

Assessment of Mobile Location Technology – Update

Final Report

July 2012

Ofcom

Mott MacDonald

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Content

Executive Summary

Mott MacDonald has conducted an updated review of mobile location technology options for emergency calls on behalf of Ofcom. It considers changes since an earlier report produced for Ofcom by Mott MacDonald in April 2010.

An increasing proportion of calls to the emergency services are received from mobile devices. Mobiles are often used indoors in preference to fixed lines, but unlike fixed lines there is no consistent means of locating them. VoIP from fixed or mobile devices is an important related topic, though not a focus for this report.

Since our previous report was issued in 2010 the key developments have been:

More provision of location capabilities:

- Rapid growth in the market share of smartphones with effective location capabilities. This is approaching 50% and looks set to continue beyond this;
- Additionally, many feature phones now include location functions;
- Increased integration of satellite navigation capabilities into standard mobile phone chips makes positioning a default feature in many cases.

Improved location capabilities:

- Increased use of multiple satellite navigation constellations provides better accuracy and availability;
- Maturing provision of WiFi positioning by major players such as Apple and Google as well as specialist providers complements satellite for indoor and urban use;
- More sophisticated hybrid positioning using a variety of methods helps to overcome environmental constraints.

Increased demand from Emergency Agencies (EAs):

- With ever increasing numbers of calls from mobiles, and greater awareness of location capabilities, EA demand for mobile location information has increased;
- A number of providers have developed emergency location 'Apps' which provide basic emergency location functionality.

Developments since 2010 give the average user significantly improved location capabilities in a wider range of environments. Maximum accuracies have not changed greatly, but the time to fix is improved, as is availability. The trend for improved positioning is likely to continue; particularly as location based services are now strongly embedded in many aspects of online commerce. Supporting techniques are also likely to improve as pattern matching databases become more sophisticated and refined through crowd sourcing and other methods.

Networks provide positioning, enhance handset positioning and communicate resulting location information to the emergency agencies. Network progress to date is now largely encapsulated in the LTE standards. The LTE Positioning Protocol (LPP) supports a number of positioning methods which can be used as primary or fallback methods such as assisted satellite positioning (A-GNSS), Uplink and Downlink Time Difference of Arrival and Enhanced Cell ID. LTE therefore provides opportunities for comprehensive location and secure, reliable forwarding of positioning information to the emergency services. The extent and rate of LTE implementation does however depend on the operators.

The report presents three possible scenarios as a basis for progress. Scenarios 2 and 3 represent an evolution of the current situation into an LTE framework. Scenario 2 is the 'standard' approach while Scenario 3 makes provision for what should be a diminishing number of legacy handsets. Both these scenarios are medium to long term and this leaves a period of a number of years before these approaches are available to a majority of users.

To provide coverage during this time gap, Scenario 1 presents an 'App' based approach which takes advantage of existing capabilities on a best efforts basis. Early trials of this approach by BT have demonstrates its benefits. It should be noted that some handsets were found to be incompatible with this approach because their location capabilities switch off during emergency calls to conserve battery power. Changes to this type of implementation would be needed to ensure that location is available if it does not threaten the voice call.

1. Introduction

1.1 Background and rationale

With traditional fixed line telephone systems, it is relatively simple for the call handler to locate an emergency caller because the location of the phone within a building or call box is held in a database. This location information provides valuable and potentially time saving information to the emergency services answering the call.

In recent years, a growing number of emergency calls are made from mobile phones and from VoIP systems. In both cases the location of the caller may be unavailable to the call handler and hence to the emergency services unless the caller can provide this information verbally. This means that the number of callers with unknown location is set to increase significantly, making the task of the emergency services ever more difficult.

This situation may come as something of a surprise to many users of modern phones whose devices can determine their position to within a few tens of metres and regularly use this information to support a whole range of location based services. Pew Internet and American Life established that 7% of Americans who go online with their mobile device use location based services.[1]

Against this background, Mott MacDonald undertook a review of options for the location of emergency callers for Ofcom in 2010. In the two years since, location technologies have advanced and become ever more embedded as part of the mobile business model. The market penetration of location capable devices has also increased significantly. As a result, Ofcom have requested Mott MacDonald to update the earlier work to define the current state of the technologies and their uptake.

The review considers the range of technologies available to locate a device under a range of circumstances and also the means by which this information can be conveyed reliably to the emergency service users.

1.2 Requirements

Emergency call handlers need location information for a number of reasons:

[1] http://www.pewinternet.org/Reports/2010/Location-based-services.aspx

- Accurate location information is needed to determine the nearest emergency responder (e.g. police officer, ambulance or fire appliance), as it is usually the one closest to the incident, that will respond to the emergency.
- Better accuracy is needed, in the case of high density areas, to determine the location of the incident and consequently the best route to reach the emergency.
- Very good accuracy of caller location information is needed to determine if multiple mobile calls refer the same incident.[2]

An indication of the location information needed for locating the terminal via service provider or network facilities based on current standards is given in Table 1.1.

Table 1.1: Indicative location accuracies needed by emergency services

Condition	Rural	Highway	Suburban	Urban	Indoor
Caller provides location information	50m to 100m	20m to 100m	30m to 100m	10m to 50m	10m to 50m
Caller provides no information	10m to 100m	10m to 100m	10m to 100m	10m to 50m	10m to 50m

Source: ETSI TS 102 650 v.1.1.1

1.3 Scope

The process of providing location information for a mobile device for use by the emergency services involves a number of elements which define the scope of this document. In summary these are:

- **The Mobile User Equipment** – In many cases this is the phone handset although other possibilities include tablets or laptop computers. The emphasis in this report is on 'standard' mobile communications rather than VoIP, though there is convergence as VoIP is increasingly used over mobile networks. The User Equipment may contain a range of facilities which support positioning such as GPS and WiFi receivers.
- **The Network** – This element serves three functions, communicating the location information from the user equipment to the emergency call handler, providing various network based positioning techniques

[2] ECC Report 143: Practical Improvements In Handling 112 Emergency Calls: Caller Location Information, Lisbon, April 2010

and also providing assistance data to the user equipment. An additional element associated with the network is the use of small cells such as WiFi and Femtocells, which can also be used to support positioning.

- **Positioning Methods** – a range of methods are available which use the facilities provided by both the user equipment and the network. The number of techniques available is increasing and the improved intelligence levels of network systems support one or more fallback methods. The method used will be matched to best suit the user's and thus the handheld device's environment. An important element of many methods is the use of databases which associate identifiable elements such as base station towers, or WiFi access point with a location. Some of these relationships are more ephemeral, for example owners often move or switch off WiFi access points and hence the update procedures applied become crucial.
- **Emergency Call Handling Systems** – The main components of the emergency system are the call handler who deals directly with the emergency caller and the emergency agency who acts on the call. The relationships between these parties are currently well established, but it is possible that changes to the information flows and changes in technology support changes in these relationships if for example costs can be reduced or a better service can be provided. In this report we explore some of these options.

1.4 Structure

Given these elements, the structure applied to this report is as follows:

- Overview and options – a summary of the findings of later sections is presented in the form of possible scenarios. These are presented as variations of the basic pathways from the mobile user equipment to the Emergency Agency and where additional investment is needed to make the approach work, this is identified.
- Positioning methods – given the convergence of handset and network methods, the basic approaches and hybridisation options are considered together.
- User Equipment – specific technologies within mobile devices and the rate at which these are becoming adopted by users.
- Networks – advances in the networks related to positioning functions, progressing from 2G through 3G to the development of LTE.

- Industry context – a short overview of the LBS industry which, together with emergency needs, drives the development of positioning in the mobile sector. This includes coverage of the database holdings provided by industry in support of LBS and the organisational structures applied.
- Emergency Services – an update on the current status of the emergency services call handling processes and an updated review of user requirements based on interviews.
- Regulations and standards – examination of the status of regulation and standards affecting the UK, including a review of US and European developments likely to impact the UK position.

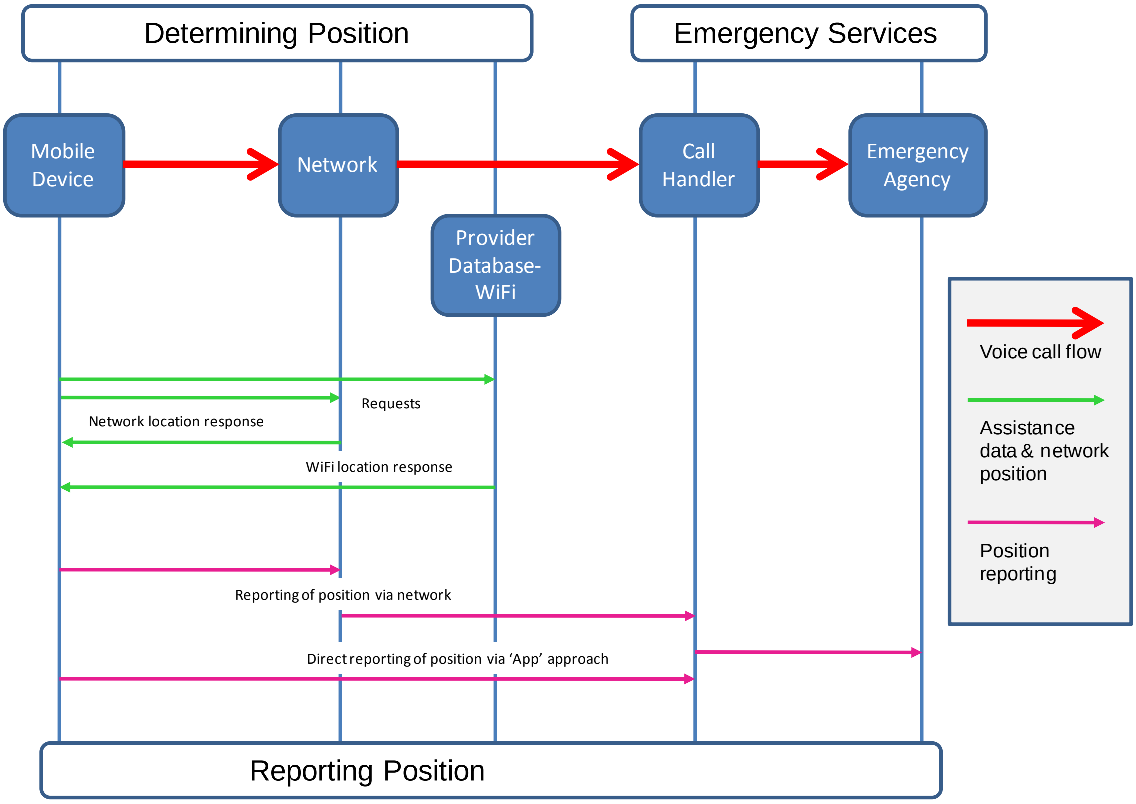
2. Overview and options

This chapter provides an overview of possible ways forward for locating mobile emergency calls, taking account of the more detailed analysis provided in later chapters. The aim is to provide a high level view which identifies the additional resources needed for each implementation.

2.1 Elements of emergency location

The main elements of the provision of mobile emergency location are illustrated in Figure 2.1. In overview, the mobile device and / or its supporting network determine the device's location. This information is then reported through the mobile network to the Emergency Services. In the UK, these are represented initially by the Call Handler who then passes the information to the Emergency Agency who will attend the incident.

Figure 2.1: Overview of elements involved in providing, reporting and using emergency location information



Source: Mott MacDonald

Mobile device: The mobile device, also referred to as the user equipment or handset, is assumed to represent the location of the emergency caller and hence its position can help locate the emergency.

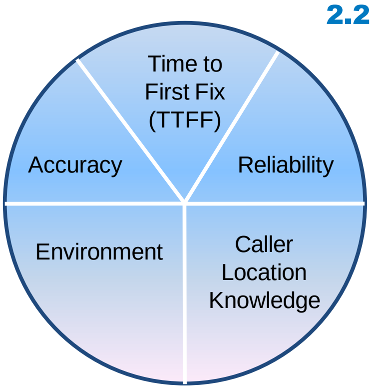
Many mobile devices can calculate their location independently, mainly by using Global Navigation Satellite Systems (GNSS) such as the Global Positioning System (GPS). This can be done with or without assistance from the network, though assistance can speed up the process. In addition, some devices can calculate or receive their location using information from within the mobile network.

Network: The mobile network serves three functions in support of mobile location. Firstly it can be used to provide assistance data to improve the speed and accuracy of positioning within the mobile device. Secondly, measurements from within the network can be used to locate the device. Thirdly, the network communicates the location information about the device from where it is calculated, whether in the mobile device or in network, to the user of the information. This may be the mobile device itself, a location based service provider or in this case, the emergency call handler.

Provider database: An important function which may be provided either by specialist companies or by major providers such as Apple and Google is a database which correlates variables measurable by the mobile device such as WiFi IDs and other RF properties with specific locations. If well maintained, this provides a valuable complement to other location methods. Mobile Network Operators (MNOs) also have a database mapping cell-ID onto locations.

Call handler: The role of the call handler is to take the emergency call, to obtain and synthesise all the necessary information both verbal and digital and then to pass this to the Emergency Agency's (EA) control room. This function, which in the UK is most commonly provided by BT and Cable & Wireless, includes provision of a database which the EA can query.

Emergency Agency: The EA control room, on receipt of the request from the call handler, will make the necessary dispatches and support them as they attempt to locate the incident.



2.2 Location assessment criteria

Key criteria for the assessment of emergency location information are given in the adjacent diagram. The upper part of the circle shows the basic criteria of position accuracy, the time taken to provide this (TTFF) and the reliability with which this can be done.

The lower half of the circle shows the controlling variable of environment and corresponding to this is the likelihood of the caller knowing their location in different environments. The environmental influence ranges from rural where generally satellite visibility is typically good, cell density limited and WiFi widely spaced, through to urban where satellite visibility is likely to be poor but cell and WiFi density much higher. The other environmental factor is whether the caller is indoors. In this case, the positional accuracy is likely to be less good since satellite signal visibility is very poor, though the likelihood that the caller can state their location verbally is much greater.

Accuracy and reliability are inversely related and so generally specified together as illustrated by the FCC 911 location requirements. These state that handset and network positioning respectively requires 50m / 100m accuracy at 67% reliability but lower 150m / 300m accuracy at a higher 90% reliability.

The measures applied by FCC are statistical and there has been discussion on the size of the area over which it is measured. It is anticipated that the size of the area over which carriers can measure the location accuracy will be shrunk to the size of a county. This will stop carriers averaging out and hence hiding really poor accuracies amongst measurements of greater accuracy. This measure is planned to become mandatory in 2018.

2.3 Scenarios

Table 2.1 provides an overview of three possible scenarios for the provision of emergency location information. The scenarios represent increasing levels of sophistication and also increasing dependence on future developments in mobile network, particularly LTE.

Table 2.1: Overview of scenarios

Scenario name	Positioning method(s) used	Mobile device functions	Network functions	Communication to call handler
1. Handset positioning sent by SMS	• Standalone GNSS • Assisted GNSS • WiFi	• (A-)GNSS location calculation • WiFi identification and database requests • Formatting of location information (via App)	• Cell ID and possible network enhancements • WiFi database checks • GNSS assistance (incl reference GNSS receivers)	• Via SMS from the mobile device • Cell ID provided directly to Call Handler for comparison.
2. Managed fallback position coordinated and sent via network	• Assisted GNSS • WiFi • OTDOA • Cell ID	• (A-)GNSS location • OTDOA calculations • WiFi identification and database requests	• GNSS assistance (incl reference GNSS receivers) • WiFi database checks • OTDOA information • Cell ID with enhancements • Synthesis and formatting of location information	• Call Handler performs lookup on MNO Mobile Location Server
3. Managed fallback position coordinated and sent via network with UTDOA	• Assisted GNSS • WiFi • U-TDOA • Cell ID	• (A-)GNSS location • WiFi identification and database requests	• GNSS assistance (incl reference GNSS receivers) • WiFi database checks • UTDOA calculations (LMUs included in network) • Cell ID with enhancements • Synthesis and formatting of location information	• Call Handler performs lookup on MNO Mobile Location Server

2.4 Scenario 1: Handset position and SMS communication

2.4.1 Overview

Simple mechanism which will take the best available location information from the mobile device and transmit it to the call handler in the form of an SMS

The logic for scenario 1 is to provide a simple mechanism which will take the best available location information from the mobile device and transmit it to the call handler in the form of a SMS message. In essence, this approach is based on that already used for the BT emergency location trial 'App'.

