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HOW FEASIBLE IS ACCURATE AND RELIABLE LBS PROVISION IN AFRICA?

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Abstract: Location-based services (LBS) are one of many services offered by some mobile subscribers on the cellular network. It gives personalized location-dependent services to registered mobile subscribers and also gives added revenue opportunities to mobile operators. LBS have changed the face of location-dependent and location-based task offered to mobile subscribers in many areas of the world. LBS have been introduced to some countries in Africa but how valuable and reliable are these services to subscribers in Africa? This paper presents a summary and conclusion of research carried out on the accuracy of LBS in Africa, highlighting the factors which might affect optimal LBS launch across Africa and proposing methods which will enhance optimal subscriber satisfaction.

Keywords: LBS, positioning methods, Africa, cellular networks

INTRODUCTION

Africa is a developing continent; she is the second largest and second most populous continent in the world. Technological penetration is quite low but surprisingly, the penetration and evolution of mobile phones on the continent had been phenomenal. Before the year 2000, fifty (50) of the fifty-four African (54) countries had less than 40 percent mobile phone coverage (Mbiti and Aker, 2010). By 2008, there is mobile coverage on the whole continent and 65 percent of the African population had access to mobile phone coverage. The growth of mobile phone coverage is incomparable to electricity which is available to barely a quarter of the African population. In Africa, mobile stations (MS) have become the ubiquitous form of communication and mobile technology penetration into rural Africa is particularly dramatic. Mobile technology has so much revolutionized all aspects of development on the continent and it is the first and only contact most rural dwellers have with modern telecommunication (Bhavnani et al, 2008).

Though mobile technology coverage is particularly dramatic in Africa, it is yet to become as advanced as those obtainable in advanced countries and mobile services offered also varies from those obtainable in developed countries. This might be because of the average revenue per user (ARPU) in most parts of the African continent. Most users are only interested in basic services such as voice and short messaging service (SMS) and introducing more services might not be of interest to mobile operators because of economic factors. The services presently available on the mobile network have presented evolution in the ways many activities are carried out on the continent and has brought benefits such as communication among social and business networks, job creation and development projects using "m - development" (Mbiti and Aker, 2010; Bhavnani *et al.*, 2008; African Partnership Forum, 2008).

Though mobile infrastructure presents challenges in offering some services in Africa, it is important to optimize the mobile network by offering more services especially in Africa where mobile technology is the only form of modern communication technology available to some of them. Some of the services that might be considered include location-based content services, menu driven information services, m-development applications et cetera.

Location-based services (LBS) can be offered to mobile subscribers on the mobile network using some positioning methods without additional handset expenses and minimal software and hardware upgrade on the mobile network. LBS offer electronic and personalized services to subscribers based on their geographical location. (Turkyilmaz et al, 2008; Lee and Rizos, 2003). Mobile subscribers all over the world have embraced LBS due to the important relationship between it and the geographical location of subscribers.

In Q2 of 2007 (second quarter of 2007), LBS represented 15% of the revenue made from downloadable applications in the Unites states of America (USA) (Francica, 2007). It is a different scenario in Africa, where LBS is only offered to very few countries. It is significant to note that each country and continent have different subscriber needs, mobile infrastructure and other enabling environment for the successful rollout of LBS, LBS in Africa can improve many lives. There are different location dependent services which can be offered, such as information services particularly for health related matters, security and management of personal belongings. For broader analyses of LBS that can be provided and adapted to the needs of some African populace consult (Dahunsi and Dwolatzky, 2012).

This paper presents analyses carried out to determine the feasibility of providing accurate and reliable LBS to countries in Africa. Some parts of this paper had been published in (Dahunsi and Dwolatzky, 2011).

Importance of LBS

There are various LBS applications that can be offered in Africa and reasons for providing them. These can be grouped as short-term, medium-term and long-term reasons. LBS can only be offered to subscribers that have their MS turned on because all location positioning methods require connectivity with at least a serving base station (BS) for network-based positioning or satellite for MS-based positioning (Juurakko and Backman, 2004).

The short-term reason for LBS

Emergency services

These are regarded as the most important LBS service offered on the network because it is directly related to emergency and rescue operations offered to people in danger and who do not know their current location (Juurakko and Backman, 2004). In most parts of Africa where the wired telecommunication service is crippling and almost non-existent at other places, automatic location estimation of MSs of subscribers can be the only way of rescuing endangered people in need of emergency assistance.

