UMTS – Competing Navigation System and Supplemental Communication System to GNSS

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BIOGRAPHY

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ABSTRACT

The requirement in USA of providing an accuracy of 125 m for E-911 calls has driven the positioning function of mobile phones. This requirement can hardly be fulfilled without GPS. Usually, with GSM the position is determined with time difference techniques in base stations. The additional drawback is that the user has no direct access to his position (if at all). The new mobile communication standard UMTS foresees WCDMA as multiple access scheme. Therefore, similar position determination techniques as with satellite navigation systems can be applied and the mobile phone can locate itself. The first-glance conclusion is, that due to less disturbing environmental influences (ionosphere, troposphere) but eventually higher multipath delays similar accuracies can be achieved; at least by far enough to fulfill the E-911-requirement.

On the other side, nowadays existing mobile phones have yet integrated GPS modules and display the position graphically on digital maps. Thus, this technique will probably be a standard feature for mobiles when UMTS will start in a few years. The transmission of differential corrections is from the technical aspect via the GSM/UMTS network an easy task so that high accuracies can be provided with this approach. Such services are yet realized (e.g. SAPOS in Germany).

GSM/UMTS as well as radio services are highly suitable for providing differential corrections for automotive applications. Both will be the standard equipment of cars in the near future. Therefore, it is very astonishing why manufacturers of car navigation systems hardly apply differential techniques at the time being. The role of dGNSS seems to lose against map matching techniques. The question can be raised if it is worth it for the mobile users mass market, as e.g. tourists, automotive applications or just man-on-the-street, to integrate a second system with the possibility to apply differential corrections or if it's sufficient to use the UMTS positioning.

This paper tries to find an answer to this question and investigates the achievable performance of UMTS in respect to navigation, i.e. accuracy and availability are estimated. Applications are discussed and weighted against GNSS.

INTRODUCTION

A trend for mobile phones is to provide position information. Besides of many possible applications the main driver for this feature is the FCC rule for E911 calls to locate a caller. This rule sets also stringent accuracy requirements. In 5 years all mobile phones in the US must be equipped with this capability. This means huge market opportunities for involved companies. There seem to be two groups representing the two principle technologies: The first group consists of GPS HW producers, which prefer GPS based or handset-based systems, where a GPS receiver is included in the handset. The second one consists of wireless carriers-near and wireless communication industry companies who prefer network-based systems. A third group, which might also be counted to the second, are the network-assisted GPS techniques.

A further discussion was led by opponents of GALILEO in Germany. It was the question if it is worth it to invest in a new satellite system when GSM/UMTS can overtake the positioning.

According to FCC rulings, network-based location systems such as radio triangulation must be accurate to within 100 meters 67% of the time and within 300 meters 95% of the time. Handset-based systems like GPS face a tougher standard: They must be accurate within 50 meters 67 % of the time and 150 meters 95% of the time. In Sept.1999 the FCC decided that handset-based solutions must provide automatic location-identification features after the Phase 1 by October 1, 2001 at least 50%, by October 1, 2002, at least 95% and by 2004 all phones.

GSM

As UMTS evolves from GSM and both systems are predicted to exist in parallel for several years a brief description of GSM is given. GSM is a digital cellular communications standard in about 100 countries of the world with more than 150 million subscribers. In addition to digital transmission, GSM incorporates many advanced services and features, including ISDN compatibility and world wide roaming in other GSM networks.

The term "GSM" stands actually for the 900 MHz band, however it is in general also used for the derivatives in other frequency bands: DCS 1800 for the 1800 MHz band, PCS 1900 for the American "Personal Communications System 1900". The existing GSM network is using time-division multiple access (TDMA).

Figure 1 gives an overview of the GSM system architecture. The mobile stations are connected to the Base stations. The Base Station Controller (BSC) manages the radio resources for one or more BSs. It manages the radio interface channels (e.g. reservation and release of radio channels) as well as handovers. The central component of the Network Subsystem is the Mobile services Switching Center (MSC). The MSC is a digital ISDN switching center, which also administrates the network and provides functionality for e.g. registering and authentication. The operation subsystem comprises all important functions for the operation and maintenance of the GSM network.