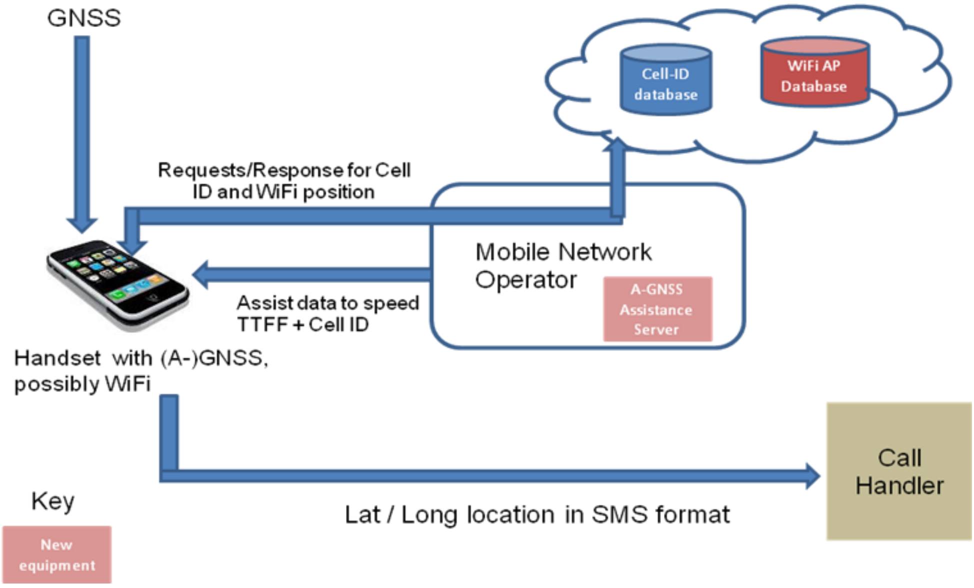
The first step for this scenario is to provide an application on the mobile device / handset which will acquire the best possible location that can be provided. If GNSS or WiFi are available on the device, these are then used to provide an improved location estimate if this is possible within a prescribed time limit. Where GNSS assistance is available and supported by the handset this would be used to optimise the TTFF. Repeated updates to the call handler either at set time intervals or when improved location information is available would be a useful additional feature. This can be compared with the cell-ID location currently available for validation, eg in cases where the mobile device may have been moved.

The provision of an assistance server is shown in Figure 2-2 as an additional item of new equipment. These may not be new equipment if the network has already been offering assistance of this type, though contacts with MNOs have suggested that GNSS assistance is available at least as a billable service. The A-GNSS server is based on the provision of a reference GNSS receiver at base stations which can provide up to date ephemeris information and combine pseudoranges from the mobile device with its own information to give rapid and precise location information back to the mobile device.

When the time limit is reached, the application on the mobile device collates the location data, formats it into a lat / long structure along with an error estimate and forwards it in SMS text format directly to the call handler. It is possible that if improved location information can be provided after a brief time interval, an update SMS could also be sent.

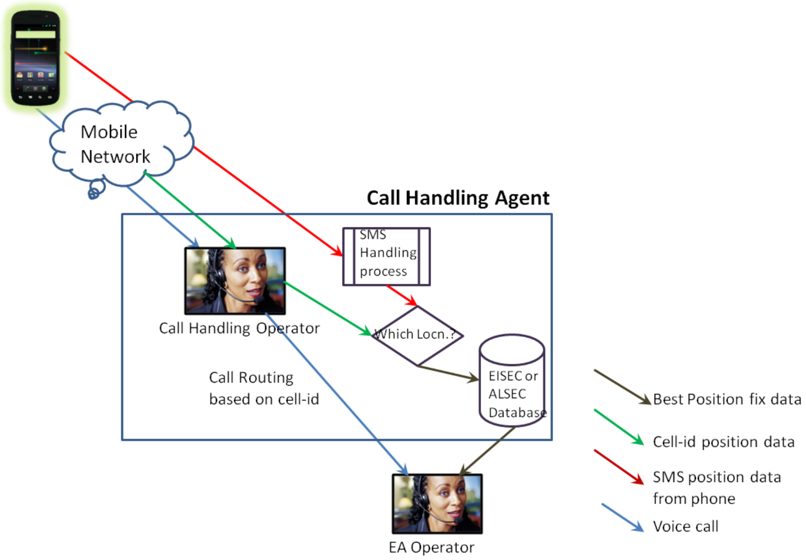
Figure 2-2 provides an overview of the handset determination of its location in this scenario and Figure 2-3 illustrates a high level description of the message flows to the Emergency Authority.

Figure 2-2: Scenario 1: Handset position and SMS communication



Source: MM

Figure 2-3: Message flows to Emergency Authority



Source – MM based on interviews

2.4.2 Discussion

It is likely that rapid implementation timescales would be possible as BT already have SMS servers deployed and delivery to the EAs would be via the existing mechanisms. Some amendments to the call handler systems are needed and while BT has indicated a willingness to support this, Cable and Wireless's position is not known. BT suggested that the improvements could be funded by a small increase in the per call charge they levy on the MNOs for handling their Emergency Calls rather than requiring capital funding. BT also stated that they could provide the SMS location message handling for all mobile calls regardless of MNO, as they do for the existing Emergency SMS service, and pass information to Cable and Wireless as necessary.

Five versions of the App would be required to cater for the five main operating systems – Windows, iOS, Android, Symbian and Blackberry OS. It is estimated that building each 'industrial strength' App would cost in the region of £30,000 per operating system.

Some difficulties with handset behaviours were encountered in the BT trial where handsets were designed to shut down all but the voice call functionality. This appeared to be by design to save battery power for the emergency call and could thus provide a technical barrier to deployment. Changes to handset with this approach would be required to avoid the undesirable behaviours found in the BT trial and the costs for this are difficult to estimate. Nevertheless, this is a generic problem and a behaviour which allows the GNSS to function except when the battery levels are very low and threaten the voice link would be preferable for all scenarios.

A disadvantage of the solution in its current form is that it is unlikely to improve accuracy of location available for roaming handsets, though this could be overcome in later versions. A further disadvantage of this solution is that it is not based on any recognised standards and so a clear specification would be required in advance of implementation by different parties and to ensure future handsets and other devices can be catered for.

We would note that for this solution, the network operators are only handling the messages as part of their network traffic and do not have control of the originating or destination points for the messages. As the General Conditions (and General Condition 4 in particular) generally apply to Communication Providers, any compulsion to adopt such a mechanism would present challenges.

In summary this could prove a useful short term route to provide enhanced accuracy of position information for about 2/3rds of calls from capable mobile handsets to the Emergency Services, subject to resolution of the technical obstacles. It does not provide a robust universal solution and in particular is unlikely to improve the situation for roaming handsets.

It may also be difficult to fund the deployment as none of the parties involved can be compelled to deliver improvements.

Table 2.2: Scenario 1 benefits and disadvantages

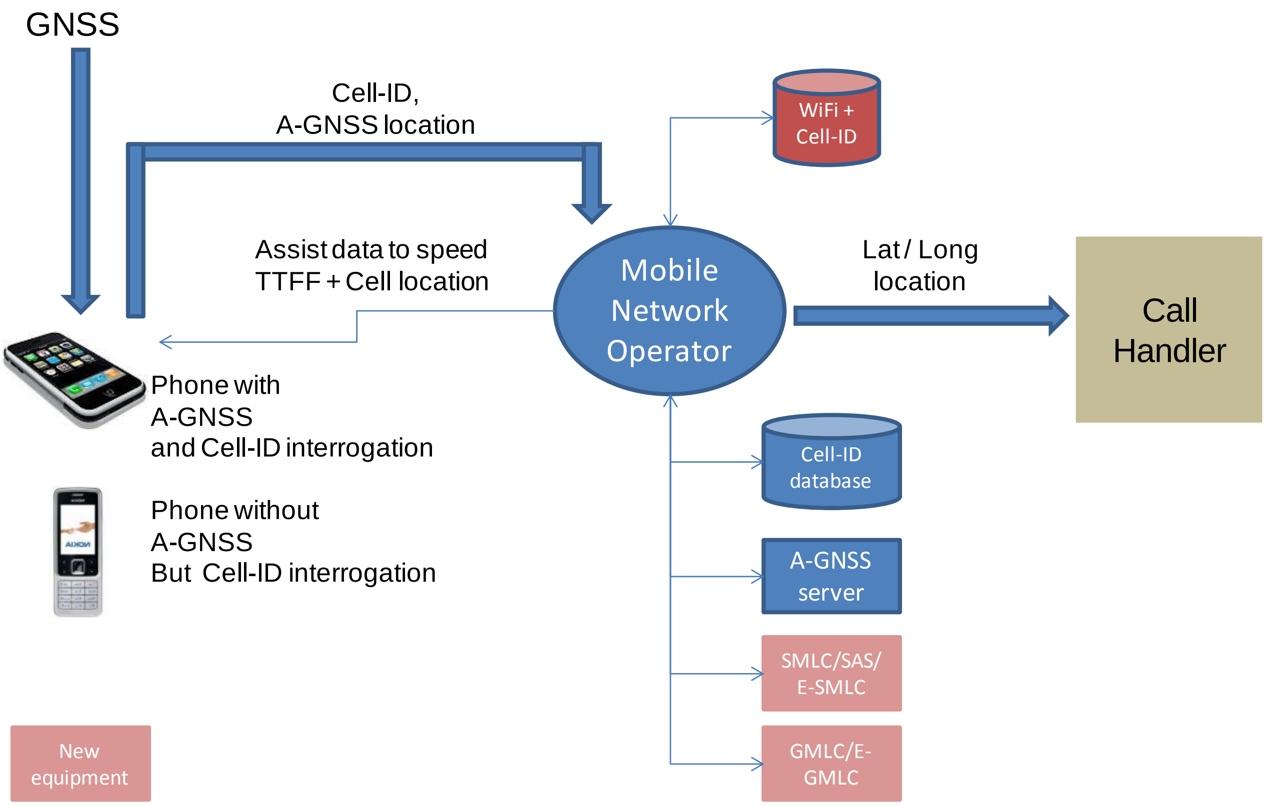
Benefits	Disadvantages
Simple to develop and can be launched rapidly	Not all mobile devices supported: Handset must support GNSS or be able to acquire a network position that can be input to the SMS
Potentially up to 10m accuracy depending on the capabilities of the mobile device and its environment	Multiple instances required to support different operating systems (Android, iPhone, RIM, Symbian, Windows)
Supports a growing percentage of users as handset capabilities improve with churn. Takes advantage of already deployed positioning methods	Improved location was available on 65% of occasions during a trial but use of SMS is not the most reliable and secure means of communicating the information.

2.5 Scenario 2: Combined position and network communication

Fallback positioning approach with location information communicated directly from the MNO to the call handler

Scenario 2 provides for a managed fallback positioning approach with location information communicated directly from the MNO to the call handler. The hierarchy of positioning methods would be A-GNSS followed by WiFi / RF pattern matching, downlink OTDOA and with cell id as a final fallback. An illustration of the scenario is given in Figure 2-4.

Figure 2-4: Scenario 2: Managed Fallback to network based methods



Source: MM

Additional equipment would be needed to support network based measurement in cases where this provision is not already in place, particularly for TDOA, and also to provide GNSS assistance. WiFi positioning is also included as an option if needed, though this would be on a 'best efforts' basis, taking advantage of facilities already provided for LBS use.

In this case, position determination is managed by the MNO. The user equipment will provide GNSS based location estimates and if the error bounds show a good result, this information will be used. If not, estimates based on the WiFi, TDOA and finally cell ID will be used instead. This information will be provided by the MNO to the call handler, ideally using the control plane.

With the assimilation of the location information within the network, the provision of additional elements of equipment to support this and the use of more secure and reliable communications channels, this becomes a more developed and sophisticated approach than scenario 1. Many of the functions it requires are already available, though its full potential will be reached through implementation of the emerging LTE standards.

Table 2.3: Scenario 2 benefits and disadvantages

Benefits	Disadvantages
All handsets supported	Limited accuracy for handsets with no GNSS
Development and management Application not necessary on phone	Additional equipment required in core to provide GNSS assistance and TDOA if not in place at present
Reliable and secure information flow from MNO to the call handler	Some changes needed to ensure that the secure and reliable information transfer is provided for (ie control plane transmission)
10 -250 m accuracy Optimised use of the best position available	Some aspects of position (eg WiFi location) are used on an opportunistic basis
Use of both handset and network based position options gives greater resilience	
Supports 100% of users in some form	

Scenario 2 represents a logical extension of the currently evolving situation which can be fully developed based on emerging LTE standards. Although it may require additional investment in some cases, many of these developments are likely to be provided in any case to ensure the continued progress of LBS applications.

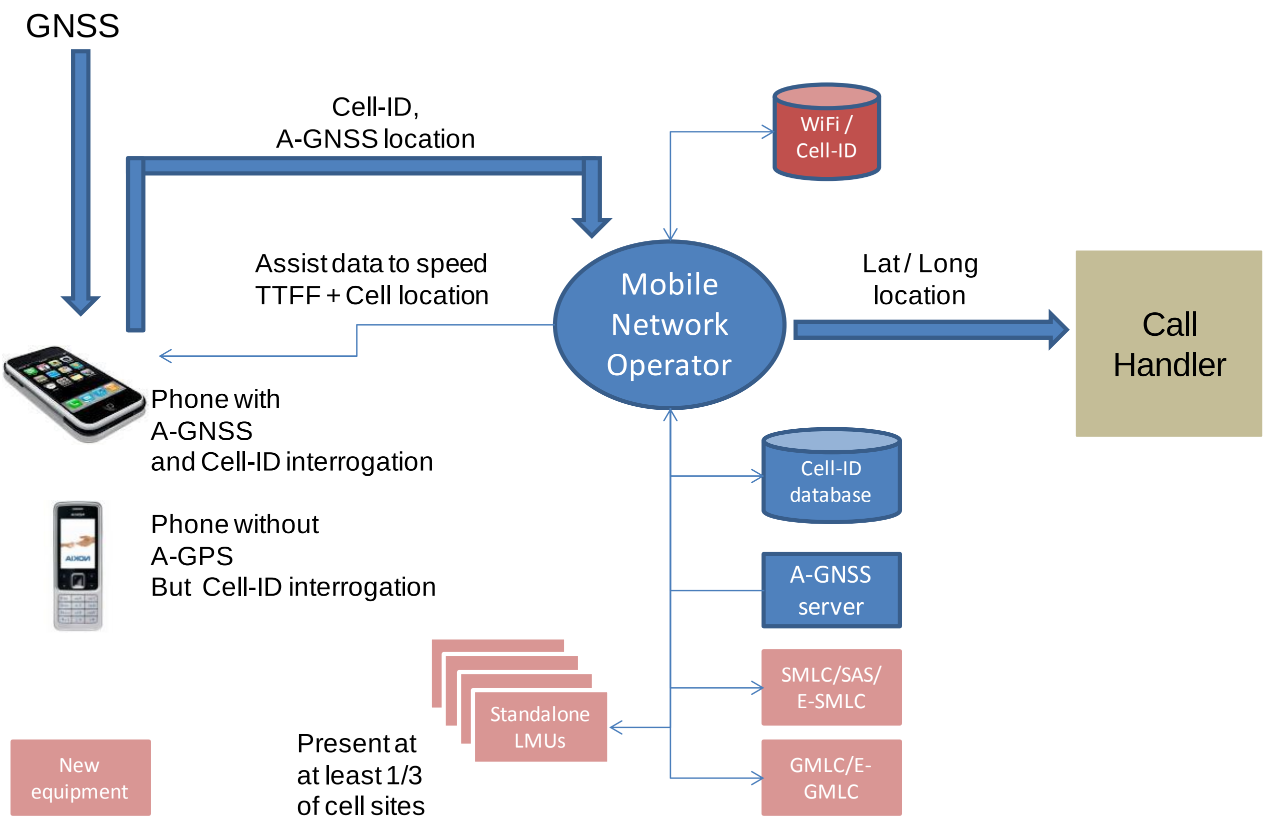
2.6 Scenario 3: Combined approach with legacy handset provision

Similar to scenario 2, adds location for non GNSS equipped handsets

Scenario 3 is similar to scenario 2, but additional provision is made to improve the location of non GNSS equipped handsets. To do this at significantly better accuracy levels requires uplink TDOA which in turn requires Location Measuring Units (LMUs) deployed in the Radio

Access Network at a minimum of one third of sites. This has significant cost implications though for LTE it is possible to obtain integrated LMUs. The approach is illustrated in Figure 2-5.

Figure 2-5: Managed Fallback Plus UTDOA



Source: MM

This scenario is the most comprehensive because it provides the best all round location capabilities for all handset types. Nevertheless, there is a trade off to be made between the cost of adding the LMUs on the one hand and providing techniques for urban canyons, indoors and for legacy handsets. In particular, if as is likely for cost reasons, this approach were to be deployed only as part of the LTE rollout, it is highly likely that the advantage of UTDOA would only be applicable to a small proportion of handsets. In addition, since the UTDOA technique has constraints under non line of sight conditions[3], it is not possible to argue that it complements GNSS for indoor use as WiFi positioning does.

