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Future Positioning Technologies and their Application to the Automotive Sector

Andrew Sage

(*Helios Technology Limited*)

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The widespread commercial availability of location-based services depends upon every new mobile phone including positioning capability. The timescales for the introduction of these devices is far from clear, and yet the demand for high accuracy services is already increasing, particularly in the automotive and telematics sector. This paper presents a summary of the current and emerging positioning technologies, their capability, predicted timescales and their suitability for the in-car environment. Will GPS levels of accuracy be available in the mobile phone? Who are the various commercial players that may affect the ultimate choice of technology? Have new satellite services such as Galileo left it too late? The paper attempts to answer these and other questions whilst offering an insight into the convergence of satellite and cellular positioning.

KEY WORDS

1. Road. 2. Telematics. 3. Positioning.

1. INTRODUCTION. Satellite navigation is now becoming commonplace in today's new vehicles as more and more 'middle range' cars include such capability as

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standard. This stems from a desire amongst car manufacturers to provide other value-added services as part of the overall package and thus differentiate themselves from the competition. Meanwhile, the emergence of off-board location-based services to the car, both within the US and parts of Europe, also offers insight into the value placed by the industry on such services. Typically, the driver of a vehicle has a mobile phone; a device that will soon become a communicator, navigator and personal assistant, offering much richer functionality than is currently possible. The widespread commercial availability of location-based services – much talked about in today's press – depends upon every new mobile phone including a positioning capability. The timescales for the introduction of these devices is far from clear and yet the demand for high accuracy services is already increasing, particularly in the automotive and telematics sector.

The options open to providers of value-added services to the car are enormous, both in terms of technology and business model. Amongst such value-added services is a valuable sub-set of location-based services that require the location of the user/vehicle. This additional requirement adds further complexity to an already confused environment, where the service provider is constrained and potentially driven by the performance, timescales and availability of suitable positioning technologies. This paper summarises the key positioning technologies in terms of performance and their commercial basis, and discusses how the choice of technology will be one of the main factors determining who will succeed in this market.

2. WHY IS THE AUTOMOTIVE SECTOR UNIQUE?

The in-car market offers a relatively unique environment into which mobile operators and service providers are able to provide mobile value-added services. Whilst the market for pedestrian users remains severely constrained by available devices and network bandwidth, the car potentially offers a number of opportunities to overcome these obstacles. This means that the in-car market could be one of the early 'hunting grounds' for operators in search of early revenues.

The factors that make the in-car environment relatively unique are as follows:

(a) Location-Based Services (LBS) are already widespread through the use of in-car navigation systems and other information services, albeit currently provided primarily by on-board systems.

(b) Satellite navigation (GPS) is already installed as standard in many models offering accurate location information. After-sale installation of GPS is also cheap and easy relative to the integration problems facing handset manufacturers.

(c) The in-car user is more likely to roam across international boundaries, is travelling faster than the average pedestrian, will be driving through tunnels and into multi-storey car parks and will still require many of the in-car services when he/she steps out of the vehicle. All of these additional requirements must be considered when selecting the necessary enabling technologies.

(d) Car manufacturers and telematics providers offer an alternative 'point of sale' for such services either instead of, or in partnership with mobile operators.

3. THE MARKET AND APPLICATIONS.

A number of organisations already offer telematics and other on-board services that depend upon location information. The vast majority of such services depend upon GPS positioning, although some also depend upon positioning via terrestrial networks or beacons. Existing services include:

(a) In-car navigation and routeing (on-board, wired systems);
(b) Traffic information (via RDS or mobile);
(c) Emergency and breakdown call;
(d) General concierge services (already widespread in the US);
(e) Fleet management and vehicle tracking (amongst a range of corporate customers).

The introduction of 2·5G and 3G over the next two to three years will offer position-enabled handsets, richer devices (e.g. Personal Digital Assistant (PDAs)) and more intelligent network services. These milestones, coupled with the establishment of integrated mobile internet application platforms within future mobile networks mean that the list of applications can be greatly extended to include:

(a) Dynamic routeing and navigation (utilising off-board server technology);
(b) Personalised traffic information;
(c) Facilities information;
(d) Points of interest finder;
(e) Automatic servicing/maintenance;
(f) E-commerce applications (e.g. car parking, ticket booking, etc);
(g) Dynamic task scheduling and navigation for dispatchers, couriers, etc.

All of these services depend to different degrees upon location information and therefore all fall into the category of LBS.