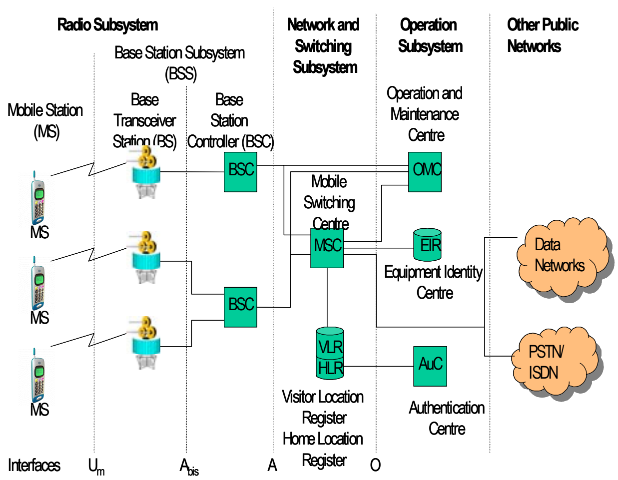


Figure 1: GSM Architecture

UMTS

The GSM standard as well as Digital European Cordless Telephone (DECT), and ERMES will be replaced by the UMTS standard in about 2003. This applies also to other mobile communication systems as e.g. TETRA.

UMTS is known as IMT-2000 in Japan, the US and ITU but the meaning is that IMT-2000 and UMTS will be merged later. In the USA, T1 (Standards Committee T1 Telecommunications) and TIA are the two standardization organizations of IMT-2000/UMTS.

For UMTS two major competing schemes have been studied and they are wide band-CDMA (W-CDMA), and time division-code division multiple access (TD-CDMA). W-CDMA is similar to standard CDMA except that it uses higher bandwidth on the transmission channel. TD-CDMA is a scheme that makes use of both TDMA and CDMA techniques. The European standardization organizations recently decided to use a hybrid scheme of both of these radio interface systems and they recommend the use of W-CDMA in the bigger, so called, paired portion of the radio spectrum and TD-CDMA in the unpaired portion.

INTERFACES

Air Interfaces

The following table shows the air interfaces of the GSM and UMTS system [6], [7].

Parameter	GSM (900)	UMTS
Frequency range [MHz] Uplink (MS to BS) Downlink (BS to MS)	 890…915 935…960	 1,920-1,940 2,110-2,130
RF channel separation	200 kHz	5, 10, 20 MHz
Duplex separation	FDD; 45 MHz Time 1.73 ms (3 time slots)	FDD; 190 MHz
TDMA Frame	8 Time slots per carrier; 1 time slot = 0.577ms	10 ms
Multiple Access Technique	FDMA/TDMA	WCDMA/ DS-CDMA (Codes similar to Gold Codes, modified Walsh-sequences; Spreading factor: 4…512) TDMA
Modulation Technique	GMSK	Uplink: O-QPSK Downlink: QPSK
Bit rate	270.833 kbit/s (33.8 kbit/s / time slot)	4.096; (options 8.192; 16.384 Mchip/s)
Pulse shape	Root Raised Cosine	Root Raised Cosine

Table 1: Comparison GSM/UMTS

External Interfaces

External interfaces are

- Public Switched Telephone Network (PSTN)
- Data Networks as e.g. packet-switched public data network (PSPDN) or circuit-switched public data network (CSPDN)

The Gateway MSC (GMSC) in general provides the access to a GSM network. The connection to other networks is performed by means of a Interworking Function (IWF), which is a physical interface to the MSC. Different interworking functions are used for different purposes such as packet data of fax traffic.

Interfaces to GNSS

GNSS Reference Stations: If corrections shall be provided GNSS Reference stations are required. They could be located at the MSC sites. Possibly, GNSS receivers will be used for time reference. These stations could then also provide the corrections.

