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A pragmatic approach to promoting location-based services.

# Location-based mobile services: the essentials

## Introduction

So much has been said and written about location-based mobile services that many people are unsure whether or not to believe all the hype. However, the uncertainty has now been resolved. Two years of technical and marketing studies have identified some potentially very profitable services. Furthermore, the difference between technical feasibility and market reality has been highlighted. What is certain is that location-based services offer operators a means to differentiate themselves in the market, and that these services are of crucial importance in a mature, highly competitive market. For the operators, the difficulty lies in the need to invest in the best technological solutions to meet the demands of their specific markets. An analysis of market trends and constraints, relating to the services to be offered, shows that the operators require simple and flexible solutions.

## A Better Lifestyle with the Mobile Phone

The major figures characterizing our increasingly mobile society are: more than 394 million Global System for Mobile Communication (GSM) subscribers worldwide, 60% of whom are in Europe, with projected growth of more than 43% in Western Europe to the year 2005.

When individuals find themselves in an environment with which they are unfamiliar, their behavior and needs are largely predictable, whether in their own country or abroad, in a vehicle or on foot. People need to find somewhere to eat, perhaps a pharmacy, somewhere to obtain cash, a taxi stand, and so on. When abroad, there are additional requirements: finding the local tourist attractions, getting around, locating a hotel and a foreign exchange. When driving, there may be other requirements, such as help with finding a route through an unknown city or details of breakdown services. Today, an ill-prepared traveler (who does not consult the Internet, buy a guide book, pick up information at the hotel or airport check-in, book in advance, etc) wastes a lot of time, and will not receive much help from his or her mobile phone. This is a dissatisfied mobile user, and therefore there is a market that needs to be met by providing suitable services that combine ease of use with efficiency.

## New Services Providing New Revenue

There is a wide variety of location-based services, of which the following four have the greatest potential in terms of sales.

### Information Services

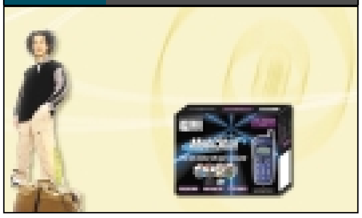
Finding the nearest service, accessing traffic news, getting help with navigating in an unfamiliar city, obtaining a local street map – these are just a few of the many location-based services that offer a new source of revenue for operators. The market for information services is considered to be one of the most promising in terms of global revenue (operators, developers, providers). By the year 2005, the European market for information services should represent a total revenue of $13.5 billion (source: Strategis Group). The type of information sought depends on the target market and users' lifestyles:

- Companies make use of this new medium of information in "Business to Consumer" relationships. Subscriber location information enables companies to target users who subscribe to this service option by launching local product promotions or advertising campaigns. According to a Strategis Group study of consumers, the great majority of subscribers to location-based services are prepared to receive advertising if, in return, they are offered lower monthly subscription rates for these services. This is especially true for younger subscribers and high volume users, who both want to reduce their monthly phone bills. Of course, these services must respect an individual subscriber's right to privacy; the market will not take off if it does not do so. Indeed, the subscriber must retain the right to choose when his or her location can be identified for the purpose of receiving advertising. The various regulatory bodies concerned have already drawn up recommendations.
- In "Consumer to Business" relationships, the subscriber actually requests his or her location to be determined in order to gain access to precise information relating to his or her immediate environment. Users might require information about local services (restaurants, gas stations, pharmacies, etc) or local traffic infor-

mation – the two most requested categories of information. Two types of subscriber will use these services: the well-off tourist and the man or woman with combined business and personal requirements, who deals with his or her daily needs in real-time and for whom the monthly bill is less important than the ability to obtain the required information quickly and easily. These two user profiles are distinguished from each other by the nature of the information sought. In general, the former requires information concerning leisure activities and business, while the latter requires information concerning business and family.