[3] Eg - http://norbertnimm.wordpress.com/2010/10/01/potential-use-of-wireless-location-

Table 2.4: Scenario 3: Benefits and disadvantages

Benefits	Disadvantages
All handsets supported, including better accuracy for non GNSS units	Substantial investment needed to provide additional equipment in RAN May be overtaken by events if rate of GNSS handset penetration continues to grow
Development & Management Application not necessary on phone	Maybe expensive if standalone LMUs are required. This is likely if deployment does not wait for full LTE rollouts
10-300 m accuracy	
Tried and tested to FCC standards	
Supports 100% of users at FCC compliant levels	Reliable 67%

2.7 Comparison of Options

Table 2.5 provides an overview of the 3 scenarios in comparison.

Table 2.5: Overview of scenarios

	Scenario 1: Handset positioning sent by SMS	Scenario 2: Managed fallback position coordinated and sent via network	Scenario 3: Managed fallback position coordinated and sent via network with UTDOA
Position determination management	Handset	Network	Network
Handset Changes Required?	Handset and OS dependent implementation	No	No
Network changes required?	Does not require changes in Network	Yes – core only	Yes - RAN
Call Handler changes required?	Yes	No	No
Technically feasibility	Yes	Yes	Yes
Time Frame	Implementation time frame possibly <1 year	Progressive with full capability at LTE rollout	LMU implementation unlikely before LTE to avoid needing standalone units
Accuracy	Expected to be within 32m but depends on conditions for GNSS	Fallback approach optimises accuracy for a range of environments	Fallback approach optimises accuracy for a range of environments
Reliability	65%		
Based on published standard	No	Yes	Yes
Roamers	No	Potentially, depending on use of SUPL; or use of control plane solution for both roamer's home and UK networks	

technologies-by-law-enforcement-agencies/

In terms of timescales, Table 2.6 provides an overview of the available scenarios in the near term, by 2015 and Table 2.7 provides an overview of possible longer term scenarios.

Roamers can be supported in two ways:

- Using SUPL and a GPS enabled handset the roaming user can ascertain their position and this may be forwarded to the emergency services. The user needs a smart phone and a data bearer subscription which has credit;
- Using control plane the user's home network is interrogated as part of the process, it requires that both networks, home and visited, have implemented the control plane solution.

Table 2.6 -Near term scenarios (2015)

Scenarios	Position determination	Conveyed over	Geographic terrains covered	Estimated Handsets supported	Accuracy
Network Based (current position)	Cell ID	MNO to CH	All	100%	500m-20km
Handset based (Scenario 1)	GPS (no assistance))	Handset App to CH	Rural/Remote	65%	10-100m
Server Assisted (Scenario 1)	A-GPS + WiFi & MNO Cell-ID	Handset App to CH	All	65%	10m-500m

In Table 2.7, although the App based methods are mentioned, it is expected that these will start to phase out as the default becomes the Scenario 2 or 3 network based approach.

Table 2.7- Long term scenarios (2020)

Scenarios	Position determination	Conveyed over	Geographic terrains covered	Estimated Handsets supported	Accuracy
Network Based (Scenario 2 or3)	ECID and (RF pattern matching or UTDOA)	MNO to CH	All	100%	50m-100m
Handset based (Scenario 1)	GNSS (with or without assistance))	Handset App to CH	Rural/Remote	98%	10m-100m
Server Assisted (Scenario 1)	A-GPS + WiFi & MNO Cell-ID	Handset App to CH	All	98%	10m-500m

3. Positioning technologies

This chapter reviews techniques available for determining user location whether based in the user equipment, the network or a combination of the two. In addition to the individual methods, means to combine or select the most appropriate location information in a given situation are also considered.

Specific requirements and market takeup are covered in the next chapter on user equipment while the techniques for forwarding the location information from the user to the emergency services are covered in chapter 5. Chapter 6 covers industry perspective and includes coverage of the databases linking WiFi and other measurable signals with location.

3.1 GNSS Satellite Positioning

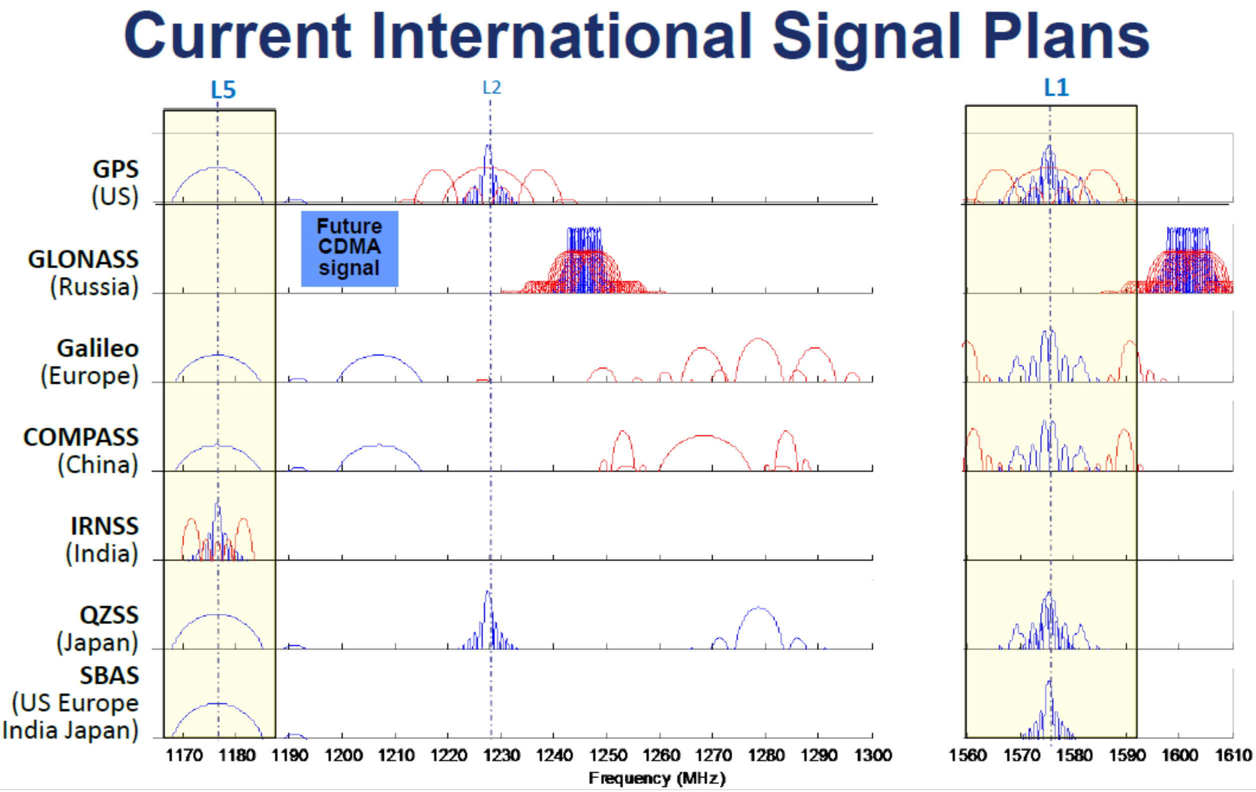
Global Navigation Satellite System (GNSS) is a generic term for satellite based positioning systems including GPS (Global Positioning System), GLONASS and the emerging European Galileo system. Satellite systems which operate in a similar way but with regionally specific orbits may also be included under this heading. The Japanese QZSS is the only example of such a system at present.

GNSS provide the most accurate positioning provided the user equipment has adequate visibility of three or more satellites. GNSS satellites transmit time signals with associated almanac, ephemeris and system health information. A receiver in a mobile device which can receive three or more satellite signals can use the time signals to range the satellites and thus determine its own location with no assistance from any terrestrial network. In this way, a device equipped with a suitable chip can pinpoint its location normally within 10m and almost always within 100m of the correct position. When a terminal equipped with a GNSS receiver calculates its own position without assistance from a non GNSS source, then this is defined as autonomous GNSS / GPS.

3.1.1 Overview and status

Global Navigation Satellite Systems (GNSS) continue to develop to provide a more comprehensive and reliable service within the physical constraints defined by signal strength and visibility. There are now four global systems in place or under development and an additional regional system designed to cover Japan and surrounding regions. This is important because the systems are generally interoperable and so as handsets start to use multiple constellations, a more accurate position can be obtained more rapidly in more difficult environments. In addition, most systems plan to offer a second open access signal in addition to the current L1, hence providing greater freedom from ionospheric delay inaccuracies. The signals used by the four global, two regional and four augmentation systems are shown in the Figure 3.1 below. These are relevant because many Smartphones are already using signals from multiple constellations to improve visibility. As multiple frequencies are also used, atmospheric errors will be reduced.

Figure 3.1: Current international GNSS signal plans



Source: Eldredge 2010, GNSS Evolutionary Architecture Study (GEAS), CGSIC, FAA GNSS Group

In summary, the status of the key systems is as follows:

- **GPS** – 30 satellites active in orbit with transition underway to IIF and III series satellites. Higher power civilian L2C signal in test (9 satellites now) to be followed by L5 safety of life signal (started 2010) and the L1C signal (starting 2014) designed specifically for interoperability and urban environment use.
- **GLONASS** – 24 satellites now operational. Launches since 2011 provide CDMA signals, with full transition expected by 2020.
- **COMPASS** – 9 satellites in place, plans for 7 launches in 2012.

- **Galileo** – 2 'standard' satellites in orbit, 2 more in 2012, 18 by 2015 with a full constellation of 30 now expected 2019 or 2020. Galileo E5a signal equivalent to GPS L5.
- **QZSS** – 1 satellite in orbit, if approved, eventually 4 quasi zenith orbit and 3 geo satellites to cover Asian region centred on Japan.

Almost all Smartphones and a significant proportion of feature phones now have a GPS capability. It is now also evident that major chip manufacturers are now transitioning from single GPS only chips to multi system receivers. For example, Qualcomm, ST-Ericsson and Broadcom are all offering GPS and GLONASS chips in a standard fit while several Chinese companies such as Unicore have already developed chipsets for receivers incorporating Compass, GPS, GLONASS, and Galileo capabilities. Already many well known phones such as the iPhone and the Sony Ericsson Xperia use both GPS and GLONASS. In fact the first GLONASS capable phone was the MTS 945 produced by ZTE which used the Qualcomm Snapdragon MSM7x30 chipset. This is considered further in Section 4.

3.1.2 A-GNSS

Standalone handheld or surveying GNSS receivers have substantial antennas and power supplies which allow them to be used in relatively poor reception environments and without battery drain concerns. In the early days of GNSS use in mobile phones, there were significant problems with battery drain because of the processing needed to provide a position and also problems with the acquisition of signals using small and conflicted antennas in a phone enclosure. The result was a very long time needed to provide a first fix and a substantial use of battery resources.

A solution to this problem was to provide some initial guidance to the handset to give it a head start in locating the satellites and then to allow the handset to transmit the time stamped pseudo-ranges without time synchronisation to a network based A-GNSS server linked to a reference GNSS receiver. This server performed the intensive calculations and returned the result to the handset.

This approach is known as Assisted GPS, or more generally Assisted GNSS. Although the capabilities of handsets have improved in all respects, the demands made of them have also increased and so the provision of assistance is still a very helpful way of improving the performance of GNSS location. Most handsets which provide GNSS also provide for A-GNSS, though not all networks provide the service.

The Mobile network can assist the GNSS in the following ways:

- Reduce GNSS start-up and acquisition times since it can provide satellite ephemeris and other data much more quickly than the handset can acquire it from the GNSS signal.
- Increase GNSS sensitivity and reduce power consumption by performing calculations within the network using a reference receiver.

The main assistance parameters vary according to implementation, including the network type and whether assistance is conveyed using the control plane or the user plane (see Chapter 5). Nevertheless, those parameters that can potentially be deployed are summarised in Table 3.1.

Table 3.1: Example of Main GNSS Assistance Parameters

Assistance	Description
Reference time	Reference time to time stamp the assistance messages
Reference position	A rough estimate of the terminal position usually computed by the cellular network (eg via Cell ID)
GPS navigation model	Mainly ephemeris to speed up the satellite position computation
GPS almanac	Almanac of GPS constellation
GPS acquisition assistance	Mainly Doppler and code phase estimation
GPS ionospheric model	Parameters for estimate of ionospheric delay

Source: Zekavat and Buehrer, 2012,Handbook of Position Location, Theory, Practice and Advances

3.1.3 GNSS issues

GNSS is essentially an outdoor positioning service and must be supported by other means including network and WiFi positioning to provide indoor coverage.

The use of multiple constellations helps to overcome some of the basic limitations of GNSS which include a lack of satellite visibility in urban canyons and the effects of signal multipath. The effect is to provide higher accuracies and a faster time to fix as well as improved performance in hitherto marginal areas. Despite this, GNSS remains essentially an outdoor positioning service and must be supported by other means including network and WiFi positioning to provide more comprehensive indoor coverage.

In practice, there remain some key issues and developments with the use of GNSS positions as a basis for emergency location.

GPS is rarely used in continuous tracking mode for privacy reasons or more often because of excessive battery drain

- Time To First Fix (TTFF) – without assistance (see A-GPS), a receiver must locate its first satellite with outdated almanac and ephemeris information and then update this directly from the low data rate GPS signals to speed acquisition of the others. This can be a slow process taking over a minute and in some cases much longer.
- Though operating in L-Band, GPS signals are transmitted with comparatively low power from an altitude of about 20,000km and so their penetration of buildings is very limited.
- Even with additional constellations and stronger signals such as those on GPS III complementary, GNSS remains of limited value in indoor environments. In urban areas, under trees or other cases of limited sky visibility, the positional accuracy can be limited by multipath effects or visibility of only a small number of satellites.
- GPS is rarely used in continuous tracking mode for privacy reasons or more often because of excessive battery drain. This has a number of possible consequences:
  - Unless the phone is configured to switch the GNSS on automatically when an emergency call is made, the user will need to do this manually. This is not always easy for regular users without cutting the call off.
  - In some cases, a handset will intentionally switch off the GNSS function during an emergency call to save battery power.
  - If the GNSS is switched on, the phone needs to obtain a fix from scratch and this can take more than 30s, particularly if poor connection speeds prevent the rapid provision of assistance data.
  - The fact that the caller will generally have the phone in the standard call position when speaking to the call handler will limit some of the sky visibility and hence the GNSS performance.

3.1.4 GNSS developments

To address some of the issues raised in the previous section, some additional techniques and developments have been made. These include:

- Assisted GNSS – as noted above, the use of the network to support acquisition of satellite signals, including ephemeris, Doppler / phase shift information, the list of satellites in view and ionospheric corrections and a head start from Cell ID. In addition to this, it is also possible for the handset to record the ranging information and then to forward this through the network where the calculation is performed and the result returned to the handset. This can save battery consumption in the handset.

- GPS receiver technology is improving year on year as finer silicon lithographies have allowed for an increasing number of GPS correlators (or equivalents) to be integrated into UE GPS receivers. In addition, the processing power and battery performance is improving and so the need to avoid handset processing is not as urgent as it once was.
- Developments such as the addition of GLONASS are now being addressed in 3GPP standards but carrier location servers will need to be upgraded to provide assistance for new satellite systems such as GLONASS (as well as the handsets).
- Space Based Augmentation Systems (SBAS) - EGNOS being the one which covers Europe, provide additional signal sources from geo satellites (currently 4) as well as accuracy assessments and differential corrections. These systems are mainly designed for aviation users with full sky visibility, but to overcome ground visibility limitations the same signals are also provided, in Europe, on the Internet though the SISNeT service. These signals could be used to provide accuracy flags for forwarding to the Emergency Services. Cross calculations using different constellations and dual frequencies within a receiver can also provide error information.

3.2 Mobile Network Cell ID

Cell ID establishes the location of the user equipment by identifying the base station (or sector) to which the user is currently connected. It is a basic but fast form of location tracking supported by all GSM handsets and usable with future 3G / LTE handsets.

The accuracy of this approach is a function of the cell or sector size. Cell size varies with population density, being between 200 metres and 1 kilometre for dense urban areas and up to 35-100 km for remote rural areas. Accuracy can occasionally fall further when a handset connects to a more distant base station for reasons of signal strength or congestion.

Cell ID is most commonly used as a fallback method when others such as GNSS or WiFi are unavailable or unreliable. It provides a very quick response and an accuracy range though its accuracy remains limited by network geometry.

In cases where the density of base stations needs to increase to support higher capacities, the accuracy of the technique will improve accordingly. In 3GPP, standard polygons are stored to describe the set of positions for a mobile device linked to the base station with a prescribed probability thus speeding up response time.