The reference stations are connected to the GSM network via a data interface. The provided data is validated by the reference station itself (rather than by GSM network components).

MOBILE PHONE POSITIONING TECHNIQUES

Wireless network operators can use any of three solutions to provide the location information the FCC demands: radio triangulation; a network-driven GPS-based scheme; and a network-assisted or autonomous GPS method. Also hand set CDMA positioning is discussed.

Network based

The network-based triangulation method uses three or more receiving sites to monitor a call and compare signal strength, time of arrival, and distance or angle of arrival of a signal from a handset. These location techniques are independent of external systems. They are described briefly below.

1. Signal Strength

Applying a mathematical model for the relation between the distance and the signal strength the distance between the mobile station (MS) and base station (BS) can be estimated measuring the signal strength at the BS. The MS lies on a circle around the BS. With two BS, two interception points can be obtained. With a third BS the ambiguity can be solved instantaneously.

The drawbacks of this method are obvious: Fading due to multipath and shadowing cause variations of the signal strength up to 30…40 dB. Additionally, if power control techniques are applied, information about the RF output power has to be known with reasonable accuracy.

2. Angle of Arrival (AoA)

Using antenna arrays, the direction where the signal originates from can be determined. With at least two BS, an interception point of the two lines can be determined. The drawback of this method is that in case that there is no LOS between MS and BS the last reflection of the signal is used for the measurement. Under multipath conditions, which is in general the case the reflected signals interfere with the LOS signal.

3. Time of Arrival (ToA)

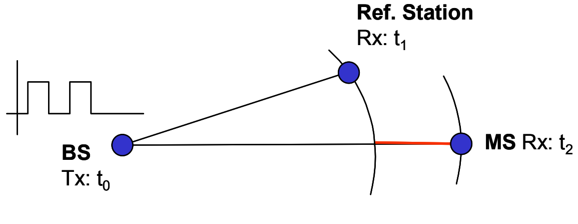
The ToA technique is based on the measurement of the time that a signal needs to travel from the BS to the MS. In 2 dimensions the distance of the MS from the BS lies on a circle. The interception of 2 circles results in two possible position solutions. Thus, in order to solve the ambiguity and to eliminate the clock error of the MS at least 3 BS are necessary. This technique is the same as used in general for GPS.

4. Time Difference of Arrival (TDoA)

TDoA is a hyperbolic position determination technique. Two BS measure the time difference of the arrival of the signal of a MS. The possible solutions where the time difference is constant lie on a hyperbola. In order to get an unambiguous position solution at least two hyperbolas, i.e. three BS are necessary. This technique is also used e.g. for LORAN-C.

5. Enhanced Observed Time Difference (E-OTD)

The signal sent by a BS is received by the MS and a reference measurement station with known coordinates. The time difference, and therefore the the distance, between the BS and the MS is then determined by correlating the two received signals. The distance still contains the clock error of the MS. Performing this operation three times for different BS solves the clock error and fixes the position of the MS (see figure 2). The necessary data exchange can be performed by means of SMS.



$$D_{BS\,MS} = D_{ref\,BS} + (t_2 - t_1)c$$

Figure 2: E-OTD

An example for realization of E-OTD is the CURSOR system of Cambridge Positioning Systems CPS.

The techniques above have in common that the accuracy depends on the number of measurements and on the geometry of the positions of the MS and BS. If the measurements are redundant least square techniques can be applied to get a better accuracy. On the other hand an unfavorable geometry degrades the accuracy. This is e.g. the case if two BS and the MS are in a line so that no intercept points can be calculated (using e.g. ToA technique two concentric circles are obtained or with AoA only one line can be calculated). This is often the case in rural areas along motorways.

Handset based without GNSS (CDMA positioning at the MS)

As UMTS is a CDMA system an idea could be to position in the same way as with GPS. However, self-positioning at the MS without GPS is difficult to achieve as will be explained in this paragraph.