- In "Consumer to Consumer" relationships, the subscriber can locate friends, family members, or more generally members of a community to which he or she belongs (sports, music, cinema, etc). This is the scenario for which the Alcatel MobiChat product was created; its target market is young people between 12 and 20 years of age who like to share experiences, exchange information and get together. As the Wireless Application Protocol (WAP) based extension of an Internet chat service, Mobichat allows them to make lists of their favorite clubs, to create their own club, to communicate with each other and to arrange meetings. Each short message is associated with subscriber location information stored by the cyberchat server. This server informs members of the same group if they are close to one another. In this way, the location-related service allows subscribers to actually meet one another. This solution, based on the Subscriber Identity Module (SIM) application toolkit, locates the subscriber at his or her request (see *Figure 1*). Alcatel was the first company to implement such a solution, as it was able to supply mobiles that were compatible with the SIM application toolkit and WAP and enhanced with other features to improve the accuracy of subscriber location (within 50 m in urban areas). Moreover, Alcatel offers a comprehensive solution based on the location-finding server developed by Nextenso, an Alcatel subsidiary.

**Fig. 1 Location-based Alcatel MobiChat pack**



#### Emergency Services

This category includes public and private emergency services for both pedestrians and drivers. Public emergency services for calling out firefighters, medical teams, etc, are currently being regulated in the United States and Europe. These services do not require a subscription and can be accessed by any mobile subscriber, in accordance with the regulations governing the rights of individuals to emergency assistance. They do not generate a profit for the operators.

Emergency roadside assistance for drivers appears to be one of the most promising of the assistance services in terms of operator revenue (again based on Strategis Group research). Such services require the vehicle's location to be accurately determined so that emergency assistance can be provided quickly and efficiently. Despite this need for accuracy, the location-determining mechanism is greatly simplified in a vehicle.

#### Monitoring Services for Fleets of Vehicles or Individuals

Monitoring mainly covers Business to Business services, operating fleet management applications, and tracking the location of external resources to optimize their use and control or ensure their safety. Here, external resources include individuals, whether in vehicles or not (truck drivers, delivery personnel, maintenance technicians, security personnel, etc), and objects (cars, trucks, trailers, containers and other such items). Services of this type offer obvious benefits for companies that hire out vehicles and equipment.

#### Operator Services

User location information can be used to improve the way that services are implemented in areas such as network planning, quality of service, optimization of radio resources (handover and channel allocation) and pricing. Location-based pricing, by no means least in importance, has been identified by the Strategis Group as one of the most promising applications in Europe, with revenue totaling in the region of $15.9 billion.

#### What Services are Available Today?

*Table 1* shows the services that are currently available over second-generation mobile networks.

These services use two main positioning methods: the Cell IDentifier (Cell-ID) and Global Positioning System (GPS), which are covered in greater detail later in this article. Here it is sufficient to mention that most pricing and information services use the Cell-ID to determine location. In contrast, individual and fleet monitoring services make greater use of GPS.

## Issues Relating to Location-based Services

Information and pricing services are mass markets. The solutions developed by suppliers are aimed at GSM subscribers (in view of the large number of existing GSM terminals) and future Universal Mobile Telecommunications System (UMTS) subscribers. The advent of third-generation networks will expand the potential of location-based services in much the same way that innovations have been made possible by improvements in network data transmission performance and mobile terminals (large screens, color, etc).

#### Minimizing Operator Investment

Location-based services use one of several available position fixing methods, all of which have their limitations. Some require the SIM card, or even the mobile terminal itself, to be changed, whereas others require changes at the network level. The ways in which the chosen method affects the global telecom network will have a direct impact on the operators' investments. Consequently, the aim is to minimize any such impact.

The three positioning methods are, in increasing order of accuracy, as follows:

- *Cell-ID:* Accuracy depends on the density of the cellular network; the smaller the cell, the more accurate the location. To improve accuracy, two network radio measurements are used in addition to the Cell-ID; this is referred to as Cell-ID++. Network measurement results

(measuring the power received from neighboring cells) and timing advance (a mechanism for synchronization on the radio channel in the mobile-to-base station direction) are used in GSM. Third generation systems use the Round Trip Time (RTT), which measures the time taken by the radio waves to complete a round trip.
- *Observed Time Difference (OTD):* Two OTD methods are available, depending on the cellular network generation. GSM uses Enhanced OTD (E-OTD), which offers only slightly better accuracy than Cell-ID++. However, UMTS will use OTD Of Arrival (OTDOA), which offers an appreciable increase in accuracy.
- *Assisted GPS (A-GPS):* This method, which is based on the GPS satellite constellation and the introduction of a reference server into the cellular network, offers the greatest accuracy.