Medium-term reasons for LBS

The medium-term reasons for proposing location-sensitive technologies in Africa are highlighted below:

Value-added services

With the small, handy, mobile, ubiquitous versatility of MSs in addition to the available mobile coverage, it has become a popular device and a necessary part of dressing for mobile subscribers (Lakmali and Dias, 2008). With its popularity, it can be used to provide innovative services and create new sources of revenue to mobile operators and their partners (developers, service providers and other third-party partners) by offering location dependent services (Turkyilmaz, Alagoz, Gur, and Tugcu, 2008; Lee and Rizos, 2003; Lakmali and Dias, 2008).

Application/ commercial value

LBS allows for subscribers to make informed decisions based on their geographical locations. The local traffic information assists in navigating through very busy areas and detailed places of interest encourages efficient planning and time management. Companies can obtain optimal returns on their businesses by tracking their personnel, vehicles and other assets (Djuknic and Richton, 2001; Hellebrandt and Mathar, 1999).

Law enforcement

Location dependent services offered to the Police and other Secret Services can improve the security of people and their possessions. Location information can be used to estimate the location of subscribers who might be hiding from justice or are being investigated. These services can also assist in other location dependent operations that might be required.

Statistical information

Once a MS is turned on it is connected to a base station and with the penetration of MS amongst all people, the number of MSs connected to a particular cell can be used to glean the number of persons connected to the cell. The location information obtained can then be used by intelligent transport management, population control agency and other related agencies.

Long-term reason for LBS

Location information can also be used to plan, design and optimize mobile network resources (Djuknic and Richton, 2001). Handovers will be reduced and faulty registration of MS(S) caused by multipath will be reduced (Hellebrandt and Mathar, 1999; Wang et al, 1999).

Technologies Employed in the Provision of LBS in Africa

There are five basic components required for the provision of location information to MS(s), communication network, service and application provider, data and content provider and the positioning technology (Steiniger et al, 2006). The communication network is the wireless network which serves as the link between the MS and the mobile infrastructure. Service and application providers process LBS request and offer location services to subscribers. Spatial data and content delivered based on the location of subscribers is maintained by government, agencies and industry partners. While different positioning technologies are used to estimate the location of the MS based on known measurements obtained from the BSs the MS is connected to. MSs have to be turned on for location estimation to take place while others require the MS to be connected actively to at least one BS (Juurakko and Backman, 2004). There are different types of positioning technologies based on the measurements used and where location estimation takes place. These can be classified as network-based, MS-based and a hybrid of the two. Network-based methods make use of the mobile infrastructure while MS-based methods make use of built-in global positioning system (GPS) modules, hybrid methods are a combination of both. From the analyses presented in (Dahunsi, 2012), it was concluded that network-based positioning technologies are the most applicable technique for locating MS in Africa. In network-based positioning methods, BSs measure necessary signals originating from a MS or vice-versa and the measured signal is used to estimate the location of the MS. Measurements available for the implementation of network-based location estimation based on Global System for Mobile Communication (GSM) standards are Cell Identification (Cell-ID), Timing Advance (TA), and strength of signals received by the handset (RXLEVs or RSS) (Spirito et al, 2001).

Advantages of network-based methods in terms of techniques include (Kupper, 2005; Beinat and Dias, 2003; Trevisani and Vitaletti, 2004):

- Existing handsets can be used.
- Minimal modifications carried out on the mobile network.
- LBS available to more users in developing countries at lower cost.
- Relatively less complex to implement, therefore requires minimal expert personnel.
- Gives better localisation indoors, urban and shadowed environments.

In terms of the application of LBS in network-based methods the advantages include:

- Improved LBS during emergency.
- Optimal mobile network utilization.
- Optimised network infrastructure.