The aim in a communication system is to retrieve the coded information, the content of the data stream, whereas with GPS the received signal shape is used for time measurement. The bit error rate in a communication system decreases with higher energy per bit. One method to get higher energy per bit is diversity reception. This means that direct and multipath delayed signals are received and despread separately and the output signal is combined optimally to increase the S/N. This concept is realized in a so-called Rake receiver. One of the usually 4 fingers in a Rake receiver, the roving finger, seeks out the next ray to be assigned as one of the three combining fingers. The PRN code could principally be the same as it is the case for multipath or a different one for each finger (further readings on Rake receivers see e.g. [11]). However, with this method, exact time information gets lost.

To add GPS-like channels is, of course, technically possible, however the advantage of using quasi only the existing communication-HW gets lost.

In the case of GSM the BS signal is usually received only from one BS and only for handovers from two base stations. With UMTS diversity *transmission* is possible, i.e. that the same signal is sent via different BS to the MS. This is applied e.g. for so-called soft handovers, where the cells can be changed without interruptions. The Rake receiver interprets this signal as a multipath signal, which is summed up together with the signal of the "old" BS. In order to get a position at the MS, three conditions must be fulfilled. First, the BS must be identifiable. This could be either achieved by different PRNs, the inclusion of an BS-ID in the channel or the assignment of an certain receiver channel when establishing the connection. A BS-ID has nevertheless to be transmitted in the latter approach. However, the DLL can easily lose lock. Second, the BS have to be synchronized exactly. GPS can help here but only to a certain extent. Otherwise a reference station is needed for E-OTD. Third, the MS needs exact position information of all received BS and, eventually reference stations. This might be achieved via SMS. From view of the network, diversity transmission reduces the system efficiency.

Without going further into detail, it is obvious that the expense is higher than a GPS handset solution and that there is an impact on the system design.

Hybrid

The network-driven GPS method places a minimal GPS front end in the handset and lets the wireless infrastructure equipment handle all the calculation and position determinations.

A realization of a hybrid system is e.g. SnapTrack where the wireless network sends an estimate of the location of the handset to a server. The server informs the handset, which GPS satellites are in its area, and the handset takes a "snapshot" of the GPS signal, calculates its distance from all satellites in view and sends this information back to the server. The server software performs complex error correction and calculates the caller's precise latitude, longitude and altitude. In the case of a 911 call, the server sends the information to the PSAP. For other location-based applications, the server can send the coordinates to a third-party service provider, a dispatcher or back to the handset. [16].

Handset based

With the fourth technology, based on a complete GPS subsystem in a handset, wireless carriers and handset vendors could place all location-determination functionality inside the phone, making virtually no changes in wireless infrastructure.

Critical technical issues integrating GPS into a cell phone are such as size, cost and power consumption. However, the latest silicon technologies and the improvement of GPS cores make it possible for GPS to share such resources as the CPU and memory already inside a cell phone.

Communication + DGNSS

Another aspect is the possibility to achieve high precision with differential GNSS. As there needs to be an additional network (of at least reference stations), this case is regarded separately in this paper.

There are national geodetic systems yet, as e.g., SAPOS GPPS (Satellite Positioning Service, Geodetic Precise Positioning Service) and SAPOS HEPS (Highly Precise Positioning Service) of surveying authorities in Germany, which use GSM for "near-online" DGPS yet. About 200 stations are planned to be put up in Germany. The data format used is RINEX.

AVAILABILITY

The term availability is used here as the possibility to receive signals sufficiently in number and performance in a geometric and geographic sense to use the intended service.

Availability of GSM/UMTS and GPS

UMTS will surely be available to a certain extent in buildings and many public underground places (e.g. metro) where positions can at least be determined roughly. GPS/GNSS on the other hand is available nearly everywhere where some degrees of free sky can be seen. This is an advantage especially in rural areas where maybe only to one UMTS base station a connection can be established. SnapTrack states that they can evaluate even the weak GPS signals tracked inside buildings.