The Cell-ID and Cell-ID++ positioning methods can be either terminal or network based. Both OTD methods require a software function to be added to the terminal (and, therefore, a change of terminal) and other equipment to be added to the radio network. A-GPS requires a change of terminal and the deployment of a reference server in the network.

**Value of Differentiation**

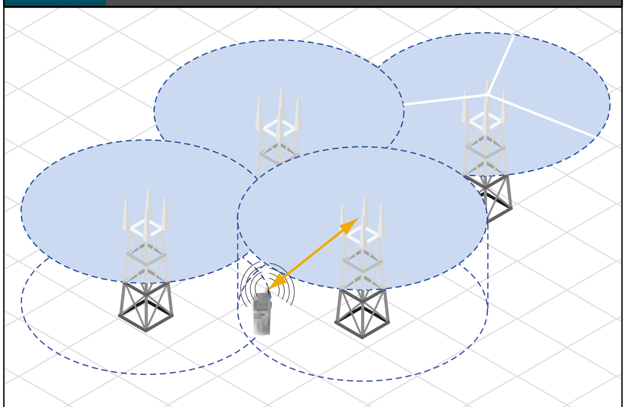
In such a competitive market, the accuracy offered to users will certainly have a role in service differentiation, but not at any price! How users judge such a differentiation will depend on the absolute gain in accuracy.

In the existing GSM market, therefore, we believe that subscribers will not be receptive to a service such as E-OTD, which only offers a slight increase in accuracy. Moreover, there is a risk of the service being unavailable to users inside buildings or in rural areas. A change of terminal will be necessary, and the operator will have to invest heavily to offer the service.

It is a different story with A-GPS, as the increase in accuracy is considerable. Also, the investment required by the operator is not on the same scale as that required for E-OTD. However, there are still problems with service availability to users inside buildings.

After describing the various positioning technologies and the degree of accuracy to be expected with each, we look at which techniques offer the required accuracy for various services.

**Fig. 2** Cellular network



## Cellular Concept and Utilizable Information

UMTS radiocommunication networks are called 'cellular' because of their radio structure. The transmitter power of the base stations (Node B) can only serve a finite number of subscribers, so it is adjusted to limit the surface area covered to this number of users. This surface forms a 'cell', the structure of which is repeated over the entire area to be covered (see *Figure 2*). An active mobile is linked to one or more cells.

Several radio synchronization mechanisms exist, at both mobile unit and network levels, to ensure that cellular networks can operate. Positioning is made possible by measuring and using this synchronization.

## Basic Principles: Radio Methods

**Cell-ID**

This is the simplest method for determining the location of a mobile. It relies on the hypothesis that the geographical coverage of a cell corresponds to that predicted by radio coverage studies. When an active mobile is connected to a base station, the mobile is assumed to be located geographically within the area predicted to be best served by this base station.

Reliable positioning therefore requires accurate maps of the base station coverage area, which are produced using cellular planning software (see *Figure 3*). It is then necessary to model the maps to transform them into a usable and easily describable format. This is the task of the Alcatel 956 RNO (Radio Network Optimization) tool, which has the ability to determine the geometric contours of cells by using polygons (referred to as 'Voronoi' polygons), as shown in *Figure 4*.

It is possible to refine positioning using RTT measurements taken by the base station, which measures the time between the transmission of a frame (from base station to mobile) and the reception of the corresponding frame (from mobile to base station). Using this measurement, the base station can work out the distance to the mobile, with a theoretical accuracy of about 80 m.