4. WHO ARE THE KEY STAKEHOLDERS? The desire to 'control' or rather 'communicate with' the driver is shared by a great many organisations. These companies will ultimately either compete for the same market revenues, work in partnership or offer slightly different solutions and applications. They may be broadly categorised as follows:

4.1. *Mobile Operators.* The majority of drivers already have a transaction-based relationship with their network provider either directly or via their employer, thus providing an obvious channel over which to offer value-added services. The operators are desperately seeking new sources of revenue or ways of increasing the average Annual Revenue Per User (ARPU). Revenues may either come via increased network usage (independent of service) or directly from user subscriptions to branded services.

The mobile operator will promote the advantages of an off-board solution to a mobile phone (independent of vehicle) thus ensuring service continuity out of the vehicle, dynamic real-time information and service flexibility. In order to retain 'control' over such market channels, the operator is likely to favour 'network-centric' technologies, or in other words, technologies that are dependent upon or heavily influenced by the operator's networks. This includes the method of positioning, as (probably) the most valuable item of information in the whole value chain.

4.2. *Independent Service Providers.* Many of the services already listed in this paper are provided by organisations that are essentially independent of the network provider. That is not to say that the services do not depend upon a mobile network for data transmission, but these are instead treated as 'pipes' over which high value application data is transferred. An operator will therefore still benefit from increased network usage, but will not collect any direct subscriptions to the service.

Such organisations include AA/RAC (UK), ADAC (Germany), Shell/BP and car hire organisations such as Hertz or Avis. These companies may already have a relationship with the car driver and are often regarded as trusted brands and therefore offer a compelling market channel for value-added services. Such organisations are independent of car manufacturers or network operators and therefore have the luxury of selecting the most optimum set of technologies, services and platforms. Also included within this category is a range of wireless consumer portals, virtual network operators and telematics service providers.

4.3. *Vehicle Manufacturers.* Organisations in the US such as OnStar and Wingcast provide visible indications of the desire amongst car and vehicle manufacturers to re-define their relationship with the customer. In the majority of cases, once a vehicle is sold to a distributor, the manufacturer loses all contact with the end user and is unable to offer follow-on services.

The integration of on-board telematics platforms, including positioning capability, provides a channel for offering such services. A large number of vehicles are already fitted with GSM and GPS capability as standard. In order to 'control' access to this channel, the car manufacturer is likely either to: favour a set of applications that are linked strongly to specific services only available via the manufacturer such as vehicle breakdown, servicing, etc.; or retain 'control' over the position information held within the vehicle, making it available to third parties in a controlled manner.

5. CURRENT, EMERGING AND FUTURE TECHNOLOGIES. The previous discussion outlined the various stakeholders with a vested interest in this emerging valuable market, triggered by the availability of improved network services, handheld devices and hosted application platforms. It is clear from the analysis so far that accurate position information is highly valuable and may be provided in any number of ways. The chosen platform for such information and its availability will therefore influence the business model (and associated timescales) that will be adopted. A brief description of each potential positioning technology is offered in the following paragraphs (in increasing order of probable accuracy).

5.1. *Network Cell Identification (Cell ID): Accuracy 250 m to 30 km.* Cell ID is already deployed by a number of networks and used as part of existing LBS. Examples include BT Cellnet's 1500 service and Vodafone's 1800 traffic information service. In rural areas, where network transmitters are widely separated, cell identification can be as inaccurate as 30 km; the measurement only puts the user in a particular cell's circle of coverage. Obviously, if the user can see or be seen by more than one cell, the ambiguity of position can be dramatically reduced. However, in rural areas, the overlap of network base stations limits the area in which such location discrimination can be expected to be available.

5.2. *Time of Arrival (TOA): Accuracy 125 m.* This network-based technique uses the time of arrival of a signal either from the network base station(s) or from the user terminal to a number of base stations. This enables the calculation of the range between those points from knowing the time it has taken a signal travelling at the speed of light to travel from transmitter to user or vice versa.

This solution requires a high degree of synchronism within the network of base stations. It also requires that the positions of those stations are known quite accurately (to within a metre or so). In areas of low multi-path (reflection of the radio signals), the accuracy of such a system can be quite high. Where very accurate synchronism of the network can be guaranteed, then such a time of arrival system can offer accuracy of location of around 125 to 200 metres. This solution requires significant network investment but can be used on existing legacy handsets with little or no modification to software.

5.3. *Enhanced Observed Time Difference (E-OTD): Accuracy < 100 m.* This network-based technique is a modification of the TOA method explained above. The ranges are computed by measuring time differences of arrival, a technique that offers greater sensitivity and less dependency on wide area synchronism of the transmitters. Some organisations are claiming increased accuracy with 3G, whilst others dispute the potential performance improvement, especially in light of the need to increase the number of 3G base stations significantly. E-OTD complements GPS and could therefore act as an augmentation to satellite-derived position fixing. E-OTD requires significant network investment and also requires specific software to be installed within the mobile. A number of operators are currently trialling this technique within existing 2G networks.