3.3 Mobile Network Enhanced Cell ID

Cell ID enhancements are generally based on round trip signal propagation time, signal strength and quality or angle of arrival.

Since Cell ID is fast and reliable in providing a location, albeit not always particularly accurate, enhancements to the technique are applied when possible. These enhancements are generally based on round trip signal propagation time, but in some cases the signal strength and quality or its angle of arrival are also used.

Enhancements to basic Cell ID based on the 3GPP standards are as follows:

- Cell ID with Round Trip Time (RTT) measurements;
- Cell ID with Angle of Arrival (AOA) – this approach needs phased array antennas which are expensive to install. This technology is not in general use and is not considered accurate enough for E911;
- Mixed Cell / Sector – uses cell ID from neighbouring cells by checking which of them can be received by the device. This approach is used as a fallback mechanism in CDMA 2000 networks.

LTE specifies three variants of Enhanced-Cell ID as follows:

- Distance from the serving eNodeB, with position accuracy a circle. Distance is measured using Received Signal Received Power (RSRP) / Time of Arrival (TOA) / Round Trip Time (RTT).
- Distances from 3 eNodeBs position accuracy is a point. Distance is measured using RSRP/ TOA / RTT.
- Angle of Arrival position accuracy needs 2 or preferably 3 eNodeBs.

The key enhancements are considered below. Some methods such as TDOA have much wider application in their own right and are therefore considered in their own sections below rather than as Cell ID enhancements.

Figure 3.2: Summary of Cell ID enhancement methods and TDOA

Method	Location Information	Pros	Cons
RTT	Range based on signal timing	High accuracy	
TOA	Range	High accuracy	Time synchronisation across source and all receivers needed LOS assumed
TDOA	Range difference	High accuracy Time synchronisation at source not required	LOS assumed
RSS	Range	Simple and inexpensive Time synchronisation not needed	Low accuracy
AOA	Bearing	Only at least two receivers needed Time synchronisation not required	Smart antennas needed LOS assumed

Source: Zekavat and Buehrer, 2012,Handbook of Position Location, Theory, Practice and Advances

3.3.1 Time of Arrival

The location of the user equipment is determined by using the time of arrival of a signal from the user equipment at each of three base stations. This allows the distance from the user to each base station to be calculated and thus the location can be triangulated. This approach is broadly similar in principle to the Time Difference of Arrival discussed below, though TOA uses the intersection of radii while TDOA examines the intersection of hyperbolas of constant differences between the TOA between two base stations. In the TOA case however, because the time is absolute rather than differenced there is a need for all the base stations and the user equipment to be time synchronised. This can be difficult to maintain. The transmission of the time signal must also be time stamped.

3.3.2 Received Signal Strength Indicator (RSSI)

In this approach, the location of the user equipment is ranged from multiple base stations using the received signal strength at each of these stations. The signal strength is converted into a distance estimate by assuming consistent transmission characteristics and environmental conditions en-route to each base station.

3.3.3 Angle of Arrival

Angle of arrival measures the phase differences at different parts of the antenna array in each base station to determine the angle at which the signal arrived. The angles at which a signal arrives at two base stations are thus triangulated to determine the location of the user.

This technique has the advantage that only two base stations are needed to determine position. Nevertheless, the main problem is that it needs expensive adaptive antenna arrays at base stations and is therefore **very expensive** for the network operators to implement. Accuracy may also be affected in urban areas due to multipath from reflections on buildings.

3.4 Observed Time Difference of Arrival

OTDOA methods, sometimes known as Observed TDOA (OTDOA), use the intersection of two hyperbolas defining the constant TDOA between two pairs of base stations. These are effectively mobile phone variants of the traditional trilateration and multilateration methods which have been used in radio navigation since the 1940s.

The approach needs three base stations to receive signals from the user equipment and thus to provide two sets of TDOA measurements. This is not always possible.

Two basic OTDOA versions. Downlink TDOA (D-TDOA) in which user equipment uses the signals sent to it from the base stations, and Uplink TDOA (U-TDOA) where base stations use the signals sent to them by the user equipment

There are two basic versions, Downlink TDOA (D-TDOA) in which the user equipment uses the signals sent to it from the base stations, and Uplink TDOA (U-TDOA) where base stations use the signals sent to them by the user equipment. In the uplink case, the base stations must be synchronised and record the time at which they record the observed signals.

LTE has emphasised the downlink variant which has been included since Release 9 of the standards. Uplink has been included in Release 11.

For the downlink case, base stations must transmit a known Positioning Reference Signal (PRS) at a synchronised time and though the transmit time is not needed, each handset must be able to make the calculation based on the signals received. U-TDOA has the advantage that calculations are done in the base stations and are hence independent of handset capabilities though investment in the network is needed. For both methods, accuracy of the timing measurements and timing synchronisation is essential.

3.4.1 D-TDOA

Downlink TDOA uses timing reference signals from the cellular base stations to the user equipment in a trilateration algorithm to produce a location fix. Hardware and firmware support is needed in the mobile device to support the position calculation.

It has the following characteristics:

- It needs all base stations to be synchronised in their timing, or external monitor receivers to provide their own time reference;
- It uses reference signals already provided by the wireless network, and monitoring of these signals and computation of the delays may already be required for other purposes, hence there are fewer battery life implications (than with the uplink counterpart);
- It requires the user equipment to detect at least two neighbour eNodeBs (ie evolved Node Bs or base stations) in addition to the serving eNodeB. The E-SMLC / SLP (SUPL Location Platform) provides the user equipment with a list of potential neighbour cells to search;

The user equipment measures and reports the Observed Time Difference of the neighbour cells and reports the results with their respective physical cell IDs. Time differences are then converted into distances and then into hyperbolas. The intersection between these defines the UE position.

CDMA networks use D-TDOA as a backup method in case a GPS fix is unavailable. It is also used as a hybrid method with GPS. One US carrier used D-TDOA as a phase II solution for GSM phones, but this did not meet the FCC's accuracy requirements and the carrier moved to U-TDOA instead. OTDOA is only likely to be deployed effectively for LTE.

3.4.2 U-TDOA (Uplink Time Difference of Arrival)

U-TDOA is similar in principle to the D-TDOA method, but relies on signals sent from the user equipment to the base stations. It supports legacy handsets but requires monitoring equipment to be installed at virtually all of the base stations. For W-CDMA expensive time stamping needs to be implemented. This is therefore potentially the most expensive form of location technique for operators to implement.

It is presently deployed in GSM networks (at least in the US). It's accuracy varies with the caller's environment and the quality / geometry of the surrounding cell sites. One particular problem with the approach is that there is a 'near / far' or 'hearability' problem. This means that a user equipment transmits with only enough power to reach the nearest base station, so the signal received at more distant base stations may be very if not too weak. This can be a particular problem in cases where good line of sight is not available.

U-TDOA has been evaluated in LTE Release 11 as a study item. It is considered to be a useful candidate because it can operate with all types of user equipment. 3GPP / LTE Release 11 includes the following rationale for UTDOA:

"RAN1 has extensively evaluated Uplink Time Difference Of Arrival (UTDOA) as a network-based positioning technique for LTE. Evaluation results have indicated that UTDOA can satisfy the FCC E911 terrestrial positioning technology performance requirements if suitable signal detection and processing algorithms are used.

UTDOA also provides benefits in being usable in areas with insufficient satellite coverage to support A-GNSS/A-GPS, as well as for scenarios where DL OTDOA is not supported, including legacy Rel-8 UEs. It does not require additional Uu interface signals, so it has no impact on RAN capacity, and it is transparent to the UE"

3.5 RF Pattern Matching

RF Pattern matching is a network based location technology with no handset dependencies and which can generally provide an error size estimate. Some additional handset software may be required. The RF pattern as seen by the handset is compared to a database of the RF pattern that has been previously collected. It gives medium level accuracy in urban environments with dense cell sites, complex RF scattering and with a well maintained RF database. It can meet the 100/300m requirement in urban and dense suburban settings.

The basic elements of an RF Pattern Matching system are as follows:

- The RF Pattern itself, which is a set of location dependent signal characteristics which are available in the radio access network (eg signal strength, signal to noise ratio, link quality, time delay).
- Correlation Databases – these store the RF patterns which are location specific and have either been collected in field tests or generated using simulation methods.

- Location server – the application which handles requests and checks with the database to estimate the user equipment location.
- RF Pattern Matching methods which compare the RF patterns to those in the database. Given the large size of the database, methods to reduce the search space are also important.

The accuracies of the technique vary according to a variety of factors. These include the density of cell sites, complexity of the RF scattering and how well maintained the RF (reference) database is. Pattern matching methods may be applied to different types of networks matched, ie longer range outdoor or indoor WiFi.

- The network needs addition of an SMLC and calibration of the deployment area to generate an RF prediction database.
- A software based method using RF measurements (signal strength, signal to noise ratio, link quality, time delay) made by handsets or the network and statistically comparing the measurements against the RF prediction database.

RF pattern matching has been deployed in some 2G GSM networks which include SunCom Wireless[4] and CellularOne GSM networks. Specifically this was Wireless Location Signatures (WLS). This positioning technique can also locate devices in CDMA2000, iDEN, WiMAX, HSPA and LTE networks.

3.6 WiFi access point location

3.6.1 Overview of the technique

Many mobile phones and other mobile devices are now equipped with WiFi capabilities. Devices equipped in this way can measure information from nearby WiFi Access Points such as the station identifiers and signal strengths. This information can then be reported to a server which can correlate the WiFi information with a location. This is known as a WiFi based Positioning System or WPS.

The database which relates WiFi to location is populated by a service provider using a range of techniques. Most common is driving the area in a vehicle that can receive signals and locate them, as Google did when creating their StreetView product. Alternative approaches are simply to allow individuals to add to or update databases themselves, or

[4] Acquired by T-Mobile in 2008

to allow handsets to provide a location for a WiFi point using their GPS position when this is available. Examples of these databases are given in Section 6.4 on Industry.

The provision of WiFi positioning services is highly competitive; services are linked to location-based advertising and asset tracking, both growing markets.

As with Cell ID, the accuracy of this technique is a function of the density of the known WiFi Access Points available within the database. This means that in rural locations the technique tends not to provide good location accuracy. Nevertheless, the fact that it is at its most useful in dense urban areas means that it provides a useful complement to GNSS based locations which struggle in these locations. The accuracy of the technique is also a function of the extent to which the database is maintained. Its time to fix is also a function of the speed of access to the database and the response time from the database itself.

The provision of WiFi positioning services is highly competitive[5]; such services are linked to location-based advertising and asset tracking, both growing markets.

3.6.2 Implementation of location information through the network

Support for transporting WiFi measurements to the location server is not currently available in the E911 control plane interface standards (ie 3GPP and 3GPP2).

Geolocation determination and transport must therefore occur in the user plane. Any risks from the use of the User Plane infrastructure can be mitigated by comparing the fine location received from the user plane with the coarse location received from the control plane.

Non-3GPP standards exist to enable more secure determination, verification and transfer of location for VoIP calls through the network, such as SUPL and GEOPRIV.

3.6.3 Architecture, protocols and elements required

WiFi capability is only present on a subset of mobile phones at present, though the proportion is growing rapidly. Estimates for the US suggest

[5] http://gigaom.com/2011/05/02/why-android-location-data-is-so-important-to-google/

that by 2015, WiFi penetration of mobile phones will be at 66%[6], though present rates fall well short of this at about 25%[7]

3.6.4 Achievable accuracies

Some indicative accuracies for the WiFi positioning approach are given in Table 3.2. Ultimately, the accuracy of the technique varies according to the density of the access points and the regularity with which the database is maintained. In general, MAC addresses are collected in addition to the SSIDs to ensure that the database entry is uniquely identifiable. This is important when dealing with multiple WiFi addresses that have the same name.

Table 3.2: Empirical position location measurements for WiFi compared to other methods

	Garmin 60Cx autonomous handheld GPS	iPhone A-GPS	iPhone WiFi	iPhone cellular network
Number of observations	10	10	65	65
Percent valid fixes	100%	100%	87.70%	98.50%
Horizontal error (m)				
Minimum	0.3	0.4	16	30
Maximum	1.4	18.5	562	2731
Median	1	6.9	74	599
68th percentile	1.1	8.6	88	827

Source: Zandbergen, P. A. (2009)

Zandbergen (2009)[8] also notes some observed limitations of WPS:

- Skyhook Wireless claims that WiFi positioning is able to achieve a median horizontal accuracy of 20 to 30m could not be confirmed and a much larger median error of 74m was found based on 57 observations.
- The only two published studies on the performance of metropolitan-scale positioning (Cheng et al. 2005, Skyhook Wireless 2008) were potentially biased in the sense that their field testing followed the exact same roads where calibration data had been collected.

[6] http://mobiledevdesign.com/hardware_news/us-wi-fi-handset-penetration-02102010/

[7] http://www.xbitlabs.com/news/networking/display/20100324154101_25_of_Mobile_Phones_Will_Be_Equipped_with_Wi_Fi_by_2012_Analysts.html

[8] Zandbergen, P. A. (2009), Accuracy of iPhone Locations: A Comparison of Assisted GPS, WiFi and Cellular Positioning. Transactions in GIS, 13: 5–25. doi: 10.1111/j.1467-9671.2009.01152.x

Results from these previous studies were therefore likely much too optimistic about the positional accuracy that can be achieved at locations at some distance from roads, and in one case an error of 301m was observed due to 'road-snapping'.

- The proprietary databases containing the locations of WiFi access points which underpin the various WiFi positioning systems have been built without knowledge or consent of the access point owners. The EU working party responsible for giving privacy compliance guidance to member states has stated that *"...companies can have a legitimate interest in the necessary collection and processing of the MAC addresses and calculated locations of WiFi access points for the specific purpose of offering geolocation services"*[9]. It follows that mandatory large-scale removal of WiFi access points from the WPS databases in the UK is unlikely. However, increasing public awareness of privacy rights may lead to small-scale permanent removal of access points from the WPS databases[10].
- WiFi may be disabled by the device user in order to conserve battery life; though it is conceivable that emergency call embedded applications could override this.

3.7 Bluetooth Wireless Beacons

Location of mobile user equipment is possible using a system based on a wireless network of Bluetooth nodes. Bluetooth beacon nodes are connected to multiple location nodes via Bluetooth. Each beacon node is connected to a centralised location server within a building using WiFi, WLAN or possibly other backhaul. The Bluetooth nodes continually broadcast their position and are provisioned to provide floor, room number, altitude, longitude, elevation, postcode, street address and user specific information. The shorter range of Bluetooth means that this approach is generally focused on positioning within buildings. It also requires a Bluetooth software application on the handset.

The approach provided by Wireless WERX for example is very much consumer oriented with the objective of providing retail support. With accuracies of 1m or less, this support can include:

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[9] European Commission, Article 29 Data Protection Working Party, 16 May 2011, *Opinion 13/2011 on Geolocation services on smart mobile devices*, available online at http://ec.europa.eu/justice/policies/privacy/docs/wpdocs/2011/wp185_en.pdf

[10] Google European Public Policy Blog, 15 November 2011, *Greater choice for wireless access point owners*, available online at http://googlepolicyeurope.blogspot.co.uk/2011/11/greater-choice-for-wireless-access.html

- Understanding of customer behaviour and intent;
- Increased efficiency of the customer experience from shop through purchase;
- Increase of passer by traffic into a shop;
- Quantification of the effectiveness of signage / displays and various retail layouts.

3.8 Femtocell network location

Femtocells are low power local base stations used to connect mobile devices to an operator's network using a customers IP broadband connection. Generally, these devices need to be used at a registered location with an associated geographic position. Although access to mobile devices other than those of the owner can be blocked, this does not apply to emergency calls. Accordingly, the owner or a third party can make an emergency call using the femtocell and the call can be located using the database entry.

One of the major issues with femtocell positioning is the handling of the database links between the access point and the address. The main problem is the need to achieve consistency of database address information. Although the ideal is to provide the location address where the femtocell is connected, in some cases other addresses have been used, such as that of the nearest full size base station. In some cases, GPS is expected to provide the location of the femtocell and this may not be possible in cases where there is no satellite visibility.

3.9 Visual pattern matching

Given the high bandwidths available within LTE, it is possible in the longer term that matching imagery provided by the phone against a visual database could be used to provide a good location. This approach is effectively the same as is used by humans.

Even if the pattern matching does not fully work, the imagery from the device would be passed to the emergency services to help them make a location assessment.

3.10 Hybridisation methods

3.10.1 Hybridisation

Methods to combine position information to provide the best quality of service have been developed

Location based services are already an embedded feature of mobile networks and so methods to combine position information to provide the best quality of service have been developed. In particular these need to provide for indoor positioning to ensure a seamless performance for most users.