Network-based technologies on GSM networks approved by the 3rd Generation Partnership Project (3GPP) are Cell-ID + TA, uplink time difference of arrival (U-TDoA), enhanced observed time difference (E-OTD) and satellite-based GPS technologies (3GPP TS 22.071 V 8.0.0, 2007). These technologies require the installation of a serving mobile location centre (SMLC) for coordination and scheduling of resources for location estimation and for final location estimation and accuracy calculation (3GPP TS 22.071 V 8.0.0, 2007; Spirito et al., 2001). E-OTD and U-TDoA technologies utilize time measurements for positioning and therefore require installation of location measurement unit (LMU). LMU determines the time offset of measurements due to the non synchronization of GSM BSs and they will cost the network provider more and increase the price of providing the service to LBS subscribers though with improved LBS accuracy. E-OTD method requires LMU installed at every BS while U-TDoA requires LMU installation at every 2 - 5 BSs. With the installation of the LMU, the MS(s) being positioned using E-OTD require software modification while for U-TDoA requires minimal software modification. Three network-based methods discussed in the paper are Cell-ID and TA and RSS technologies. RSS-based methods are not specified by the 3GPP because RSS-based measurements are generally inaccurate compared with time measurements in built-up areas and therefore all technologies approved by the 3GPP apart from Cell-ID are based on time measurements (3GPP TS 22.071 V 8.0.0, 2007). The error introduced by RSS can be as much as 30-40dB especially in built up areas (Caffery and Stuber, 1998). However RSS is more applicable in rural environments where multipath is considerably lower which is a good consideration for Africa where at least 50 percent live still live in rural areas. Tables 1 and 2 present a summary of position estimation using Cell-ID, TA and RSS-based methods based on some evaluation criteria such as coverage area, reliability, accuracy and applicability.

Table 1: Cell-ID, TA and RSS methods with some evaluation criteria

		Cell-ID	TA from single BS	TA from multiple BSs	RSS
Evaluation Criteria	**Coverage Area**	Coverage area is as large as the mobile network	Coverage area is as large as the mobile network	Coverage area is dependent on the number of BSs TA information can be received from.	Coverage area is as large as the mobile network
	Reliability	Very reliable because the mobile network is always on and a MS once subscribed and turned on connects to the network.	Reliability is similar to that obtainable for Cell-ID positioning.	Reliability is dependent on the ability of the location estimator to receive measurements from three at least three BSs.	Dependence on highly variable factors makes it not very reliable especially in multipath environments.
	Accuracy	Accuracy is dependent on the size of the cell and the connection of the MS to the closest BS.	Indirect wave propagation effect is greatly reduced in square annuli method as compared to the annuli method.	It has a higher accuracy in comparison with only the use of conventional TA methods.	Accuracy of the RSS-based method is highly dependent on the network density, the propagation conditions and the geometry of the network.
	Applicability	Applicable in developed and developing countries. It is usually the pilot technology deployed.	Provides the easiest computation of the MS coordinate limits. Applicable in developed and developing countries.	The disadvantage is that forced handover is needed for practical implementation. More applicable in developed and not applicable in developing countries.	Applicable in developed and developing countries.

Table 2: Hybrid methods with some evaluation criteria

		TA + Cell-ID	RSS + Cell-ID	RSS + TA +Cell-ID
Evaluation Criteria	**Coverage Area**	Coverage area is as large as the mobile network	Coverage area is dependent on the number of BSs RSS information can be received from and coverage area of the serving BS.	The coverage area is as large as the mobile network
	Reliability	Always available where there is cellular network coverage	Increases with the number of BS used and statistical estimation gives better reliability than geometric estimation.	This is more reliable because it combines the strong points of all the parameters available and it always gives a location estimate

	Accuracy	This technique overcomes some of the major flaws inherent in Cell- ID only. Better in suburban areas.	Accuracy usually increases with the number on RSS measurements.	Accuracy scales according to the cell size, network density, the propagation conditions and the geometry of the network. Gives better accuracy in densely populated area with smaller cells.
	Applicability	Has an impressive trade-off between increased precision and implementation costs therefore highly applicable in developing countries.	Applicable in developed and developing countries.	Applicable in developed and developing countries.

Related Work

CI, TA and RSS measurements were collected off the GSM from the urban and suburban area in Tallinn, Estonia. Based on their analysis, Cell-ID accuracy was between 500m and 1.1 km in the urban and suburban areas respectively while Cell-ID + TA + RSS's accuracy was 300m and 800m respectively (Spirito *et al.*, 2001). Trevisani and Vitaletti in 2004 conducted an experimental study of Cell-ID location technique. They collected data from three distinct environmental context – urban, suburban and highway and from 2 major cities in the world the New York area in the US and the Rome area in Italy. Their results concluded that estimated accuracy in Italy is between 500m and 1 km while in the USA it was between 800m and 3km when urban environment was considered. From the analyses, they concluded that cell-ID might not be suitable for the provision of all types of LBS but it is very effective for the provision of some other important ones (Trevisani and Vitaletti, 2004). Mohr, Edwards and McCarthy carried out an empirical study of the accuracy of LBS in the UK. It presented that most mobile operators in the UK use sectorized Cell-ID + TA for the provision of LBS. The average accuracy provided across all networks was about 266m in urban areas considered (Mohr, Edwards, and McCarthy, 2008).