This makes it possible to restrict the area of inaccuracy. Although the information is of little use for a cell served by an omnidirectional antenna, it can offer improved accuracy in the case of "sectored" cells served by several antennas (see *Figure 5*).

Unlike second generation systems, in which a mobile only communicates with a single base station, a third generation mobile terminal can be in communication with several base stations in *soft handover* situations. An additional difficulty lies in the fact that the base stations for which the mobile is active can change several times a second. A method is therefore needed to identify the cell that best represents the geographical position of the mobile. For example, the mobile may be asked which is the best cell for reception, or statistical processing of the cells used by the mobile can be carried out. The latter solution would allow further refinement of the positioning accuracy by determining in which zone of the cell the mobile is located.

In conclusion, methods based on cell coverage may turn out to be effective for services that do not require an accuracy better than a few hundred meters. The advantage

is their low cost of deployment and operation, as well as the fact that they can be implemented across the whole population of mobile users, since no special development is required to the mobile itself.
The main difficulty with these methods lies in correctly predicting the geographical coverage of the cells, as the “best” base station will not always be the one that is physically closest. The reliability and accuracy of the positioning obtained depend on the precision of the radio predictions.

### Triangulation

We can avoid the coverage prediction problem by using a triangulation method, using measurements of the time taken by signals coming from several base stations.
If the position of two base stations is known accurately, and it is possible to measure the difference in time that the signals transmitted by these stations take to reach the mobile – the System Frame Number (SFN) observed time difference, that is, the time difference observed on the system clock as received from the two base stations – it is then possible to work out a locus (hyperbola) for which this time difference is constant and equal to that measured by the mobile. The estimated position of the mobile is obtained by repeating this operation and taking the intersection of the hyperbolas defined in this way.
This method can be combined with the RTT measurement to further increase positioning accuracy.
This triangulation method (see *Figure 6*) is more accurate than the method based on cell identification and, in particular, does not depend on correctly predicting the coverage. However, its accuracy is related directly to the time taken for the signals to travel from the base stations, and can therefore be affected by multiple reflections in urban areas. In addition, it requires three base stations to be visible, which may not be the case in a rural area or inside buildings.
The mobile can only measure observed time differences. Differences in signal transit times can only be worked out if the time interval between two base stations (Relative Time Difference; RTD) during transmission is known. Several solutions exist for dealing with this situation:

- Synchronize the base stations’ transmission relative to a common time reference (GPS type).

