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Accuracy of current Mobile Phone Location: Limitations on the New Cellular Geography

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1. Introduction and Justification

Contemporary conceptions of cities and urban life give mobility a primary role as its major structuring component, using such metaphors as ‘the space of flows’ (Castells, 1989), or as ‘a place of mobility, flow and everyday practices’ (Amin and Thrift, 2002). Traditional social research methods that try to map and understand the spatiality of the ‘mobile society’, fail to adequately measure its rapidly changing spatiotemporal dynamics (Cole, et al., 2002). Mobile phones currently form part of the everyday life experiences of around 80% of the adult population in Western Europe (Eurostat, 2005). One of their technological side effects is *mobile phone location*, which, together with the individual identification of its user, can provide a new methodology to understand population mobility in contemporary societies (Miller, 2004) if certain accuracy and privacy issues are solved.

Most of the research undertaken so far on mobile phone location from a geographic point of view has primarily focussed on the spatial information or its visualizations requirements to support Location Based Services (LBS) at the individual user level (Mountain and Raper 2001, Dykes and Mountain 2003, 2002). This research focuses on evaluating the spatiotemporal accuracy of current mobile phone location technology, which is based on *cell identification* methods. The main aim is to assess its validity as a methodology to measure the mobility patterns of large groups of population, as opposed to individual tracking. Knowing the level of spatiotemporal accuracy is essential to determine the geographical scale of mobility that this technology can measure today, and provide a baseline against which forthcoming future enhancements of mobile phone location methods (3rd Generation) can be compared with.

2. Brief technological review

The basic type of current mobile phone positioning is called Cell Identification or *Cell-ID* location (referring to the cellular network of transmitters), a method that requires little network investment but provides poor accuracy since cells vary greatly in size, especially outside urban areas (Spinney, 2003). Accuracy of *Cell-ID* location is directly linked to the size of the cell where the user is located, and can vary from 100 metres to over 5 km (Faggion and Trocheris, 2004). A variation of *Cell-ID* methodology is *Cell-ID++*, which adds Timing Advance calculations (TA) to improve accuracy slightly. Many other network-based methods have been proposed to improve *Cell-ID* positioning accuracy; ‘Angle of Arrival’ (AOA), ‘Enhanced Observed Time Difference’ (E-OTD), and ‘Time Difference of Arrival’ (TDOA), but improvements are not significant and implementation costs are high (Mountain and Raper 2001).

Asissted-GPS (A-GPS) is a new hybrid solution that combines both network and handset based location methods (Zhao, 2002), but puts the cost of accuracy improvement on the user’s side (Spinney, 2003). *A-GPS* requires a GPS-enabled mobile phone that works in conjunction with Cell-ID to reduce urban interferences to GPS signal (Faggion and Trocheris, 2004). *A-GPS* location methodology is substantially more precise than current location technology with accuracies of under 20 m (Zhao 2002). The US market is experiencing a quick shift towards GPS-enabled mobile phones as a consequence of the e-911 initiative that requires telecommunication operators to provide the user position in emergency calls within 50 to 100 m. accuracy in most cases (Federal Communications Commission, 2004). As 3rd generation mobile phone standards (UMTS) start to replace current phone and network technology, *A-GPS* will eventually become the standard for mobile phone location (Faggion and Trocheris, 2004).

3. Methodology

The main objective of this research is to evaluate the spatiotemporal accuracy of current mobile phone location technology commercially available in the UK. It is suspected that the information about the accuracy of this technology available from commercial suppliers is substantially flawed to encourage early usage. Therefore, this research conducts 'empirical exploration' of the technology through a series of mobile phone location tests that surveyed the movements of a small sample of participants in the UK.

The first test aimed to measure the mobility patterns of a group of students in the city centre of Leicester, corroborating that the location accuracy provided by the operators was indeed much worse than advertised by the service providers[1]. The second test measured the actual spatial and temporal accuracy, by locating three mobile phones from different operators, travelling together through several areas of the city of Leicester, comparing the locations provided with their true location determined with a GPS unit (Figure 3). A third test was carried out measuring inter-urban movements, by tracking a single mobile phone during several car trips around the UK. These three tests provided a total number of 319 different Time Location Stamps (TLS), upon which the analysis is based. Table 1 below summarizes the general characteristics of the three tests.