Geographical Distribution

The GSM, UMTS/IMT-2000 standard is adopted in over 100 countries. Inside the countries especially in areas where the population density is high the GSM/UMTS service is highly available. However in some rural areas, aside from motorways no GSM/UMTS service is available. In some countries network operators are obliged to cover a certain percentage of the population.

ACCURACY

Handset based

The accuracy performance depends mainly on the location where the mobile station is used for a position determination. At locations where less than 4 navigation satellites are in line of sight, no position can be determined if no other supplementary means (e.g. INS, GSM/UMTS techniques) are used. This is the case e.g. inside buildings or inside a car, if the antenna is inside the car. In urban areas the usual multipath environment results from case to case in a position degradation of several 10 m. This is of course rather a general limitation of positioning systems than a problem of the combination with GSM/UMTS. However, the user might expect a good accuracy and availability, quasi independently of his location.

Hybrid

Where GPS is available the known accuracies of GPS apply.

Item	**Hand Set Based / GPS**	**Network Based/ Triangulation**
Accuracy	10 m with use of WAAS or DGPS sub-m; 3-dimensional positioning	10…20 m UMTS (tbc.; multipath + geometry! dependent on location and number of base stations) 100…300 m GSM 2-dimensional positioning
Availability	Global; E-911 where > 0 base station	> 2 base stations, i.e. mainly cities Indoor (to a certain extent)
Time to Position Fix	Up to several minutes; SnapTrack: 10…60 s (cold start)	5 s
Companies (no claim for completeness)	SnapTrack, SiRF, Trimble, Qualcomm	CPS (Cambridge Positioning System)
Privacy	high	Depends on service provider

Table 2: Comparison of performance parameters for GPS-based and network-based positioning solutions

Communication + dGNSS

Under good conditions (low DOP, low multipath) an accuracy of far better than 1 m can be reached because the distance to the reference stations can be kept very low (up to a few kilometers) and thus even tropospheric corrections could be used. The low distances are an advantage over other systems as e.g. RDS where the distance is up to, say, 100 km and LW/MW systems where the distance can be several hundreds of kilometers.

The achievable performance of SAPOS is for HEPS 0.01…0.05 m and for GPPS 0.01 m (note: to achieve these accuracies a measurement time of eventually several minutes and a baseline of less than e.g. 17 km is necessary).

It is the choice of the service provider (network or external provider) how dense the reference stations are located and thus how accurate the position can be determined (besides of multipath and visibility aspects).

Network based

The following table shows the 67% performance in [m] of the localization techniques described above.

	GSM	UMTS
TdoA/ E-OTD	90…160	5…20 (predicted by "CURSOR"; TBC!)
AoA	100…200	100…200
ToA	N/A	50…100

Table 3: GSM/UMTS localization performance

The performance given in Table 3 is according to statements of companies providing positioning services.

Reasons for worse position accuracy in comparison to GPS are

- Raised cosine -> slightly higher multipath
- Communication traffic on frequency (1. high number of users and 2. high data rate -> Higher noise
- Compensation of near / far effect
- Diversity reception which stands in contradiction to a cross correlation with single, pure signal as needed and used for GPS
- Often no direct visibility or not sufficient base stations
- Very low spreading gain: spreading factor: 4…512
- Walsh sequences might have negative effects to correlation
- short integration time of the correlation process due to high data rate

These disadvantages are compensated only to a certain degree by

- Higher signal levels due to less distance losses
- No ionosphere
- Low troposphere (depends on distance)
- Slightly lower noise of raised cosine signal in comparison to rectangular signal

Note: No vertical position is available by GSM/UMTS.

Some interesting figures can be obtained calculating the DLL-performance.