Various ways of combining two or more location determination techniques are available. Most techniques can be combined, but some combinations are complementary while others may provide a final result worse that a single approach.

For example, A-GPS used with U-TDOA, RFPM or D-TDOA offers better results than blending two cellular technologies such as U-TDOA and D-TDOA.

3.10.2 Fallback method

A fallback method is simply to invoke a hierarchy where a second or third method is used when the first method fails to meet pre specified accuracy criteria or fails to return a fix within a time limit.

This can be done sequentially if a range of methods are specified, each triggering if the previous method fails. Fallbacks of this type are presently deployed for example from AGPS to WiFi and then to Cell ID.

3.10.3 Selection method

This approach uses two or more methods and then uses the result expected to provide the most accurate result based on a range of factors. These include the following: quality of available measurements, uncertainty of location fixes or the user environment. Examples of this approach are where primary method would be challenged such as the use of A-GNSS in heavily urbanised areas.

The difference between this approach and the previous fallback one is that here both, or all, methods are applied simultaneously so that they can be compared; while with fallback each is invoked sequentially.

3.10.4 Joint estimation

Rather than selecting a preferred method and using it directly, this approach combines the measurements from two or more location methods. This approach works well provided methods are blended so that the strengths of the two methods are complementary.

The extent to which techniques are complementary varies with environmental conditions and this needs to be taken into account during selection. For example, if a GPS solution is based on a relatively strong signal, hybridising it with a network location can actually make the estimate worse.

This approach is most useful when A-GNSS has limited value because of limited line of sight conditions and hence not enough satellites to calculate a proper position. An example of its use is in CDMA networks with A-GNSS and D-TDOA.

3.10.5 Adaptive and self learning approaches

An interesting extension of a joint estimation approach is to incorporate a self learning ability and thus an adaptive approach which optimises the mix of ingredients according to circumstances. The approach can also be used to provide improvements to the information already available and then, by updating the statistics for an area, to improve the selection criteria for subsequent positioning in the same area.

This approach is already in evidence in some applications used for LBS. For example, the Google approach to WiFi positioning refers back to the user equipment once a GPS fix has been achieved and uses this information to enhance the accuracy of the WiFi database.

These approaches are being included into developments of LTE positioning.

3.11 Performance Assessment

The main performance variables are the horizontal location accuracy and the time taken to provide it often referred to as the time to first fix (TTFF). In addition to these, the availability and reliability are also important factors, though it should be noted that these are inversely related to the accuracy level specified.

The main difficulty in specifying comparative performance variables for the positioning techniques is that each is highly dependent on the environmental circumstances of the user equipment, the network configuration or both.

GNSS signals are weak and handset antennas generally small, which means that generally a clear line of sight to at least three satellites is needed to achieve good accuracies. In urban environments, the problem of multipath from reflected signals adds to the problem of limited visibility. The effect of this on positioning performance can be seen in the examples given in Figure 3.3 which show the performance for assisted GPS.

In the rural case, the spread of given positions is largely within 10m of the target with very few estimates being more than 20m from the real position. For the urban case however, although the bulk of estimates are within 50 - 100m of the target, there is still a reasonable number of estimates outside 200m and a small number of outliers at 400m or worse. This highlights a major limitation of GNSS in that it performs best in locations where accuracy is often least critical.

Figure 3.3: GPS positioning accuracy in rural and urban environments.

Figure 32.26 A-GPS accuracy in a rural environment.

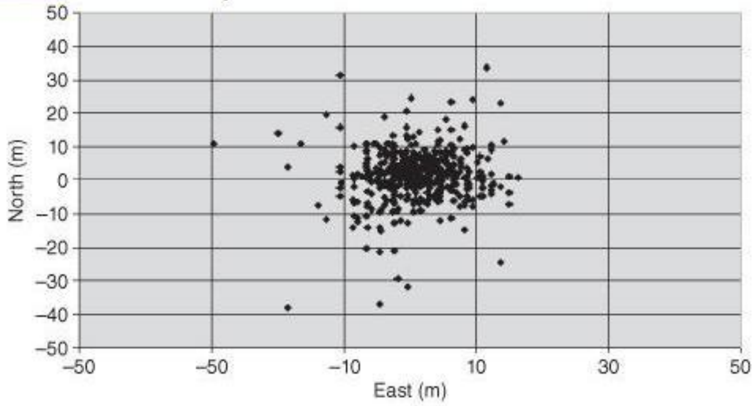
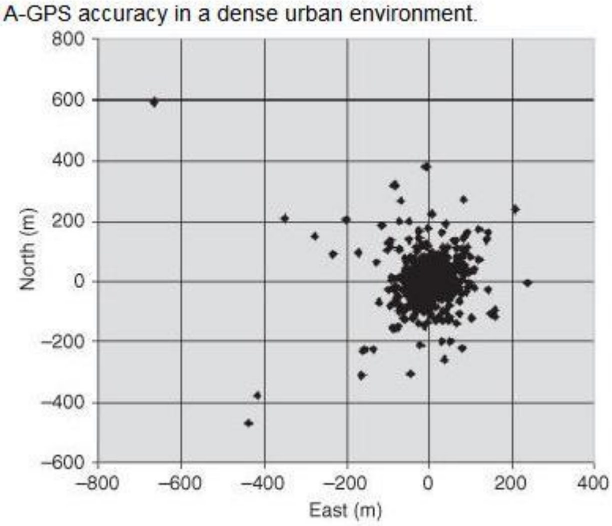


Figure 32.27 A-GPS accuracy in a dense urban environment.

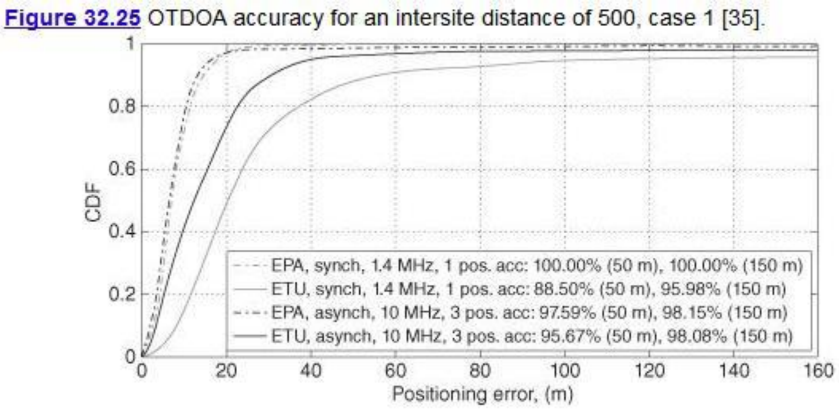


Source: Zekavat and Buehrer, 2012,Handbook of Position Location, Theory, Practice and Advances

Other positioning methods also exhibit a statistical error distribution based much more on the geometry of the network in the area around the user equipment. The greater ability of the signals to penetrate the surrounding buildings and other clutter means that line of sight is less of an issue. This means that errors are more predictable, but only for the specific area and geometry for which the positioning is being done.

Figure 3.4 provides an overview of the cumulative distribution function (CDF) for OTDOA network based positioning for four cases covering different frequencies and at different accuracy levels.

Figure 3.4: OTDOA accuracy overview



Source: Zekavat and Buehrer, 2012,Handbook of Position Location, Theory, Practice and Advances

Table 3.3 presents a summary of positioning capabilities for the most prominent techniques.

Table 3.3: Summary of accuracies for various positioning techniques

Method	Accuracy (m)	TTFF (s)	Environment	Power Consumption
GPS / A-GNSS	5 – 20 - 250	5 - 30	Outdoor Limited in dense urban and indoor	High for GPS, lower for A-GNSS
D-TDOA	Medium accuracy	5 – 10s	Limited in rural areas with sparse cell networks and linear cell site locations	Low
U-TDOA	100 – 300	<10s	Limited in rural areas with sparse cell networks and linear cell site locations	Low
RF Pattern Match	100 – 300	5 – 15	Accuracy limitations in remote areas and those with complex RF conditions	Average
WiFi	10 – 50	1 – 4	Limited in outdoor locations where WiFi coverage is poor	Above average
Cell ID	500 - 10000	2 – 6	Very poor accuracy in rural areas with sparse cell networks	Low
E-Cell-ID	100 - 300	2 – 6	Better in urban areas with greater base station densities. Function of enhancement techniques applied	Low

Source: Synthesised from a range of sources

Table 3.4 provides a corresponding assessment of reliability and suitability of the different techniques, including a summary of the air interfaces with which they can be used.

Table 3.4: Comparison of positioning techniques by application

Location Solution	Accuracy Performance		Reliability	LLS	LBS	Air Interfaces	E911	
Wireless Based (RF Pattern Matching)	Dense urban and indoors	<50m @67%	Very high	Yes	Yes	All	Yes	High Accuracy (meets E911)
	Suburban	<100m @67%						
Wireless Based (RF Pattern Matching)	Line of sight (LoS) urban	<75m @67%	High	Yes	No	GSM / Future UMTS	Yes	
	Non LoS / indoor urban	<100m @67%						
A-GNSS	Suburban / rural	<50m @67%	Medium	No	Yes	All	Yes	
	Dense urban / indoor	Very low						
O-TDOA (Handset based)	1/8th cell coverage area in LoS conditions (average <250m)		Low	No	Yes	CDMA 2000 (fallback to A-GPS) Possible in future LTE	No	Medium Accuracy (marginal for E911)
Enhanced-Cell ID (Network based)	1/8th cell area (average <300m)		Low	No	Yes	All	No	
Cell ID + Timing Advance (Network based)	1/4 cell area (average <500m)		Very Low	No	Yes (limited)	All (RTT needed for UMTS)	No	Low Accuracy (does not meet E911)
Cell ID (Network based)	Cell area		Very Low	No	Yes (limited)	All	No	

Source: Derived from Dr M Feuerstein, CTO Polaris Wireless (http://www.convergedigest.com/bp/bp1.asp?ID=633

4. User equipment technologies

This chapter reviews the latest developments in handset technologies needed to support the positioning methods set out in the previous Chapter.

In addition to the technical analysis, this chapter also considers the extent of market takeup both now and in future to determine which technologies have sufficient critical mass to be generally applicable.

4.1 Enabling technologies

To enable location-based services, handsets may provide some or all of the following functions which are listed in increasing order of their contribution to location accuracy:

- Internet access (through a range of means), in order to upload a list of detected transmitters to a location database service provider and receive an estimated position in return. This is the baseline requirement for location determination by the handset[11];
- WiFi receiver, in order to add local WiFi MAC addresses to the list of detected transmitters sent to the location service provider. This improves accuracy;
- GPS receiver;[12]
- GPS+GLONASS receiver;
- GPS+GLONASS+SBAS[13] receiver.

4.2 Handset GNSS implementation

The range of handsets and operating systems is important because it affects the ease with which some location determination approaches can be introduced.

At present, there is a very wide range of handsets in circulation with an equally wide range of location capabilities. Nevertheless, given that many users replace their handset every 18 to 24 months, a review of

[11] There is one exception; the location database service provided by the Fraunhofer Institute (Awiloc). This stores a transmitter footprint database compressed on the handset in advance.

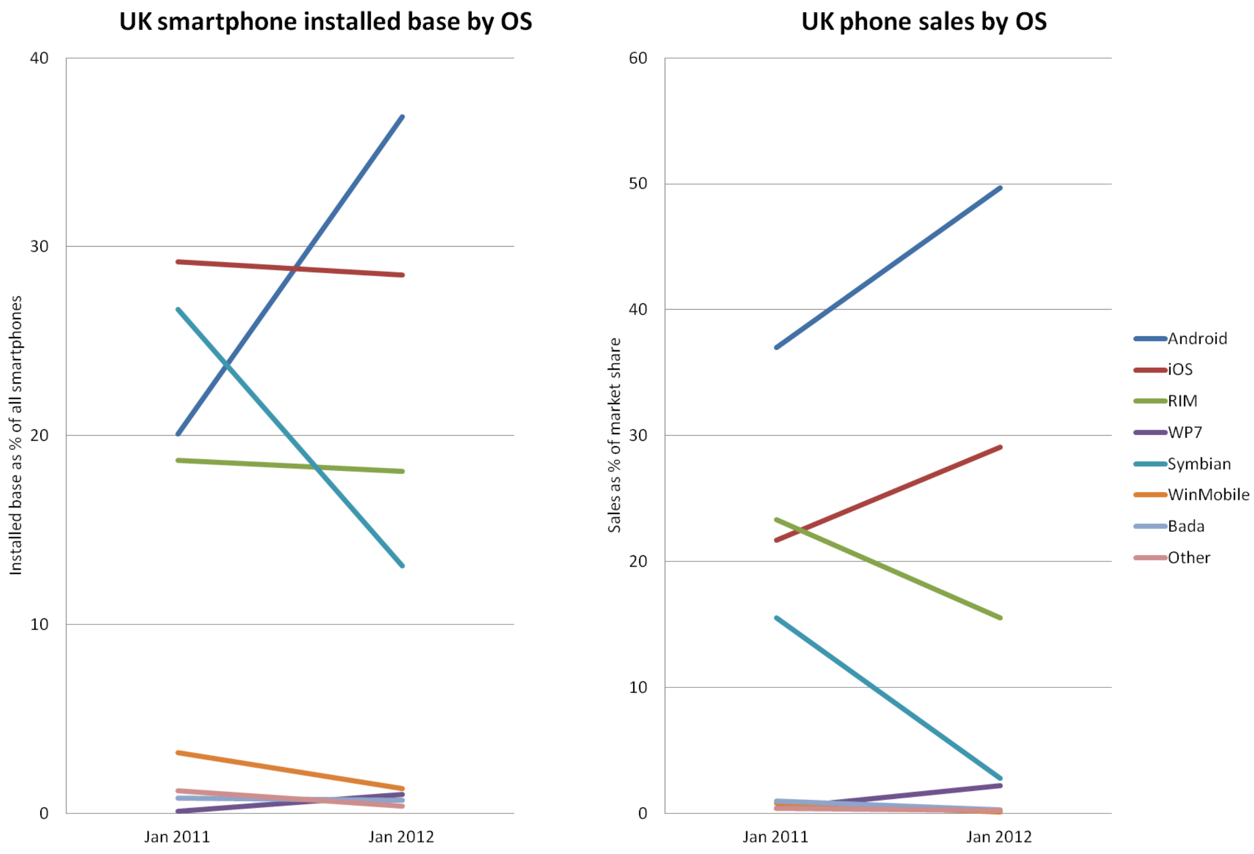
[12] If the handset has Assisted-GPS, this improves cold-start time-to-first-fix from several minutes to several seconds by downloading ephemeris information from the network rather than the satellites.

[13] Space-Based Augmentation Service; this consists of a number of satellite overlays to GPS around the world. In the UK it is EGNOS, in the US it is WAAS. Receiving EGNOS, horizontal GPS accuracy is improved to 1-7 metres.

the most popular handsets in the UK helps to provide an indication of the situation in two years or more. These handsets are therefore identified, and the status of location-awareness and location-reporting technology for each handset (i.e. A-GPS, WiFi, SUPL support) is determined.

As of January 2012, the majority of mobile phone users in the UK own a Smartphone[14]. Sales figures by handset per country are not generally published by handset makers. However, useful insights into handset takeup may be gleaned by inspecting published UK operating system takeup and referencing other estimates of UK handset sales. Figure 4.1 clearly shows the dramatic change which has taken place in UK handset ownership and sales during the past year.

Figure 4.1: UK handset Operating System (OS) ownership (left) and sales (right) trends



Source: Mott MacDonald (visualisation), Kantar Worldpanel ComTech (data)

[14] http://www.guardian.co.uk/technology/2012/feb/21/android-smartphones-os-uk-apple

All of the top 10 best selling phones in the UK during April 2012 were smartphones with high performance location capabilities

It may be seen that Android handsets have become the most-carried and most-bought Smartphones in the UK. iOS handsets are also popular, and Android and iOS phones together comprise 65% of UK Smartphones in use and 80% of all new UK handsets sold each month. From the figures, it is clear that as RIM's market share is declining. If this trend continues then the market share of Android and iOS Smartphones will be in excess of 90%.

As of 12 April 2012, UK weekly mobile phone handset sales data[15] indicates that people are presently buying the following handsets, in descending order of sales volumes:

1. Samsung Galaxy S II (Android)
2. HTC One X (Android)
3. Apple iPhone 4S (iOS)
4. Samsung Galaxy Ace (Android)
5. Samsung Galaxy Note (Android)
6. Sony Xperia S (Android)
7. HTC One S (Android)
8. HTC Wildfire S (Android)
9. Samsung Galaxy Nexus (Android)
10. Sony Ericsson Arc S (Android)

The geolocation capabilities and costs of inclusion for these handsets are described below. Note that all of the handsets listed provide WiFi functionality.