**Fig. 3** Map showing predicted coverage based on radio propagation models - Alcatel 955 Radio Network Planning

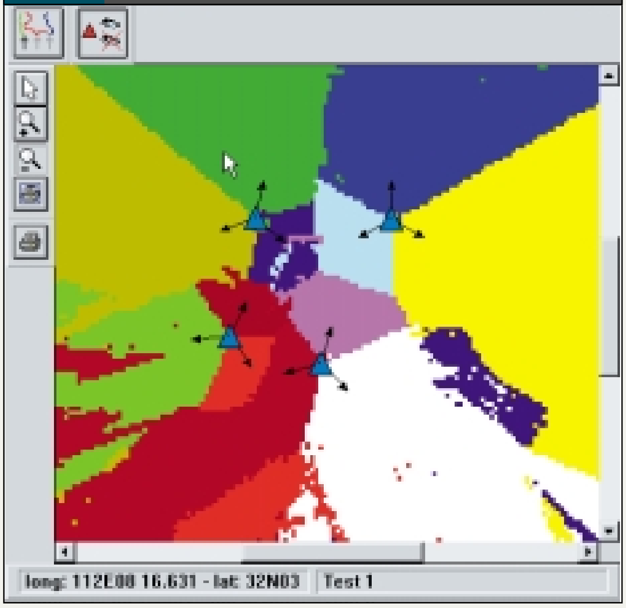



**Fig. 4** Cell modeling using Voronoi polygons - Alcatel 956 RNO

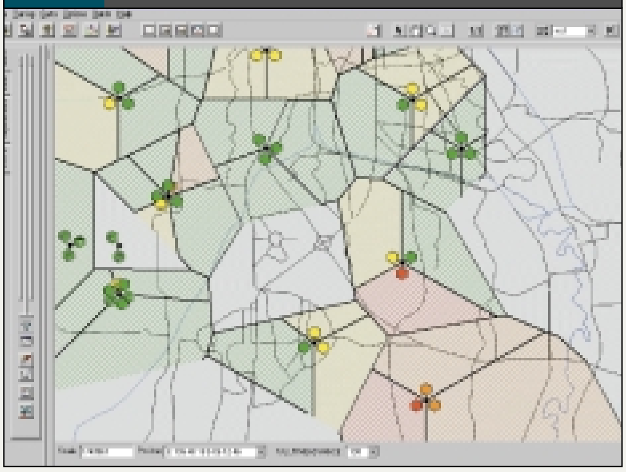


**Fig. 5** Use of RTT

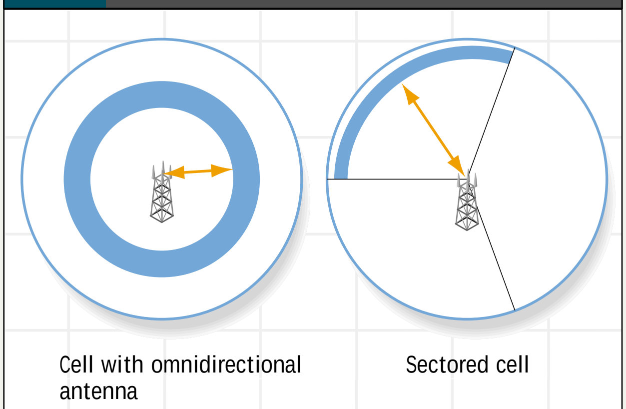
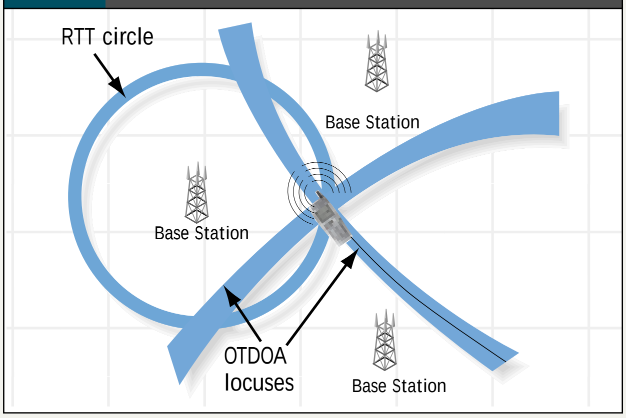



**Fig. 6** Observed time difference of arrival



- Regularly observe and measure the RTD and its drift using dedicated Location Measurement Units (LMU).

Both solutions are relatively costly, either because of the price of the GPS receivers (equipment, layout of site to give a direct view of the sky), or because of the prices of the LMUs, which are expensive to install (site, monitoring).
There are two versions of OTDOA, depending on the role assigned to the mobile:

- When the mobile only reports observations of the SFN-SFN observed time difference to the network, with the position calculations being carried out by the network, this is referred to as mobile-station-assisted OTDOA.
- It is also possible to transmit the RTD information measured by the LMUs and the positions of the base stations to the mobile. After measuring the SFN-SFN observed time difference, the mobile can calculate its own position independently. This is referred to as mobile-station-based OTDOA.

**Satellite**
Satellite positioning systems, such as GPS or Galileo, can be used to further improve accuracy.
Terrestrial mobile networks offer the possibility of transmitting support information (e.g. ephemeris, time references or even differential corrections) to these satellite receivers. Using this support data, positioning time (time-to-fix), accuracy and sensitivity are improved considerably. Accuracies to within several meters can be achieved in this way. However, the service is not available inside buildings, unless the user is close to a window.
Moreover, this method requires a full satellite receiver (processing + radio) to be integrated into the mobile, which has an adverse impact on the cost.