5.4. *Stand-alone GPS: Accuracy 2–20 m.* Currently, the prime method of position location is the US Department of Defense's Global Positioning System (GPS), offering worldwide coverage. Development of GPS started late in the 1960s and became fully operational around 1990. The current system comprises 28 satellites that form a birdcage of orbits around the Earth. A network of ground stations tracks the position of the satellites and sends this tracking data to a computing centre to produce the ephemeris message. GPS is a passive system, there being no transmission from the user to the satellites, and therefore the number of users is unlimited.

If the measurements are made to four or more satellites at the same time, it is possible to derive a three-dimensional position fix of the user's GPS receiver antenna. The accuracy of the resultant fix can be between 2 and 20 metres. The GPS constellation has been designed and is maintained to provide coverage of at least 4 satellites over all parts of the Earth, 24 hours per day. With the current constellation, it is sometimes possible to track 12 or more GPS satellites for part of a day, in certain locations. Unfortunately, this situation usually means that there are other times of the same day when only 5 or 6 satellites may be visible. While the system will produce fixes with this low number, there is also the problem of the location of the satellites. If they are all in one area of the sky, the geometry means that the accuracy of the resultant fix could be very poor. A low number of satellites also makes using the system very difficult in urban canyons or in areas with natural shielding of large portions of the sky (e.g. trees). A small number of manufacturers have already produced mobile phone handsets with stand-alone GPS capability built-in.

5.5. *Differential GPS (D-GPS): Accuracy 1–10 m.* GPS errors can be largely removed by the application of range correction measurements derived from a GPS reference location. This technique is known as differential GPS (D-GPS). The accuracy of the position of the user equipment is thus relative to the accuracy of the position of the reference station. In effect, this means that if the position of the base reference GPS receiver is in error, this error will translate almost directly into an error in the position of the user's equipment. It is normally possible to report the position of the user terminals to within 1 to 2 metres under good conditions, using publicly available corrections.

5.6. *Assisted GPS(A-GPS): Accuracy 1–10 m.* We have seen how GPS can be enhanced by the application of differential range corrections; however, these do not improve the satellite receiver tracking performance. Other techniques exist that enhance the sensitivity of the GPS receiver when it is required to operate under unfavourable conditions. These might be under foliage, in an urban canyon or even inside a building. A key problem is that of getting the first fix from a GPS receiver after it has been out of sight of any satellites for more than about three hours (Time to First Fix – TTFF). In areas where the GPS antenna has a clear view of the sky, the receiver may take up to a minute or more to acquire the signal and then download the ephemeris message. This message is only transmitted at 50 bits per second so, if there is any fading of the signal strength during this initial period, it may be necessary to wait until the message is broadcast again before the user's receiver knows the satellites' accurate positions. In a poor reception area, this process could take forever, even though the GPS receiver is able to detect the satellites, because it is unable to decode the vital part of the message.

A GPS reference receiver can be set up and connected to the network in such a way as to make available the ephemeris data from all of the satellites in view. It can also make available the identification of which satellites should be in view to save the user's system looking for out-of-view satellites. The network-assisted nature of this technique allows the border between the GPS functionality and network functionality to be 'blurred'. If the mobile terminal has a complete GPS receiver, then the position computation is carried out in the handset and the network is polled by the terminal to issue the necessary data to enable a quick first fix. Alternatively, if one removes much of the non-RF elements of the GPS transceiver from the device, then the position computation may be carried out in the network. The first option requires more power in the user terminal to process the GPS fix but it does, however, allow for fast update rates where the system is to be used in a tracking mode. Once the GPS receiver has been given the necessary data to get it started, there is no load on the network until the user requests a location-enabled service. This approach also puts control of the location in the user's hands. By comparison, the second method offers a significant saving in battery power by shifting much of the processing into the network. However, depending upon the degree of network coverage and the type of application, such a high degree of dependency on the mobile network may not be desirable.

6. SUMMARY OF CAPABILITY.

Many of today's value-added mobile services would be greatly enhanced in commercial value by the inclusion of location information. Even very approximate positioning obtained from cell identity represents a 'step up' from today's services. However, the majority of LBS applications will always benefit from improved accuracy and indeed, many depend upon it (e.g. turn-by-turn navigation). It is the author's opinion that operators are now convinced of the need for accurate positioning (driven initially by E-911 legislation); it is just a matter of time before the networks, handsets and applications work together to realise the benefits. This requirement naturally therefore leans towards GPS-enabled positioning solutions of some kind. However, the issue of TTFF presents an even stronger compelling case towards the various network-assisted solutions.