The path loss can be assessed by the PCS extension to the Hata Model as defined by the European Co-operative for Scientific and Technical research as

$$L_{50}(urban) = 46.3 + 33.9 \log f_c - 13.82 \log h_{te} - a(h_{re}) + (44.9 - 6.55 \log h_{te}) \log d + C_M \quad (1)$$

where

h_{re}	Receiver height over ground (e.g. 40 m)
h_{te}	Transmitter height over ground (e.g. 2 m)
C_M	0 dB for medium sized cities; 3 dB for city centers
f_c	Carrier frequency

$$a(h_{re}) = (1.1 \log f_c - 0.7) h_{re} - (1.56 \log f_c - 0.8) \quad (2a)$$

for small to medium cities and

$$a(h_{re}) = 3.2 (\log 11.75 h_{re})^2 - 4.97 \quad (2b)$$

for large cities

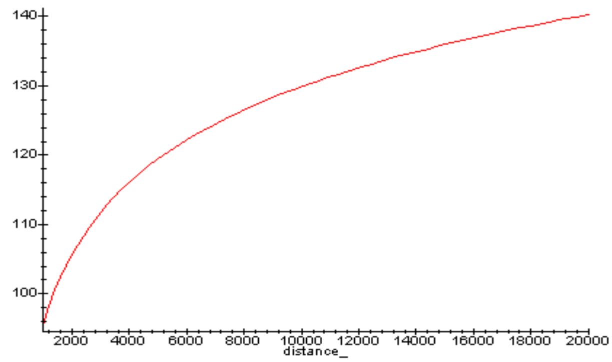


Figure 3: Propagation loss for urban areas (x-Axis: distance [m], y-Axis: Propagation loss [dB])

With the UMTS system parameters (chip rate f_c = 4.096 Mchip/s, output power P_{out} = 0.1 W, $N_0 = k_{Boltz} T_{eq}$, equivalent noise temperature T_{eq} about 700 K) E_b/N_0 can be calculated at a distance of about 4000 m to about 6 dB.

With

$$\sigma = \frac{T_c}{2} \sqrt{\frac{1 + 2 \, {}^{N_0}\!/\!_{E_b}}{m \, {}^{E_b}\!/\!_{N_0} - 1}}, \quad (3)$$

m = 4	Sampling rate
T_c = 73 m	Chip rate
E_b/N_0 = 6 dB	Energy per bit–to–noise ratio

the measurement noise results to σ = 11 m

This is however a theoretical value. As a rule-of-thumb for real systems the measurement noise can be estimated to $\sigma = T_c/4$ = 18 m.

Of course, further limiting factors of the system in respect to positioning are multipath and DOP. A typical delay of the indirect signal is 1 µs, which corresponds to 300 m and results in a multipath of up to 17 m (see [1] for details).

In contrary to GNSS signals, where the pure and unchanged signal is wanted the aim for communication systems is to synchronize and combine all multipath components in order to obtain a high Eb/N_0.

COSTS

Handset based

In this case there are only costs for additional hard- and software in the MS. These costs are purely costs for the user and no costs for the system operator (see table 4).

Network based

An investment of 25000…50000 US$ (CPS/CURSOR: "<10000 US$") per base station is necessary for the service provider (see table 4).

Item	Hand Set Based / GPS	Network Based/ Triangulation
Network Costs	None	Medium to low; depends on solution; Soft- and hardware
Handset costs	Add. 30…5 US$ for antenna and RF front end; Comm and Nav.-processor can be combined and memory included on-chip. Add. Power Consumption 150…50 mW (dep. on chips)	Software update
Current costs Infra-structure	None	Medium to low 25000…50000 US$ / base station (CPS: <10000 US$ per unit; 2000 units for UK) High communication traffic; Central Station calculates position
Current costs non-infra-structure	Battery lifetime lower; Runs autonomous	Billed by Service Provider

Table 4: Comparison of costs for GPS-based and network-based positioning solutions

Note: The table above does not account for all solutions.

Comm + dGNSS

In principle, there are two scenarios: The operator builds up his own reference station network. In this case he has on the one hand additional costs but on the other hand he can charge this service. It is his choice how dense this network shall be and how accurate the corrections can be. In the second scenario the GSM/UMTS network is used only as a data transmission medium and an external service provider provides the differential corrections (as in the case of RDS). Such a service is provided yet with e.g. "SAPOS" in Germany where differential corrections are provided by state authorities (Landesvermessungsamt) via GSM (with typical maximum baselines of 10…17 km to guarantee the accuracy; not provided in rural areas). In this case the GSM network operator has no additional costs (besides of the data traffic which he charges in the usual way).