Table 1. Summary of Location Tests performed

Test Nr.	***Objective***	***Nr. of mobile phones located***	***Nr. of Time Location Stamps (TLS)***	***Service Provider (TPSP)***
1	Test intra-urban mobility patterns of 9 people	9	152	ChildLocate
2	Test location accuracy of mobile phone operators	3	83	FollowUs
3	Test advantages of mobile phone location for inter-urban mobility	1	74	FollowUs

[1] Twelve different Service Providers of mobile phone location to third parties were identified in the UK. Four of them were pre-tested; FollowUS, ChildLocate, Verilocation and WayHey, and the first two were finally used in the tests.

	pattern analysis			

4. Analysis of Results

The mobile phone location tests carried out in this research have provided a very rich empirical exploration of this technology, leading to the exposure of the true spatiotemporal characteristics of current mobile phone location, which can be briefly summarized around the following topics:

4.1 Cellular Geography and Location Accuracy

The spatial disposition of 'mobile phone's geography' is determined by the location method used by all the operators in the UK, the basic Cell-ID method, without any slight enhancement such us Cell-ID++ (Faggion & Trocheris, 2004). The consequence is a very coarse spatial resolution, which determines the geographical scale of studies that could use mobile phone location as a proxy for mobility. The tests have demonstrated that the actual location accuracy provided by operators is substantially worst than commercially advertised, and than previous research in Japan has shown (Hato & Asakura, 2001). The estimated average accuracy of actual locations was 3615 m., with a minimum of 500 m. and a maximum of 5000 m., while the values commercially advertised[2] oscillate between 150-400 m.

Furthermore, since the accuracy estimate given by operators is always the same within a cell, this results in a discrete representation of space where the basic geographic unit is the mobile phone cell. The tests showed that the operators always provide the worst possible accuracy estimate (cell radius), when in fact the reality in most cases is much better (closer to the cell centroid), with an average of 800 m. (see Figure 1).

Therefore, this technology is not appropriate for studies which require locations which are more specific than the cell, but rather for where the scale of analysis only requires a minimum geographical resolution of 3,000 m radius, for example in interurban mobility analysis.

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[2] ChildLocate advertises these accuracy estimates figures at:
http://www.childlocate.co.uk/faq.html
http://www.christmas-shopping-uk.com/locateyourchildren.htm