METHODOLOGY

Measurement data were collected from a field test in South Africa and over a thousand LBS requests were made and 938 responses were received. The LBS requests were sent from 60 geographical location points though due to measurement error only data from 51 geographical locations could be used for the analyses. LBS requests were also sent from three distinct environments; urban, densely populated suburban and a relatively sparsely populated suburban area. There are three quality of service parameters which is usually considered during the provision of LBS (3GPP TS 22.071 V 8.0.0, 2007); vertical and horizontal accuracy of the geographical location and the response time of between the request and delivery of the service required. Vertical accuracy is not a requirement and therefore not considered for the provision of most LBS currently provided (3GPP TS 22.071 V 8.0.0, 2007). The horizontal accuracy is therefore used as the measure of the quality of service for this paper and the major requirement to be met by mobile location providers. Therefore, vertical accuracy and response time will not be considered while horizontal accuracy is referred to as "accuracy". The LBS requests were made and collected using basic MSs while another smart phone with built-in GPS was used to collect the true locations of where the request where made from. Location of the MS estimated by the LBS provider was given relative to the closest road to the serving BS the MS is connected to. The accuracy predicted as part of content during the delivery of location information was estimated based on the cell size of the serving BS. The accuracy provided was grouped as "lower bound accuracy" and "upper bound accuracy". The lower bound accuracy is estimated from the distance between the MS's true location to the road specified by the location providers. Upper bound accuracy considered the length of the road specified by the mobile operator in addition to the lower bound accuracy estimate. The length of the road is considered here because the location information provided makes the user assume that any part of the road might be referred to. Geospatial data for the analysis were collected from Gauteng City-Region Observatory (GCRO) (Municipal Demarcation Board, 2009) and analysed using Geographical Information System (GIS) available in ArcGIS 9.2. The geospatial data included maps showing places, sub places, major and minor roads.

RESULTS

From Figure 1 and the descriptive statistics presented in Table 3, it can be observed that the average predicted accuracy for the urban environment, Johannesburg CBD was 345. The densely populated suburban environment Soweto has an average predicted accuracy of 924 while Sandton, the sparsely populated suburban was 628. The values calculated are distinctly different for the three environments considered. The average lower bound accuracy for Soweto, Sandton and Johannesburg CBD are 627, 617 and 307 respectively and average upper bound accuracies are 2460, 2007 and 1714, respectively. It can be concluded that the upper bound accuracy is about three times more than the lower bound accuracy.

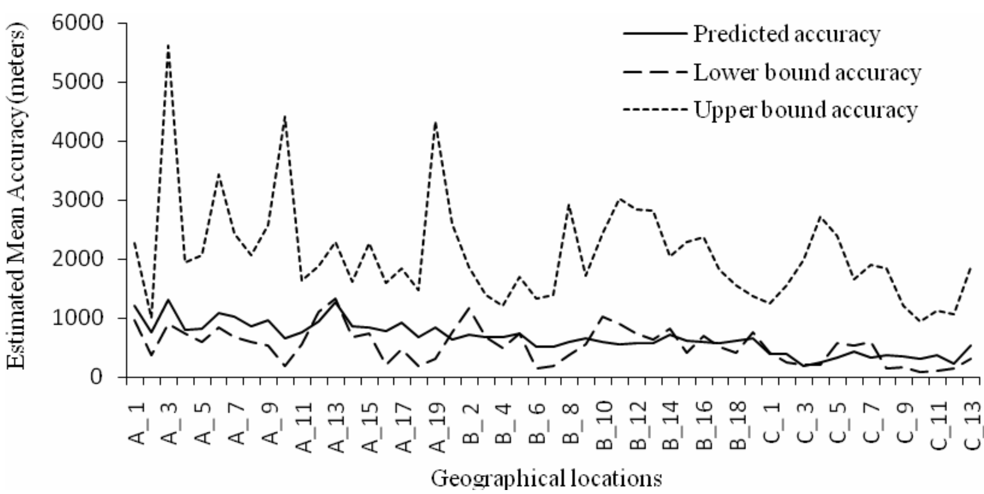

Figure 1: Mean plot of accuracy for LBS request sent from different geographical locations