APPLICATION FIELDS

Generally, UMTS is usable for terrestrial applications where the performance outlined above is sufficient. It should be kept in mind that a GPS handset solution gives the position without billing, if no other data or differential corrections are needed and no connection has to be established. Some communications / positioning applications are listed below and discussed briefly with respect to the need of GNSS.

- Emergency management: UMTS sufficient; GNSS would enhance the service in respect of availability and accuracy.
- Location sensitive billing. As road application: GNSS required if UMTS is not used as comm system.
- Fraud detection. GNSS required, regardless of comm system
- Fleet management. City region: UMTS sufficient; however GPS yet introduced and common. Wide area: GNSS required
- Intelligent transportation systems. GNSS required if UMTS is not used as comm system.
- Tourist guide. UMTS mostly sufficient; depends on special case.
- Geodetic applications. GNSS or dGNSS required
- Traffic telematics and information services. UMTS sufficient
- Leisure (Mountain climbing etc.). GNSS required.

In car applications, usually INS systems are supplemented by GPS. The role of GPS there is to initialize the position and to update the position. The exact position is determined by map matching rather than by GPS. At least on the German market no dGPS car navigation system is available. The reason for that is that INS+GPS+map matching is the minimum equipment and sufficient for car navigation. To increase accuracy with differential corrections is not worth the expense for producers; even not although the corrections are received by a built-in radio system providing GPS corrections (besides other information) as e.g. RDS. Thus, it can be expected that this application is no driver to apply differential corrections to GPS/UMTS positioning.

Of course, there are many highly important applications, which can only be fulfilled by GPS/GNSS without UMTS as e.g. spacecraft, aircraft, vessel navigation, GIS recording, Geodesy, so that the question is not if GPS/GNSS is replaced by UMTS but if UMTS is better suited for certain mass applications and if it is better to have a GPS module on-board the mobile for emergency calls.

CONCLUSION

UMTS and GPS/GNSS are – depending on the application – as well competing as supplementary systems. UMTS will certainly not reach the accuracy of GPS/GNSS where both systems are available with comparable quality. For reliable position determination, also outside of city centers and for 3-d position determination GPS is necessary.

The positioning capability with UMTS will be sufficient for E-911 requirements in urban areas. The accuracy of GNSS, however, will not be reached due to the low LOS visibility probability.

The great practical advantage of UMTS over GNSS positioning is that UMTS can be received in buildings and in bags. However there are GPS-solutions that also offer this capability.

It is supposed that in future both kind of mobiles will exist in parallel – with and without GPS module. For the E-911 ruling it will do without, both options can't guarantee position determination everywhere. A combination of both methods, GPS and network-based positioning would be the best solution in terms of availability and accuracy. The additional hardware costs are acceptable.

The benefits of use of UMTS in conjunction with GNSS

- The main application, i.e. combination of mobile communication and precise positioning with differential GNSS can be integrated in one small (mobile phone-) handset.
- Data exchange for positioning (both directions) would be very easy.
- High availability throughout the world (one standard).
- As a mass-market application the costs for the user would be low.
- Precision depending locally on the distance to next reference stations and globally on the geographical density of the reference stations (matter of provider).

ABBREVIATIONS

BS	Base Station
CPS	Cambridge Positioning Service
DS-CDMA	Direct Sequence Code Division Multiple Access
FDD	Frequency Division Duplicating
GMSK	Gaussian Minimum-Shift Keying
INS	Inertial Navigation System
MS	Mobile Station
MSC	Mobile Switching Center
O-QPSK	Offset Quadrature Phase Shift Keying
PSAP	Primary Public Safety Answering Point
PSTN	Public Switched Telephone Network
SMS	Short Messages Services
WCDMA	Wideband Code Division Multiple Access

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