific devices and subscribing to specific carriers. However, there is strong evidence that these games are capturing the imagination of a new audience, and if the games can mature to give a wider variety of gameplay and experience, they might yet achieve their potential as a major location-based service.

ACKNOWLEDGMENT

The authors wish to acknowledge Nokia for providing support to the authors of this article through the facilities of the Informatics Group in Infolab21 at Lancaster University where this work was carried out.

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Received June 2005.