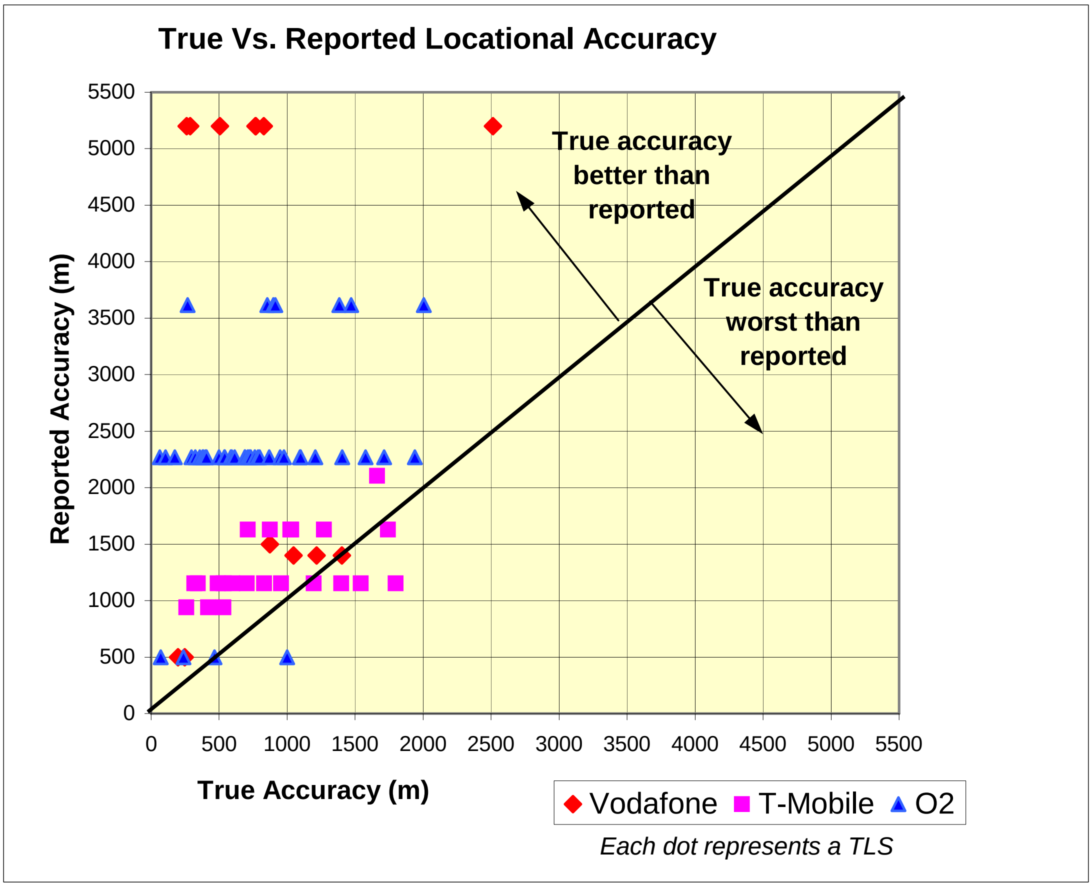

Figure 1: True vs. Reported Accuracy

4.2 Temporal Resolution

Time is as important as position in mobile phone location, and many of implications of Hägerstrand's 'Time Geography' can be re-applied to this technology (Hägerstrand 1970). The datasets will have an specific temporal resolution that will drive the type of applications in which it will be used. The minimum temporal resolution will be determined by the 'amount of mobility' that is to be monitored (i.e. high speed will require high temporal resolution).

Furthermore, the research identified the issue of assessing temporal accuracy, since not all the TLS were provided in real-time. As shown in Figure 2, a significant proportion of TLS can be 'old locations' (showing where was the phone 'in the past'), which can have serious consequences for some studies.

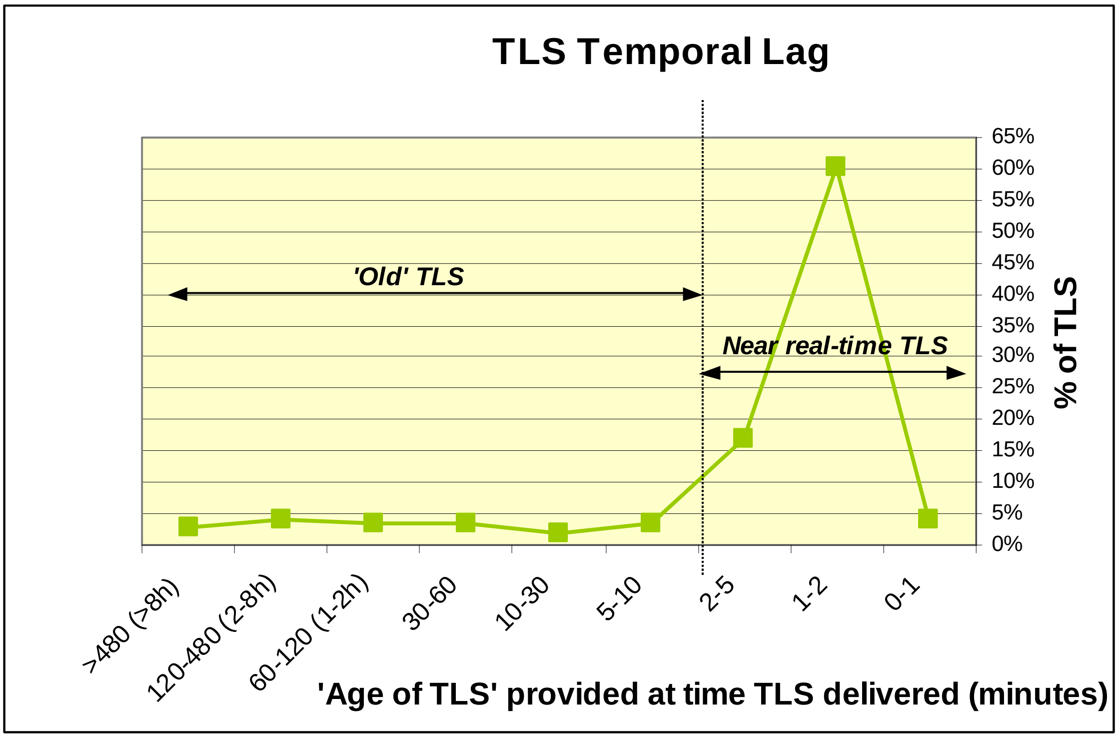

Figure 2: Time Location Stamp (TLS) Temporal Lag

5. Conclusion

Mobile phone location is a promising methodology to measure the mobility of large groups of the population in developed countries. Nevertheless current commercially available location methods present a poor spatiotemporal accuracy, which limits the geographical scale of application to the measurement of inter-urban mobility.

As new generations of mobile phone devices and network technology are being deployed, assisted-GPS technology will allow more accurate spatiotemporal measurement, and much finer geographical scale applications to measure intra-urban mobility will be possible. It is believed that once this point is reached (spatiotemporal resolution of less than 20m and 10 seconds), mobile phone location will transcend as a new spatial reference system, drawing a parallelism with the evolution of the Postcode to become the ‘New Geography’ a decade ago (Raper *et al* 1992).