4.2.1 Samsung

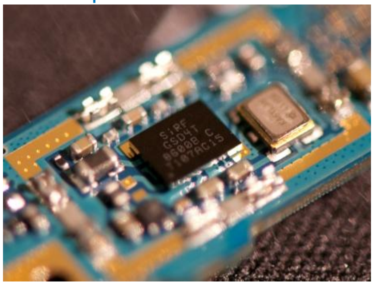
Galaxy S II (May 2011)

The Galaxy S II is the most-bought phone in the UK, and has been for over 11 months[16]. It uses a discrete GPS chip from CSR plc, the SiRFstar IV GSD4t; this is shown in Figure 4.2 attached to the handset's main PCB.

[15] Uswitch.com, *"The UK's most popular mobile phones this week, ranked by deal popularity and sales. Statistics are derived from uSwitch.com, plus our network of mobile phone comparison partners*". http://www.uswitch.com/mobiles/mobile_tracker/

[16] http://www.forward.co.uk/files/533450_SAMSUNG_GALAXY_SII_IS_UKS_MOST_POPULAR_PHONE_FOR_ELEVENTH_MONTH_ANDROID_PHONES_DOMINATE_MOBILE_CHART.pdf

Figure 4.2: Samsung Galaxy S II board showing CSR SiRFstar IV GPS chip



Source: anandtech.com

CSR states that the GSD4t has *"excellent pass margins for E911 and 3GPP"* and includes anti-jamming techniques. Cost of inclusion is unknown. The chip covers less than 20mm^2 of board area (Anandtech notes it *"is absolutely tiny and difficult to photograph"*), consumes 8mW when hot and draws 150-500µA when warm.

Galaxy Ace (February 2011)

This is a cheaper Android Smartphone - available SIM-free in the UK for £144. It has a discrete GPS receiver, the Qualcomm RTR6285, included as part of a Qualcomm MSM7227 chipset[17] (i.e. an off-the-shelf configuration of components also used in other handsets). The RTR6285 is RF-only; GPS processing is done on the MSM7227 chip.

The MSM7227 chipset with A-GPS is designed for handsets selling for less than US$150, indicating that GPS capability is no longer a luxury feature[18]. Marginal cost of inclusion appears to be nil, as the RTR6285 chip is also the RF stage of the GSM and UMTS radios. At least 40 other handsets use the MSM7227 chipset[19].

Galaxy Note (November 2011)

The Galaxy Note uses a discrete GPS receiver chip: the Broadcom BCM47511[20], providing GPS+GLONASS capability, along with a Satellite-Based Augmentation System receiver[21]. SBAS is useful to Galaxy Note users in the UK as the European Geostationary Navigation Overlay Service signal can be received, improving the horizontal accuracy of GPS positioning to 7m by design and 1m in practice.

It is likely that the Broadcom GPS chip supports the SUPL protocol, but confirmation has not been obtained.

Galaxy Nexus (November 2011)

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[17] http://news.softpedia.com/news/Qualcomm-Announces-Low-Cost-MSM7227-Chipset-104554.shtml

[18] http://www.qualcomm.com/media/releases/2009/02/12/qualcomm-targets-sub-150-smartphones-versatile-high-performance-chipset-su

[19] http://pdadb.net

[20] http://www.broadcom.com/press/release.php?id=s624273

[21] http://www.broadcom.com/press/release.php?id=s548713

The Galaxy Nexus uses a discrete GPS receiver chip: the CSR SiRFstar IV GSD4t[22], the same receiver used in the Galaxy S II. Cost of inclusion is unknown. The chip covers less than 20mm^2 of board area, consumes 8mW when hot and draws 150-500µA when warm.

4.2.2 HTC

One X (April 2012)

The HTC One X supports A-GPS, however no further information has been found regarding the hardware or implementation. It is known that there are two versions of the handset; the US version contains a Qualcomm processor and the international version contains an Nvidia processor. This could conceivably affect the GPS implementation of E911 capability on non-US handsets, but we consider it unlikely.

One S (April 2012)

The HTC One S is a slightly smaller version of the HTC One X. It supports A-GPS, however no further information has been found regarding the hardware or implementation.

Wildfire S (May 2011)

This handset is built upon the Qualcomm MSM7227 chipset[23], including an A-GPS receiver – as for the Samsung Galaxy Ace.

4.2.3 Sony (was Sony Ericsson)

Xperia S (January 2012)

The Xperia S handset is built upon the Qualcomm MSM8260 Snapdragon S3 chipset, with an integral GPS+GLONASS software processor implementation[24]. The GPS RF stage chip is unknown. To prevent excessive power consumption, the GLONASS receiver is disabled whenever there are sufficient GPS satellites in sight.

Arc S (September 2011)

[22] http://www.ifixit.com/Teardown/Samsung-Galaxy-Nexus-Teardown/7182/2#s30574
[23] https://developer.qualcomm.com/device/htc-wildfire-s
[24] http://blogs.sonymobile.com/wp/2012/01/19/glonass-support-in-our-latest-xperia-phones/

The Arc S handset is built upon the Qualcomm MSM8255T Snapdragon S2 chipset[25], with an integral GPS software processor implementation. The GPS RF stage chip is unknown. Although shipped without GLONASS support activated, GLONASS may be activated via a software update[24].

4.2.4 Apple

Though only the iPhone 4S is on the current top-ten list, previous models are discussed to show the recent evolution of Apple's geolocation implementation so as to better estimate future developments.

Figure 4.3: Apple iPhone 3G GPS antenna (being prised)

Source: Fixit.com

iPhone 3G (mid-2008) - The first Apple handset with GPS. To achieve this, the Infineon PMB2525 Assisted-GPS receiver chip is used. Cost of inclusion is unknown, but the total parts cost of the handset is lower than the previous handset version without GPS[26]; we estimate GPS chip cost to have been $2.25 to $2.50, based on the reported cost of the identical chip in the iPhone 3GS. PCB area used is approximately 50mm^2, not including the antenna mounted to the case interior[27]. The Infineon GPS chip supports the SUPL, RRLP and RRC protocols.

iPhone 3GS (mid-2009): The iPhone 3GS GPS receiver is the same[28] Infineon PMB2525 chip used in the iPhone 3G, with a cost of US$ 2.25[29]. The Infineon GPS chip used supports the SUPL, RRLP and RRC protocols.

iPhone 4 (mid-2010) - The iPhone 4 GPS receiver chip is the Broadcom BCM4750, with a cost of US$ 1.75, not including antenna[30]. From the datasheet[31], PCB area used is 35mm^2, power consumption is

[25] http://www.sonymobile.com/cws/corporate/press/pressreleases/pressreleasedetails/xperiaarcspressreleasefinal-20110831

[26] http://www.appleinsider.com/articles/08/07/15/iphone_3gs_final_build_price_just_174_33.html

[27] https://www.infineon.com/dgdl/PMB2525-Hammerhead+II-pb.pdf?folderId=db3a304316f66ee80117824fc0d71e07&fileId=db3a304316f66ee8011782518d4a1e08

[28] http://www2.electronicproducts.com/Apple_iPhone_3GS_16GB-whatsinside_text-82.aspx

[29] http://www.isuppli.com/Teardowns/News/Pages/iPhone-3G-S-Carries-178-96-BOM-and-Manufacturing-Cost-iSuppli-Teardown-Reveals.aspx

[30] http://www.isuppli.com/Teardowns/News/Pages/iPhone-4-Carries-Bill-of-Materials-of-187-51-According-to-iSuppli.aspx

[31] http://www.datasheetarchive.com/datasheet.php?dir=Datasheet-025&file=DSA00437457.pdf&id=1&keywords=BCM4750

13mW and cold-start TTFF is 30s. The Broadcom GPS chip supports the SUPL, RRLP and RRC protocols.

A notable interim development is the iPhone 4 CDMA handset, which is produced for the US market and not sold in the UK. This does not have a discrete GPS chip; instead the GPS receiver is integrated in the Qualcomm MDM6600 baseband/RF transceiver chip along with the CDMA radios[32]. This is the next level of geolocation integration.

iPhone 4S (mid-2011) - The iPhone 4S includes two major developments related to GPS compared to the previous models available in the UK:

- The addition of GLONASS reception. Partly as a result of Russian pressure, major chip makers including Qualcomm, Samsung, and Texas Instruments said in 2010 that they would make chipsets that support GLONASS[33].
- The integration of GPS and GLONASS (generically referred to as GNSS) receivers into the baseband/RF chip, rather than as separate chips. This was possible as a result of Apple's switch of supplier to Qualcomm from Infineon.

Figure 4.4: Apple iPhone 4S chip combining network GPS & GLONASS radios

Source: techrepublic.com

The baseband/RF chip containing the GNSS receivers is the Qualcomm MDM6610. A technical review noted reduced time to fix and improved outdoor and indoor horizontal accuracy compared to the GPS-only iPhone 4[34]. The specific implementation within the chip is of Qualcomm's gpsOne gen 8, which provides capability for compliance with US FCC-mandated E911 requirements. It provides a standalone time to first fix hot, warm cold of 1s, 27s and 29s respectively, and supports SUPL 2.0.[35]

4.2.5 Positioning capability conclusions

The current best-selling handsets in the UK are all Smartphones with GPS and WiFi capability.

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[32] http://www.isuppli.com/Teardowns/News/Pages/New-iPhone-Carries-171-85-Bill-of-Materials-IHS-iSuppli-Teardown-Reveals.aspx

[33] http://blogs.wsj.com/tech-europe/2011/10/20/iphone-4s-supports-russias-glonass-navigation-system/

[34] http://www.anandtech.com/show/4971/apple-iphone-4s-review-att-verizon/9

[35] http://www.qualcomm.com/solutions/location/gpsone

GPS cost of inclusion is marginal and approaching zero

GPS cost of inclusion is marginal and approaching zero as GPS receiver chips no longer need to be discrete components, and are instead being integrated with the network/WiFi/Bluetooth modems (and possibly the antennas).

Increasing addition of non GPS GNSS gives better performance

GLONASS and space-based augmentation capability is becoming a standard feature on expensive handsets (e.g. Apple iPhone 4S, Samsung Galaxy Note). In three years we would expect these extra receive bands to be standard on most Smartphones. In practice, this will usefully improve horizontal positioning accuracy in dense urban areas.

4.3 Market takeup analysis

4.3.1 UK estimates

Since the last report was produced, there has been a considerable increase in the market penetration of Smartphones. The definition of a Smartphone is not precise and is also dynamic as 'smart' features become ordinary and accepted features.

In terms of positioning capability, Smartphone numbers present a significant underestimate of the reach because almost all Smartphones now have GPS but many 'feature' phones now offer GPS as well.

Ofcom 2011 survey figures (mid 2010 to mid 2011, based on a survey of over 2000 people) gave the following figures:

- 27% of adults have a Smartphone
- 57% of these have acquired their Smartphone in the last year

More recent figures from Ofcom (December 2011) give a higher figure for smartphone ownership with ownership nearly doubling in the UK between February 2010 and August 2011 from 24 per cent to 46 per cent[36].

UK smartphone ownership around 50%, and GPS penetration is higher than this

Other reports give similarly high figures with Kantar Worldwide estimating 48.9% of the British population having a smartphone. According to this report, smartphones made up 70.7% of sales over the 12 weeks at the end of 2011, meaning that 48.9% of the British population now own a smartphone.[37]

[36] http://media.ofcom.org.uk/2011/12/14/uk-consumers-are-a-nation-of-online-shoppers/

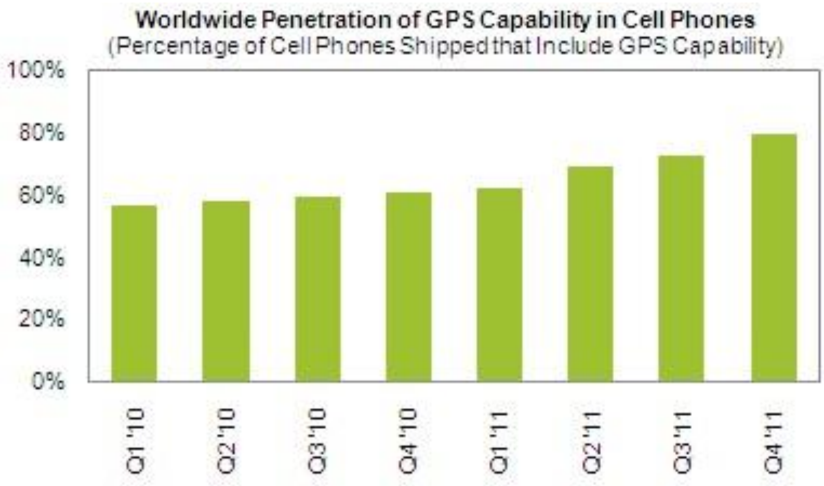
[37] http://www.mobilenewstoday.co.uk/2012/01/apple-pips-android-to-1-us-smartphone-

4.3.2 GPS phone penetration and US trends

Looking beyond the UK, it is possible to gain a better perspective on likely future trends and also more specific information on GNSS penetration of phones. In the US, the FCC are working on the basis that 85% of mobile phones in use will provide GPS by 2018. On this basis, the FCC anticipates mandating the provision of GPS in phones by that time.

In the period since the previous report, ie early 2010 to the present, iSuppli estimate[38] that the percentage of phones delivered worldwide with a GPS capability has risen from 60% to 80%. This suggests that the FCC US estimate is already very close if not already achieved.

Figure 4.5: Worldwide GPS mobile phone shipments



Source: iSuppli

4.3.3 Overall assessment

The implications of the ownership levels and the sales figures is that location capabilities are becoming normal feature of most phones and will soon be present in all but entry level devices. This view is confirmed in the analysis of chipsets given above which shows an increasing trend for GNSS capabilities to be provided as an integrated part of the main chipset rather than a discrete addition. Even in devices

slot/

[38] http://www.isuppli.com/Mobile-and-Wireless-Communications/News/Pages/Four-out-of-Five-Cell-Phones-to-Integrate-GPS-by-End-of-2011.aspx

such as iPads, which have no GNSS capability, the WiFi capability is used for positioning to good effect in urban areas.

The rationale for this growth in GNSS and other positioning capability is consumer expectation. LBS, although it has never really achieved the 'big bang' once expected of it in its own right, has nevertheless grown progressively so that it is now expected. Similarly, just as cameras are now ubiquitous within phones, it is now increasingly expected that a phone should be able to provide similar navigation capabilities to specialist vehicle devices. These business factors, with the addition of the need to support emergency location, will ensure that within the next few years, only a small proportion of phones will not have some form of effective location capability.

5. Network technologies

Networks support position determination and forwarding of location information from a mobile user terminal to the emergency services

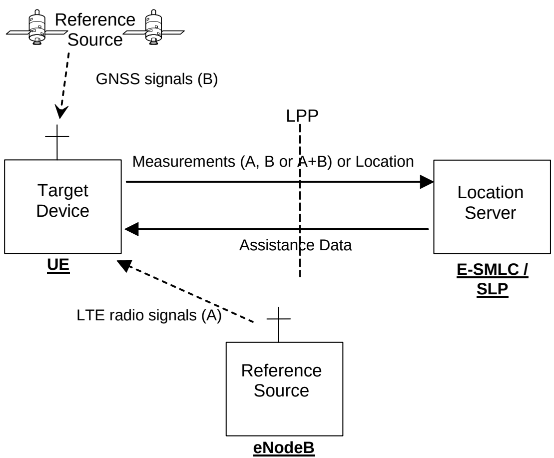
This chapter reviews techniques available now and under development to support position determination and forwarding of location information from a mobile user terminal to the emergency services. The emphasis is on emerging LTE standards as 2G and 3G were discussed in our previous report.

LTE developments offer a long term secure and fully reliable approach though there is some uncertainty about the rate of uptake. Once licenses are awarded, LTE base stations could be substantially rolled out within 3 years. Assuming licenses are awarded next year, 50% population coverage could be achieved by 2015. A more pessimistic scenario could be that coverage only reaches 50% of the user base by 2020 and still with a bias towards urban areas. Given this uncertainty, alternatives which use the standard data transfer capabilities of the networks but with lower security and reliability properties are presented.

We determine which position determination technologies are supported in which release of LTE. Equipment vendors have been reluctant to divulge information about product roadmaps and there release dates.

Figure 5.1 illustrates the different elements involved in providing support to position determination and onward communication of the location information to a location server either operated by the MNO or LBS Provider.

Figure 5.1: LTE using assistance data for location



Source: 3GPP TS 36.335 v 10.4.0: LTE LPP release 10

In our previous report we outlined two key approaches for conveying positioning information, the control plane and the user plane. We discuss these below and provide updates on the status of the two approaches.