Table 3: Descriptive statistics of accuracy predicted and provided at different environments (meters)

	Soweto			**Sandton**			**Johannesburg CBD**		
	Min	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**
Predicted accuracy	657	1310	924	510	749	628	196	547	345
Lower bound accuracy	182	1323	627	145	1150	617	76	618	307
Upper bound accuracy	993	4412	2460	1191	3015	2007	933	2714	1714

With such a large disparity between the predicted and upper bound provided accuracy, the ability of the LBS user to make an informed decision from the location information provided is very difficult. Because of the unpredictable accuracy, users can't depend on the information provided and hence it might not be useful to most LBS users (Katasonov, 2004). The inaccuracy observed is consistent for all environments and geographical locations considered and this might be why LBS have not been embraced by more subscribers. Although the LBS provided are inaccurate and undependable, they are relatively reliable with about 94 percent reliability. This makes LBS desirable if the issue of accuracy and dependability is improved.

Challenges Encountered During LBS Provision in Africa

The Accuracy, Size and Coverage of the Spatial Data Available in Africa

Most areas in Africa do not have well addressed houses, roads, street and areas due to constant development. The spatial data is not well populated and maps available are rarely updated. The data and content provided by LBS providers is obtained from the aforementioned sources thereby leading to the provision of inaccurate LBS.

Provision of LBS not Adapted to the Needs of Africa

Applications rolled out in Africa are mostly imported from developed countries and very few of them are home- grown and adapted to the needs of African users (ConnectWorld, 2009). This might be due to the extra expense which might be incurred by the mobile providers and also unavailability of trained local staff and personnel to develop the services and applications.

Lack of legislation for LBS

Nothing works according to specifications all around the world if there are no adequate regulatory bodies to make sure the requirements for the provision of such services and quality of service are met. Africa does not have any regulatory body at present to ensure quality of service.

LBS Infrastructure

The type of positioning techniques employed for the provision of LBS in Africa though has many advantages, it is still quite inaccurate compared to those obtainable using other techniques such as GPS and time-measurement based location estimation methods. MSs with built-in GPS are too expensive for most African subscribers and upgrading a BS with a LMU and synchronization ranges from £3000 - £4000 and at a conversion rate of about 267 Naira to 1 pound, it translates to about ₦800 000 – ₦1 060 000 according to a report by (OFCOM, 2010).

Solutions proffered to Highlighted Challenges

Spatial Data in Africa

The spatial data of any area or place is very important for various applications such as e-government, planning and management of resources by the government, business purposes etc. Most times, the first institution to sponsor spatial analyses and database is the government. This is because it requires large investments and the major users of the spatial data is the government. This is a major requirement for the intended e-government roll-out in many African countries. Investment by the government of most African countries will be a major step in the right direction for many application also included is LBS.

Provision of LBS not Adapted to the Needs of Africa

An academic-industry collaboration will ensure proper research and investigation be carried out to identify the LBS needs most suitable for subscribers. There applications will be developed with good research and investigative studies carried out to identify the best way to provide such LBS.

LBS Infrastructure

Due to the expense that is anticipated if LBS equipments are acquired, it is better to do some more research and invest in the provision of LBS using hybrid positioning methods which has proved to give a better accuracy.

Lack of legislation for LBS

It is important for a group to be formed to look into LBS and the legislations which can make it dependable, useful and available to all that requires it.

LBS groupings

LBS should be tested at different areas and data collected and analysed before deploying them at different areas. The accuracy obtained should then be used to choose the type of LBS that will be deployed based on the accuracy it requires.

CONCLUSION

LBS helps its users to make informed decisions on location-based activities they are about to embark on. Inaccuracy in location information provided results in accuracy in the decision arrived at by the user (Katasonov, 2004). LBS are useful and important but they are a useless, lead to errors and wrong decisions made by its users if the predicted accuracy is different from the correct information. With the infrastructure already in place it is feasible for LBS to be rolled out in Africa but the main limitation that might be encountered is the inaccuracy. The inaccuracy can be addressed if the different solutions proffered above are considered. LBS provide additional services to African mobile subscribers where the only form of modern communication available to them is the mobile communication. With various types of LBS that can be rolled out (Dahunsi and Dwolatzky, 2012), its provision and inaccuracy is definitely an issue to be looked into and addressed by mobile operators and the government.

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