## Standard Architecture of a Positioning Network

The new network elements required for location fall into three categories:

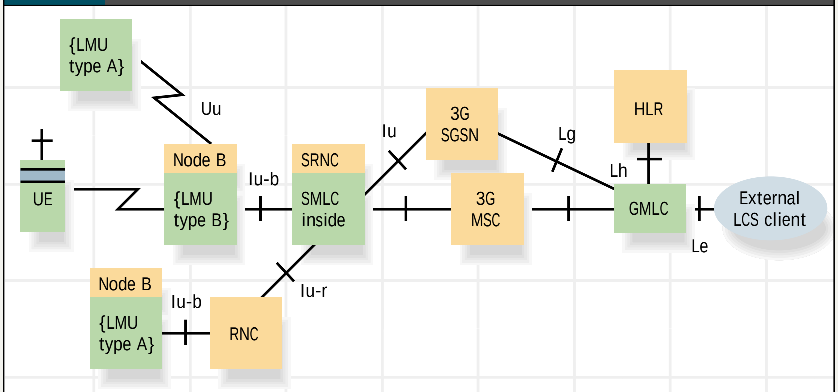
- *Gateway Mobile Location Center (GMLC):* Responsible for the interface with the outside world, the 'LoCation Services (LCS) clients', suppliers who are the source of positioning requests. The center receives the positioning request, authenticates the client, and checks that he or she is authorized to request a user location. The GMLC is also responsible for transmitting the required service quality (accuracy, response time, etc) to the network, and for converting the positioning results into the desired format, for example, a different coordinate system.
- *Serving Mobile Location Center (SMLC):* Whether integrated into the Radio Network Controller (RNC) which controls the base stations, or located in a separate network element, the SMLC has the role of determining the position of the mobile, that is, its geographical coordinates plus any potential degree of uncertainty. It is free to choose the positioning method in accordance with the quality of service requested by the GMLC and the capability of the mobile. In addition, the SMLC receives information about coverage and cellular planning when a knowledge of the network geography is needed.
- *Location Measurement Unit for OTDOA only:* The role of the LMUs is to help the SMLC take base station synchronization measurements. LMUs are either integrated into Node B (B type LMU), or distributed over the network (A type LMU). In the latter case, it is considered that one LMU is required for every three or four base stations.

In addition, the existing network elements have to be modified. The Mobile Switching Center (MSC) has to be capable, in particular, of verifying in the Home Location Register (HLR), that an LCS client is authorized to determine the location of a user, depending on the identity of the LCS client, among other things, and the subscriber profile and options. For positioning methods that require the mobile to be actively in communication, the MSC must also be capable of activating a communication, with or without notifying the subscriber.
The RNC is also affected, since it has to incorporate the SMLC functions, or even control the SMLC.
Lastly, the Node Bs have to incorporate B type LMUs, and must be able to measure RTTs.
*Figure 7* illustrates the global architecture of a UMTS network with the elements necessary for positioning as defined in the Third Generation Partnership Project (3GPP) standard.

## Choosing an Appropriate Positioning Technology

Each positioning method is characterized by an important parameter with respect to positioning: accuracy. *Table 1* lists each positioning method and shows its accuracy, impact on the access terminal and impact on the network.
Taking these levels of accuracy into account, we can establish a correspondence between services and positioning methods (see *Figure 8*). Technologies based on Cell-Id and Cell-Id++ meet the accuracy requirements for pricing and information services, whereas only the A-GPS

**Fig. 7** **Architecture of a positioning network in compliance with the 3GPP standard**



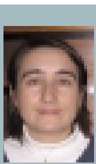

**SGSN:** Serving GPRS Support Node **UE:** User Equipment and OTDOA technologies would be suitable for navigation and assistance services. OTDOA offers better accuracy than Cell-ID++, making it a genuine alternative to the latter in a future market such as UMTS.

### Advantages for Operators

A consideration of operator requirements confirms the preceding viewpoint. *Table 2* shows the main operator requirements, and indicates the appropriateness of each positioning method to meet this requirement.