5.1 Control and User Plane approaches

5.1.1 Overview

There are two broad classes for communicating location information through mobile networks for applications:

- Control Plane (C-Plane): Use of the C-Plane which refers to the signalling channels of the LTE networks allows for communication of location information in a way that the home mobile network operator controls.
- User Plane (U-Plane): This uses a data bearer service. The Secure User Plane Location (SUPL) standard as defined by OMA uses this approach. This is an IP based technology that allows SUPL enabled user equipment and servers to communicate location information in the user plane. SUPL version 2 supports network initiated position determination.

The benefits of using the control plane are:

- Reliability / Availability are built into the transport mechanisms of the control plane;
- Not subject to the problems arising due to congestion;
- No special handsets or data subscriptions are required
- Avoids dropped location sessions due to inter-node handover.

The LCS (Location Services) control plane solution was originally introduced in GSM to support emergency services and so is secure and reliable.

The downside of the control plane is that it may be expensive to retrofit to existing implementations.

The user plane can be used provided the user's handset supports a SUPL agent. SUPL is the user plane technology developed by the OMA (Open Mobile Alliance) for use over a wireless network based on secure user plane IP tunnels. It is an application layer protocol operating over the interface between the SUPL Location Platform and the SUPL enabled terminal.[39] The benefits of the U-Plane approach are that:

- The user can use the service to access commercial location based services;
- The operator can authenticate the user and bill for use;
- The user can select a 3rd party supplier for the location based services and for use by roaming.

The disadvantages are that as a user plane it can be subject to problems arising due to cell congestion at certain times of day in the mobile networks and the session may drop at inter-node handover, resulting in delay to obtaining the location information. In some configurations the public internet could be used to communicate the location information and this also could suffer delays and time outs at certain times of day. The user also needs a data subscription.

5.2 LTE and emergency calls

Provision for emergency calls is emerging in LTE as the standards develop. Release 8 of LTE does not support emergency calls and these are handled by fall back to circuit switched networks in 2G and 3G.

Release 9 of LTE supports an emergency attach procedure that allows a mobile handset/device to attach even without a Universal Subscriber Identity Module (USIM)[40]. So this would support non-handset type terminals.

5.3 LTE network and location services

LTE networks can support a range of positioning technologies that can be used singly or as a hybrid solution. Positioning technologies are important for LTE because in addition to emergency location, they also serve commercially important LBS services. The Mobile Operators can charge the users of LBS for SUPL based queries. Some positioning technologies such as RF Pattern matching can also be used to help network optimisation by reducing the cost of drive tests to operators and so they may have another motive for implementing these.

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[39] MSF Whitepaper on Location Services in LTE Networks, MSF-TR-SERVICES-005-FINAL, 2009

[40] http://www.nttdocomo.co.jp/english/binary/pdf/corporate/technology/rd/technical_journal/bn/vol12_1/vol12_1_045en.pdf

In this section we describe the changes which LTE brings to support these positioning technologies. The LTE network needs to support the best combination of positioning technologies available and deliver that information to the emergency services. One of the challenges is that users may assume that all positioning technologies will always work, this is far from the case and some technologies will support position determination in one environment and another will be required in a second environment.

LBS in LTE is a work in progress with both 3GPP and OMA. During the last two years the SUPL and C-Plane approaches have converged to co-exist, each offering different services

LBS in LTE is a work in progress with both 3GPP and the Open Mobile Alliance (OMA). During the last two years the SUPL and C-Plane approaches have converged to co-exist, each offering different services to different organisations. SUPL can operate both with LTE to assist with position determination or with other networks.

A key feature of LTE is support in the control plane for a comprehensive list of positioning technologies. Further convergence between 3GPP and OMA in this area will help to ensure interoperability with the SUPL standards, enabling those implementing user plane solutions to “call” on the positioning techniques implemented within the core of the terrestrial networks. It should be noted that these features are not yet available to 2G and 3G networks.

Support for positioning within LTE releases 8-11

Table 5.1 shows the location functionalities supported in the progressive releases of LTE. These include support to the position finding processes themselves, such as the provision of GNSS assistance information as well as means to transmit the position data from the user equipment to its user elsewhere in the network.

Table 5.1: Location standards in LTE

LTE Release number	New location functionality	Date "Release" closes	Vendor release date
Release 7	LCS for I-WLAN,	Q4 2007	not provided
	OMA SUPL,		not provided
	A-GNSS (Galileo)		not provided
Release 8	A-GNSS (GLONASS, GPS, QZSS)	Q4 2008	not provided
Release 9	C-Plane LCS over EPC,	Q4 2009	not provided
	Enhanced Cell-id,		not provided
	Downlink-OTDOA		not provided
Release 10		Q1 2011	not provided
Release 11	Uplink TDOA,	Q3 2012 (TBC)	not provided
	RF Pattern Matching		not provided
Release 12		Not defined	not provided

In general non-network specific terms, the most important parameters for location QoS are the response time, and the horizontal accuracy. The accuracy specified is associated with a confidence value, the two being linked by the associated statistical error distribution.

For release 9 A-GPS is expected to be the primary location method with OTDOA as fallback if measurements from 3 eNodeBs are available and Enhanced Cell-ID if measurements from 3 eNodeBs are not available. Study items for release 12 are not yet finalised but non-voice emergency services have been proposed.

In summary LTE does not support effective position determination and conveyance of location information until release 9. The C-plane is preferred for emergency service applications as it uses the more reliable signalling links and is less prone to failure due to network congestion effects.

It is worth clarifying the terms User Equipment (UE) based, UE assisted and network based/assisted as it helps to clarify the interdependency between SUPL and C-Plane approaches. In summary LTE offers the following:

Position determination consists of two steps:

1. Radio signal measurement; The radio signal which is measured may be either from a terrestrial network or from a GNSS.
   a. By the UE or
   b. By the network (E-UTRAN).

2. Position estimate, which is either UE based or E-SMLC (network) based.

UE Assisted is defined as UE performs the downlink radio measurement and the E-SMLC estimates the position. UE based is defined as the UE performs the downlink measurement and the position estimate. In this case the UE may need assistance data from the network in order to perform the downlink measurement which may be autonomous or on UE request. This is summarised in Table 5.2.

Table 5.2: How Positioning methods operate in LTE

Method	UE Based	UE-Assisted	eNodeB - Assisted
A-GNSS	Yes	Yes	No
Downlink OTDOA	No	Yes	No
Enhanced Cell-ID	No	Yes	Yes
Uplink UTDOA	No	No	Yes
RF Pattern Matching	No	Yes	Yes

Source: Rohde & Schwarz LTE Release 9 Technology Introduction

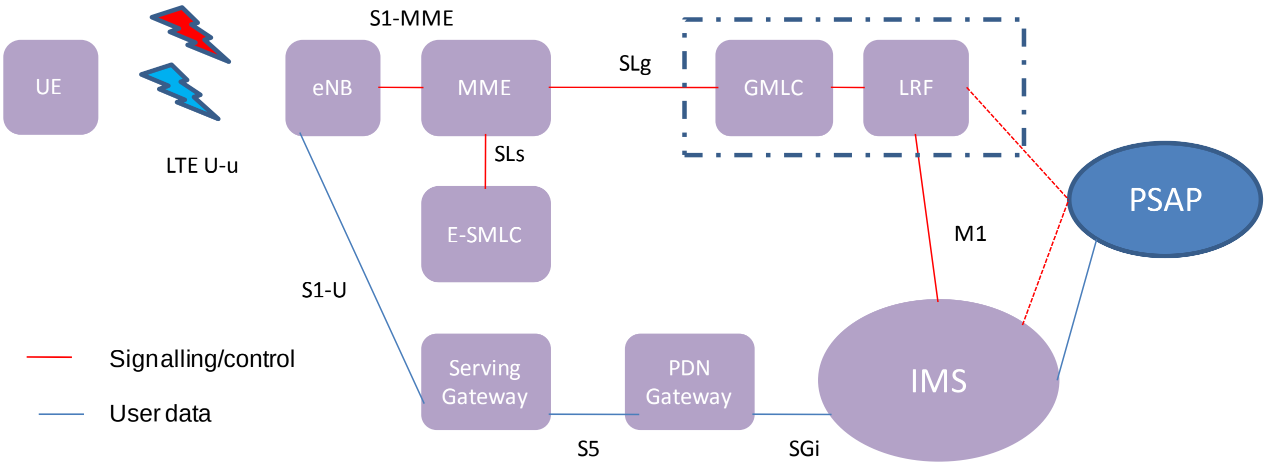
In addition to the 3GPP developments in Table 5.1, the work of the OMA on SUPL is also important. SUPL 2.0 has specific enhancements to support the emergency services and this is considered in more detail in Section 5.7.4.

5.4 Architectures for location information through the LTE network

LTE supports both commercial and emergency services location of mobile users. There are two slightly different architectures reflecting the differing needs of the two services.

The Control Plane architecture presented in Figure 5.2 below supports a network invoked request for emergency position determination. The objective of this architecture is to avoid impacts to a locations session arising due to inter nodeB handover. This may occur because the user is moving or due to reduced signal from the attached eNodeB.

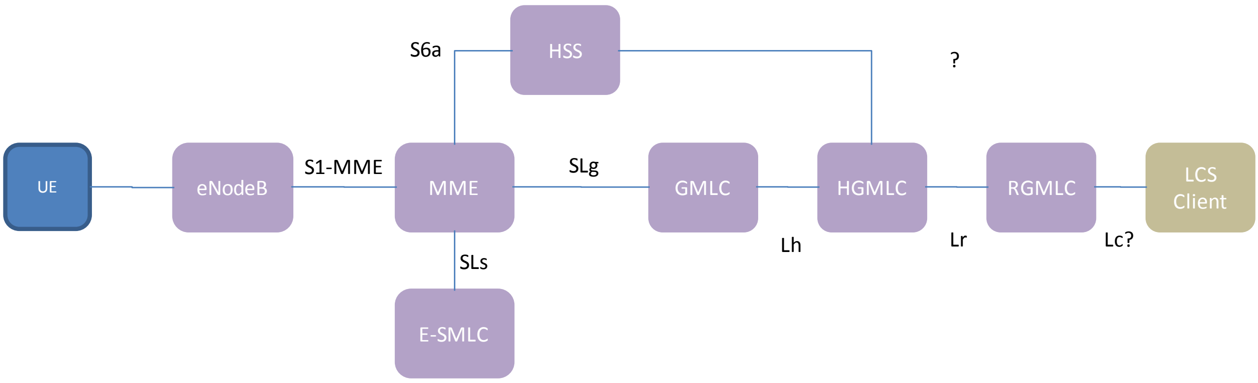
Figure 5.2: Positioning information transiting from UE (User Equipment) to PSAP using LTE



Source: OMA

LTE also supports Mobile Originated and Mobile Terminated Location requests (MO-LR and MT-LR). The architecture supporting this is shown in Figure 5.3. This architecture supports authentication, billing and third parties.

Figure 5.3: Commercial Architecture supporting mobile originated and mobile terminated requests



Source: OMA

The Commercial Service Positioning Information architecture (MO-LR and MT-LR) in LTE is in Release 9.

5.5 New protocols for LBS in LTE

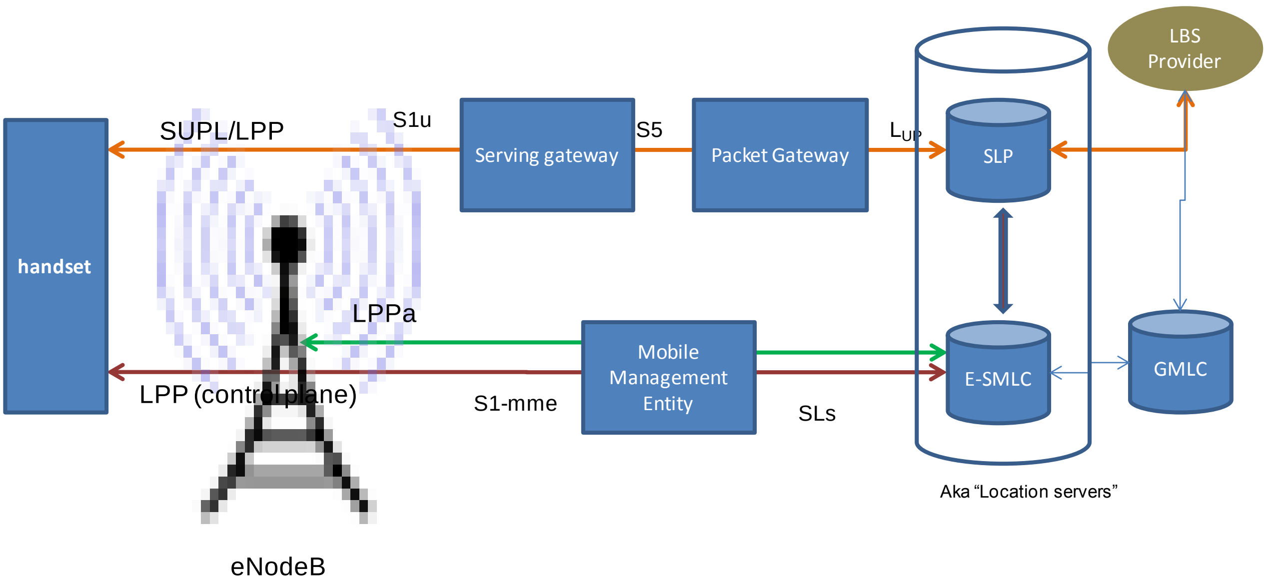
5.5.1 Overall

The following protocols are new / modified to support LBS in LTE.

- LTE-Uu;
- S1 This allows communication between LTE MME and E-UTRA and also the S-GW and E-nodeB;
- SLs (Release 9). This allows the SUPL location platform and the LTE MME, to communicate with the E-SMLC;
- SLg (Release 9);
- LPP;
- LPPa;
- S6a, which can be used for authentication of (paid for) location searches.

The interactions supported by the new protocols are shown in Figure 5.4.

Figure 5.4: Diagram showing LPP protocols in LTE



Source: Various

Two of these, LPP and LPPa have a particular significance and these are now considered in more detail.

5.5.2 LTE Positioning Protocol (LPP)

LPP is an application (Layer 7) standard and can support a number of different transport layers below. An LPP session is used between a Location Server and the target UE/handset in order to obtain position related measurements or a location estimate or to transfer assistance data.

LPP can be implemented across the user plane or the control plane.

LPP in the control plane uses reliable transport (including all three of duplicate detection, acknowledgement, and retransmission) but this is not used in the user plane solution.[41]

LPP was defined to be limited to the native capabilities in the GNSS domain, and in other positioning methods to the methods strictly needed to fulfil the emergency-call positioning requirements.

LPP consists of three independent procedures:

- Capability exchange, - what the terminal is capable of in terms of positioning eg GPS or no GPS.
- Assistance data exchange, from the E-SMLC to the terminal and
- Location information exchange, which refers to both measurement and position.

These allow the server/network to interrogate the UE capabilities and its position.

Since the 2010 study 3GPP-defined LPP has become the de-facto standard for basic positioning not only in the LTE control plane, but also in IP networks over SUPL 2.0 and 3.0.

The UE positioning protocol is an end-to-end protocol with terminations in the UE and the E-SMLC (Enhanced Serving Mobile Location Centre). This is a transaction-oriented protocol with exchange of LPP messages between UE and E-SMLC where one or more messages realise each transaction. A transaction results in one activity or operation such as assistance data transfer, UE positioning capability transfer or position measurement/estimate exchange.

[41] 3GPPTS 36.355v10.4.0

5.5.3 LTE Positioning Protocol (LPPa)

There is a second UE positioning protocol, LPPa. LPPa is a protocol between the eNodeB and the location server (E-SMLC). It is a control plane protocol but can be used to support user plane positioning by querying the eNodeB for information and measurements.

Currently, the LPPa is used for the delivery of timing information that is resident only to the E-UTRAN and/or is semi-dynamically changing, which is required for the **OTDOA** positioning method. Apart from this the LPPa also supports the exchange of E-UTRAN assisted measurements that are used for the **Enhanced Cell ID** positioning method.

Currently LPP does not support all positioning methods, for example, GSM and WCDMA-based positioning (ECID, hyperbolic TDOA methods), WLAN and short-range nodes such as Bluetooth. Extensions are being added to LPP to support these (see Section 5.8.2 on LPPe).

One of the advantages of LPP is that non-3GPP standard positioning protocols such as SUPL can be supported over it.

The positioning technologies supported by Release 10 LPP are:

- OTDOA, and E-CID using LPPa;
- A-GNSS using LPP;
- LTE post release 10 will be capable of interrogating a handset to determine its capabilities and thus selecting the most appropriate positioning determination technology and managing any fallback to a secondary method should this be necessary.