From a social science perspective, it is recommended that in the near future central governments should conduct a statistical survey initiative that samples the personal location of the population on certain survey days. Access to the location information should be granted without the need for prior individual consent based on public interest (Fisher & Dobson, 2003). This initiative should be based on similar guidelines as the national census of population to safeguard anonymity and require coverage of a large part of the population. This information should then be published and visualized in aggregated ways that preserve individual privacy, but that would allow access to much more accurate and frequently updated population mobility data for urban researchers.

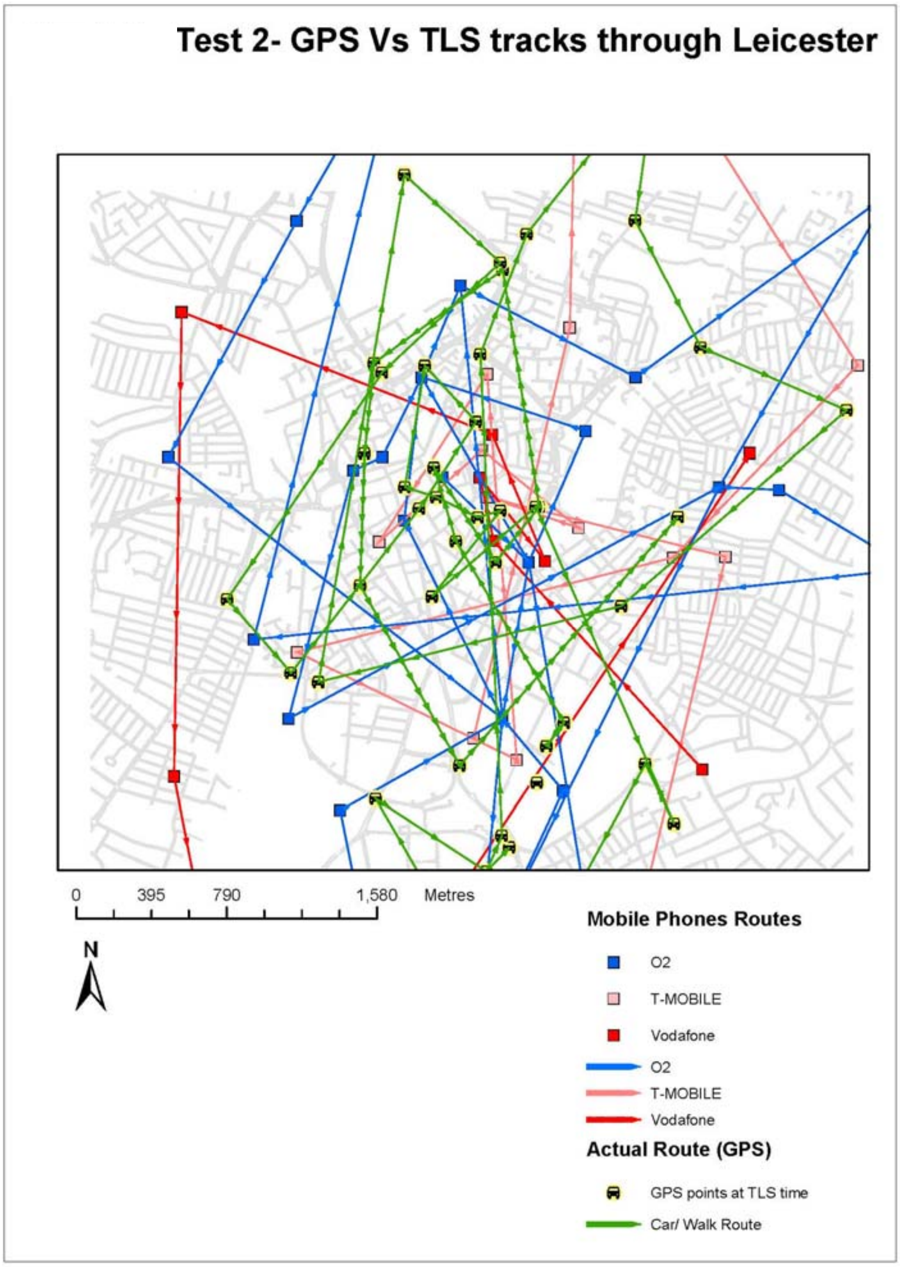

Figure 3: Visualization of Test 2, GPS vs TLS tracks through Leicester, UK

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Biography

Pablo Mateos is a PhD student at CASA, University College London, as well as research associate at Camden PCT (NHS). He gained a Business Studies BA (1994), a Geography BA (2001), and an MSc in GIS (2004). His research interests are the applications of GIS and Geodemographics in Social Geography and Public Services. The work described here was conducted as part of his MSc dissertation at the University of Leicester

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