## Conclusion

Alcatel is actively preparing for the introduction of positioning services into its second- and third-generation networks. Based on meticulous analysis of the needs of users and operators, Alcatel is optimizing investment by carefully selecting the positioning technologies to be implemented, and by promoting these technologies within the standardization organizations. ■



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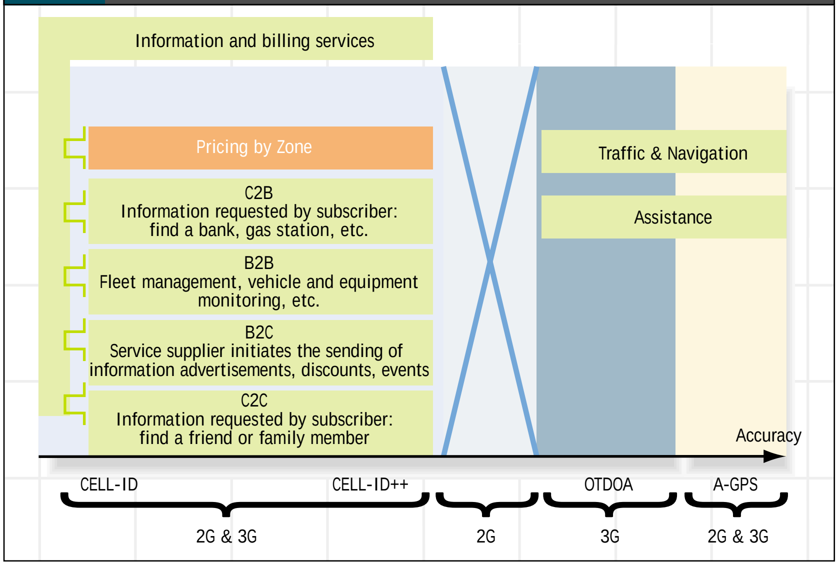
**Tab. 1 Choice of positioning methods**

| Positioning technology | | Accuracy | Terminal-based | | Network-based |
|---|---|---|---|---|---|
| CELL-ID | | from 300 m to 10 km | SIM Tool Kit | OR | IN (handset universal) |
| CELL-ID++ | NMR TA RTT | from 100 m to 500 m | SIM Tool Kit | OR | BSS/UTRAN (handset universal) |
| E-OTD | GSM | from 150 m to 500 m | Software | AND | Hardware |
| OTDOA | 3G | from 30 m | Software | AND | Hardware |
| A-GPS | | from 5 m | Hardware | AND | Hardware |

**NMR:** Network Measurement Results **TA:** Timing Advance

**Fig. 8 Services supported by different positioning technologies**




**Tab. 2 Operator needs in relation to positioning technologies**

| Operator positioning requirements | | Cell-ID | | Cell-ID++ | 2G | A-GPS | 3G | E-OTD | | OTDOA | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GSM and UMTS shared investment | 1 | Average | 1 | Medium | 3 | High | 3 | Low | 0 | Low | 0 |
| Ease of maintenance and operation | 3 | High | 3 | High | 3 | High | 3 | Low | 0 | Low | 0 |
| Supply of emergency services with limited investment in the mobile network | 0 | Low | 0 | Low | 3 | High | 3 | Low | 0 | Low | 0 |
| Coverage inside buildings: shopping centers, parking lots, high rise buildings | 3 | High | 3 | High | 0 | Low | 3 | Medium | 0 | Medium | 1 |
| Consumer market | 3 | High | 3 | High | 0 | L H | 3 | Low | 0 | High | 3 |
| Complete end-to-end control | 3 | High | 3 | High | 1 | Medium | 1 | High | 3 | High | 3 |
| No intellectual property copyright | 3 | High | 3 | High | 0 | Low | 0 | Medium | 1 | Medium | 1 |
| Differentiation / competitive advantage | 0 | Low | 1 | Medium | 3 | High | 3 | Medium | 1 | High | 3 |
| Mark | 16 | | 17 | | 13 | | 16 | 6 | | 11 | |