GPS suffers from obvious coverage issues in urban canyons and other similar environments. Opinions regarding the degree of these issues vary, although there is little sign yet of the end user complaining of such behaviour. To this end, terrestrial network techniques act as a strong complement to GPS, also providing greater penetration inside buildings. The secret of ensuring end-to-end availability is therefore likely to lie with those solutions that attempt to integrate both technologies. In the meantime, whilst the networks remain focused upon urban areas, GPS provides a global, standardised roaming capability in those areas where coverage is sparse. This will be of primary importance in the early days of 3G when coverage will be limited.

The treatment of location information is highly sensitive as regulators now see the privacy implications of such information being transmitted between several parties. As well as adhering to any regulation that applies, providers and operators must be careful not to alienate the user with a flood of unwanted information, advertisements and 'spam'. Those positioning techniques that are at the control of the user and independent of the network are likely to alleviate such fears. However, this does not sit comfortably with the desire amongst network providers not to be seen purely as 'pipes' for valuable applications.

7. THE KEY ISSUES FACING THE AUTOMOTIVE SECTOR. The issues described above apply in equal weight to the automotive sector. The range of applications in the car demands a wide range of accuracies, coverage and availability requirements and commercial models that point towards a wide range of positioning technologies. A high proportion of today's value-added services to the car are provided by on-board systems with little or no wireless connection (e.g. in-car navigation). The disadvantages facing such traditional systems are:

(a) The inability to provide continuity across different user platforms;
(b) The lack of dynamic real-time functionality (e.g. dynamic routeing and traffic information);
(c) The need to store up-to-date valid map and navigable data on-board the vehicle;
(d) Inflexibility in functionality and therefore added cost to the user.

Many of these issues will be overcome by the introduction of off-board systems served from centrally hosted mobile internet application platforms. Such applications are already under development by specialist telematics companies as well as emerging organisations in this space such as Webraska (FR), Yeoman Group (UK) and Televigation (US). However, at the same time, there is a strong case for retaining some degree of on-board functionality in order to achieve the optimum architecture and lower user costs.

The shift towards off-board services poses a dilemma with regard to the choice of positioning technology. In theory, a combination of all methods, open and available to everyone, would be the best solution for the user. However, in these early immature days, there are opportunities for different providers to gain an 'upper hand' by influencing the chosen method and architecture. If however, the public telecommunications industry is able to work together with the telematics and automotive sector, then the user may be the overall winner.

8. ROOM FOR ANY MORE? The last few years have seen the emergence of many new positioning techniques, driven both by demand and technology

advancement. Perhaps therefore, before drawing a conclusion, it is worth considering what else may lie ahead and whether there is room for any more potential solutions. The answer, inevitably, is yes. There will always be room for further and improved methods of positioning whilst operators and service providers look for more and more value to demonstrate to customers and thus differentiate them from their competitors. The evolution of A-GPS techniques has been very quick and much has yet to be learnt whilst these solutions are tested and (potentially) introduced. Ultimately, the range of potential solutions that seek to combine the best of satellite navigation with terrestrial positioning is extremely wide.

Bluetooth is emerging as one of the strongest technology enablers in this market, offering LAN functionality over a short-range wireless communications link. Whilst offering basic positioning, its most notable effect will be to remove existing architecture constraints and almost create a 'blank sheet of paper'. This is highly valid for the in-car environment where Bluetooth could play a key role in ensuring that the car and mobile phone work together instead of in competition.

Finally, the European Commission continues its programme of introducing a European civil satellite navigation service known as Galileo. The strategic and political basis of such a system is clear and fully justifiable. However, will it be able to compete with GPS in the open market and return revenue to the commercial sector? Its accuracy and coverage will be comparable to GPS in the eyes of most users and therefore its largest differentiator is likely to be integrity. For many applications, such information will be highly valued and by the time that the service is introduced in 2006, operators and providers will still be looking for new differentiators.

9. CONCLUSIONS.

It is the author's opinion that, in the long term, the mobile operators will be the largest influence in the in-car LBS marketplace. This is primarily driven by the fact that it is *service*s that users buy, not technology. Equally, it is the author's opinion that satellite navigation will also play a strong role as the LBS applications become widespread over the next two years, typified by the in-car market.

However, in the short term, the only way of obtaining accurate positioning from commercially available products is via GPS external to the handset. This provides a short window of opportunity for the automotive and telematics sector greatly to influence the future market and business model, and achieve their ambition of getting 'closer to the user'.