5.6 QoS and its potential impact on emergency services location information

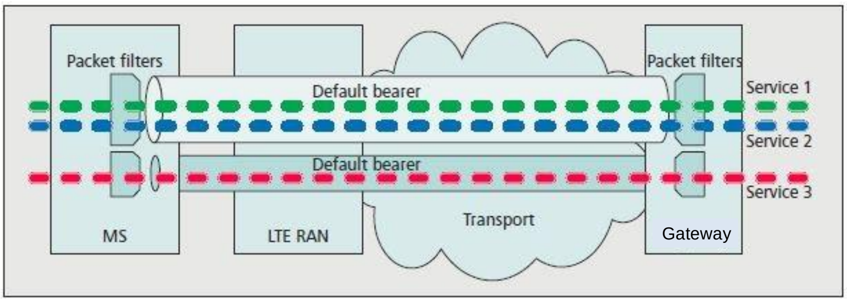
This section considers the QoS parameters in LTE to determine the user-plane support for high availability service if used to convey location information rather than the C-Plane approach.

LTE unlike its circuit switched predecessors 2G and 3G is an IP based network. The 3GPP standards specify QoS levels may be applied to

EPS bearers; these are called Quality Class Indicators (QCI)[42] and allow resources in the radio and core networks to be allocated to particular bearers. QoS on a per user basis is unlikely to be implemented in the short term due to complexity. An EPS bearer is a dataflow between the PDN-GW and the mobile terminal (UE). This allows data to be differentiated between important and / or real-time and lower value best efforts data. In theory this means important data can get through even when networks are congested. Whether this is an effective means in practice on loaded networks of categorising different types of traffic remains to be seen.

Data between a particular client application and the service is assigned to a particular service data flow (SDF) and SDFs are mapped onto an Evolved Packet System (EPS) bearer (see Figure 5.5). Everything in an EPS bearer has the same QoS parameters applied to it (eg scheduling policy, queue management policy, rate shaping policy, radio link control (RLC) configuration).

Figure 5.5: EPS bearer



Source: http://knol.google.com/k/harish-vadada/qos-over-lte-wimax-networks/39mvtk6o5rtho/4#

Figure 5.6 shows the LTE priorities in terms of traffic type. Signaling/Control Plane is assigned the highest possible priority. User plane (data) would take any of priorities 2 to 9.

[42] http://www.lightreading.com/document.asp?doc_id=191295

Figure 5.6: LTE QoS-Based Data Flow Specifications and Class Identities (QCI)

QCI	Resource type	Priority	Packet delay budget	Packet error loss rate	Example services
1	GBR	2	100 ms	10^{-2}	Conversational voice
2		4	150 ms	10^{-3}	Conversational video (live streaming)
3		3	50 ms	10^{-3}	Real time gaming
4		5	300 ms	10^{-6}	Non-conversational video (buffered streaming)
5	Non-GBR	1	100 ms	10^{-3}	IMS signaling
6		6	300 ms	10^{-6}	Video (buffered streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		7	100 ms	10^{-6}	Voice, Video (live streaming), Interactive gaming
8		8	300ms	10^{-3}	Video (buffered streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9		9		10^{-6}	

Source: http://knol.google.com/k/harish-vadada/qos-over-lte-wimax-networks/39mvtk6o5rtho/4#

In addition to QCI there are three other QoS parameters:

- Allocation & Retention Policy (ARP) is the mechanism that allows bearers to be dropped or downgraded if the network is congested and is important in cell handover conditions.
- Guaranteed Bit Rate (GBR) GBR bearers should not experience packet loss on the radio link or the IP network due to congestion. Best efforts services are carried on non –GBR bearers.
- Maximum Bit Rate (MBR)

GBR and MBR only apply to real-time services.[43]

The highest priority traffic in the LTE network is the signalling traffic (also known as the Control Plane).

[43] http://www.ixiacom.com/pdfs/library/white_papers/policy_management.pdf

5.7 Vendor support for LTE positioning

5.7.1 Overview

Although the LTE standards set out the potential to enable a wide range of services, it is the vendor implementation that will actually provide these services.

Although the LTE standards set out the potential to enable a wide range of services, it is the vendor implementation that will actually provide these services. Vendors have been reluctant to share their roadmaps and the following has been taken from publicly available material, whitepapers and limited discussions, Table 5.3 summarises the vendor support for the LTE standards for Huawai and Ericsson at different release numbers.

Table 5.3: Vendor support for positioning

Supplier	Feature	Release number
Huawei	CID	8
Huawei	AGNSS	9
Huawei	E-CID	9
Huawei	OTDOA	9
Ericsson	CID	8
Ericsson	AGNSS, E-CID,OTDOA	9
Ericsson	RF finger-printing, AECID, hybrid	9
Ericsson	UTDOA	11
Alcatel	E-CID, A-GPS,OTDOA	8, 9

Source: Publicly available information and interviews

Note that the A-GPS solution does not need support from the RAN.

Popular implementations of location servers allow a single box to act as a SUPL or a GMLC server. In addition the Alcatel variant can also act as a server to provide WiFi based cell-ID methods and supports UMTS as well as LTE.

5.7.2 Constraints of positioning techniques

OTDOA alone can achieve the FCC E911 requirements with some caveats. The mobile device must be able to receive a signal from 3 cells and this will depend on operator rollout and cell location. It is therefore beneficial if the operator knows the requirement before RF planning of the network is carried out. The Positioning Reference Signal (PRS) is provided so that mobile devices can “hear” cells even though there is insufficient power to place a voice call over the cell.

OTDOA relies on very precise positioning information of the antenna, ie it latitude, longitude and altitude. There are internal delays between the antenna and the equipment. These delays may be due to length of cabling and number of equipment through which signals pass.

The accuracy of this delay information impacts the accuracy of the mobile device position information. The mobile device also impacts the accuracy of the position. The location server then does a computation based on the known variables. This length should be measured electrically rather than by sight.

OTDOA is most effective when the macro cell is synchronised with GPS. For cells which cannot receive a good GPS signal ie in urban canyons or mobile device is in a high rise building. These cells are synchronised using a phased timing signal and OTDOA should not be used for these cells.

When deploying RANs with OTDOA it would be advisable for operators to electrically measure the delay rather than relying on putting together information and making an estimate. Typically base stations are put together by many different subcontractors and collating all the information through visual inspection can be difficult to do accurately. The delay figure needs to be updated if the antenna is moved or other changes are made to the cell.

Only a proportion of base stations are therefore likely to support OTDOA.

5.7.3 LTE and relaying

There may be synchronisation issues that would affect OTDOA when using an eNodeB as a relay for a more remote eNodeB. The further the node is from the core network the greater the inaccuracies for OTDOA. For instance a 30 km radius might only determine accuracy to within 100s m because of unaccounted delays imposed by the data transfers.

OTDOA is also thought to suffer lower accuracy with Femto cells.

Applying the E CID technique to a typical current macro cell does not satisfy the E911 requirements. Since the cell sizes are typically a few km. Smaller cells may change this. As the industry deploys more Femtos and metro cells E-CID will start to meet the FCC requirements.

UTDOA will be supported. There are both integrated and standalone options for the UTDOA approach

5.7.4 Summary of reliability and accuracy information from LTE Vendors

We were unable to speak directly with all of the vendors and the information they were able/prepared to provide was limited. In this section we have listed publicly available information.

Table 5.4 shows the target which Ericsson is currently working towards although it is not clear if or when they will achieve this. Ericsson are expected to respond to the FCC's position to make the target technology neutral and Ericsson's proposed method is to offer a basket of positioning technologies, using the most accurate and reliable for the geographic domain in which the handset is with automatic fallback to other techniques if one fails.

Table 5.4: Ericsson location accuracy targets

Ericsson[44]	Position accuracy	For percentage of calls	Measured across
Terminal based or terminal assisted	50m	67%	Country
Terminal based or terminal assisted	150m	95%	County
Network based	100 m	67%	County
Network based	300 m	95%	County

Ericsson favours GNSS for outdoor and remote /rural areas whereas for indoor and urban canyons they favour OTDOA. Assistance data is less draining on handset battery power than OTDOA, however OTDOA requires no investment changes in the RAN and can operate well in urban canyons and indoors where 50% of mobile calls now originate. Ericsson's system determines which positioning technology to use based on service class, handset capability and the target positioning QoS. Equivalent estimates based by Nokia are set out in Table 5.5.

[44] "Positioning with LTE: maximizing performance through integrated solutions" Ericsson, Sept 2011

Table 5.5: Nokia location performances

Nokia[45]	Position accuracy	For percentage of calls	Measured across
Terminal assisted	50m	67%	Not specified
Terminal assisted	150m	95%	Not specified
Fallback methods	50m	73%	Not specified
Fallback methods	159m	85%	Not specified
Combined approach	50m	78%	Not specified
Combined approach	150m	95%	

5.7.5 Positioning QoS in LTE

LTE supports the following; response time (secs), horizontal accuracy, optional vertical accuracy (may not yet be a positioning technique that supports this) and associated confidence levels. In UMTS only two response levels are supported, low delay and delay tolerant and 128 coded confidence levels.

5.7.6 Equipment availability

During our previous study the solutions were mostly through overlay equipment provided by Andrews, TruePosition etc. At this time Ericsson, Nokia, and Alcatel seem to have made significant progress in developing integrated systems aimed at ensuring some measurement in all environments, though this will still vary in accuracy and reliability.

5.8 Emerging approaches

5.8.1 OMA SUPL and new approaches

The OMA SUPL standard makes use of the LTE LPP protocols. These provisions, known as SUPL, have been implemented at version 1 and 2 (v2 completed late 2009 / early 2010) with version 3 now defined by the Open Mobile Alliance with a series of enhancements as set out below: A summary of the SUPL functionality at version 3.0 is given in Table 5.6

[45] Performance of 3GPP Rel-9 LTE positioning methods. 2nd Invitational Workshop on Opportunistic RF Localization for Next Generation Wireless Devices June 13 - 14, 2010 Karri Ranta-aho
Senior Specialist, Radio Standardization

Table 5.6: SUPL v3.0 functions / requirement categories

Function	Comments
Position determination	• Support Cell ID, Enhanced Cell ID, A-GPS, standalones (eg autonomous GNSS), EOTD, OTDOA, AFLT • Support A-GNSS according to the 3GPP and 3GPP2 specifications. • Support delivery of assistance data from the SUPL network to the SET (SUPL Enabled Terminal) • Extensible framework to allow for new technologies supported by the network to be added efficiently • Support extended location information, eg motion state • Support periodic triggers of location requests
Position conveyance	• Support SET-initiated location request for the transfer of the SET's position information to a third party • SUPL SHALL support the conveyance of a location URI from the SET to the SLP (determination also)
Security	• Prevent unauthorised access to data • Provide mechanisms to prevent Denial of Service (DoS) attacks
Privacy	• Protect end user's privacy in all transactions (excepting emergencies) • Multiple layers of privacy protection supported.
Network	• Allow coexistence with existing location related standards specified by 3GPPs and 3GPP • Must be compatible with all underlying network technologies (Data Bearer, Independence). For example, air interface standards (GSM, WCDMA/TD-SCDMA, LTE, CDMA, HRPD, UMB, WLAN, WiMAX) and transport media (packet data services, SMS, etc) • Support SETs attached to WLAN or WiMAX
Emergency services	• Allow support for location requests associated with emergency services where applicable by local regulatory requirements • Enable emergency service location requests to have a higher priority than others • Support both SET and network initiated positioning for emergency location requests. • Support emergency location for unauthenticated SET
Implementation	• All SUPL events to be time stamped • Support backwards compatibility
Charging	• Support SUPL provider to apply different charging schemes for different services

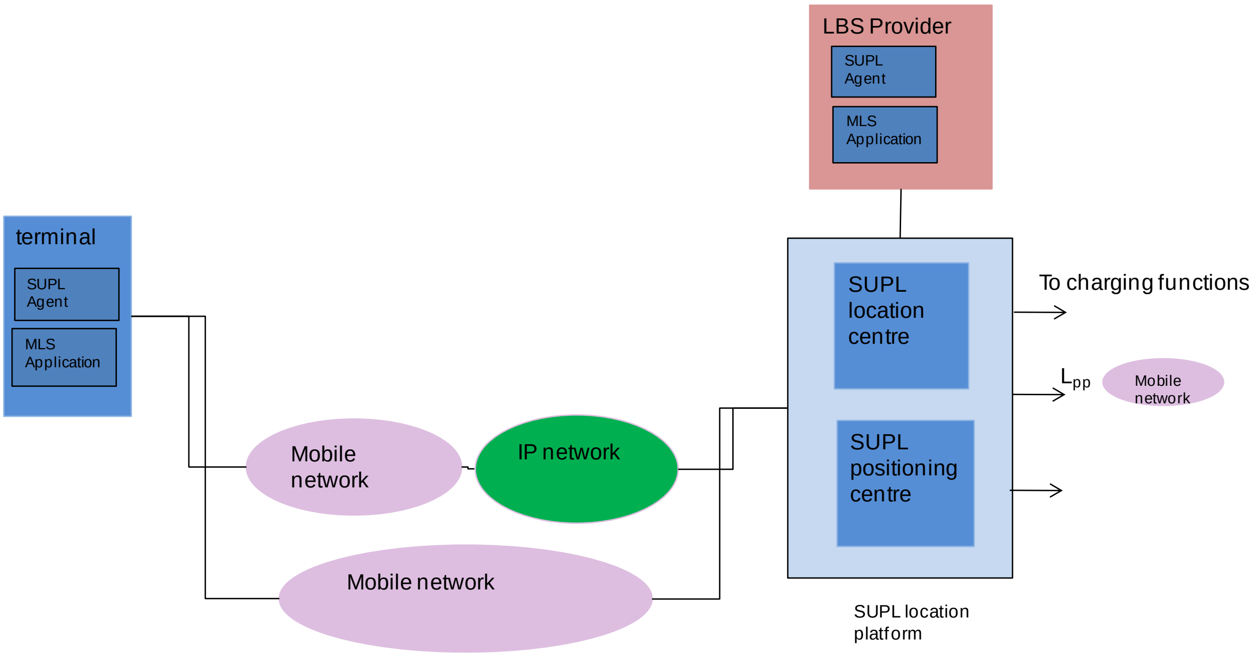
Source: Based on OMA-RD-SUPL-V3_0-20100126-C

In order to support SUPL the mobile phone must be:

- IP based;
- Contain a SUPL agent;
- Contain the Mobile location service client side of application;
- Contain a GNSS chip;
- Have a post pay subscription or be in credit;
- Be able to roam on other national networks (where home network has no coverage.

A very simplified architecture of the SUPL approach is provided in Figure 5.7. There has been much hype about the use of SUPL and its ability to remove the complexities of the mobile networks from the location equation. For SUPL to make use of network based or network assisted positioning determination technologies these and the LPP and LPPa must be implemented by the MNO.

Figure 5.7: Simplified SUPL architecture



Source: (Multi-Service Forum) MSF

SUPL can operate two modes and in instances where mobile device-based positioning is used and no terrestrial network assistance is required it can be used without co-operation of the MNO (apart from the provision of a normal bearer for the location session). This comes with the drawbacks of no terrestrial network assistance and no terrestrial fallback methods. It also has potential to be used for SIM-less devices such as netbooks and iPads. Where alternate assistance sources can be provided it may offer an alternate solution such as WiFi positioning although ubiquitous coverage is some way off for these methods and may never offer the availability and reliability levels obtained with a managed MNO network.

SUPL has two broad methods of operation:

- Proxy mode: This is where the SUPL Positioning Centre (SPC) has **no direct** connection with the SUPL terminal;

- Non-proxy where the SPC does perform direct connections with the SUPL terminal (**Currently only for CDMA implementations**[46]);

SUPL supports both network and terminal initiated location services. It was initially targeted at commercial mobile location service applications. It supports both roaming and charging functions. The roaming service has variants and these depend on a number of parameters

- Roaming agreements between SUPL providers;
- Location ID;
- Cached information;
- Home-SUPL Location Platform to SUPL terminal negotiation parameters such as positioning method.

SUPL supports a number of positioning methods. Location ID (aka Cell-ID in MNOs) is supported as mandatory to perform translation of a location identifier to a geographic location expressed in latitude and longitude.

Autonomous GPS can be supported without the (mobile) network positioning methods, (however a mobile network is still required to communicate with the mobile terminal to retrieve the autonomous GPS positioning information). The L_{up} interface is used between the SUPL Location Platform (SLP) and the SUPL terminal to deliver messages for Location Management (to/from the SLC) and Positioning Determination (to/from the SPC). Positioning Determination messages make use of existing GSM/UMTS/CDMA control plane LCS protocols (RRLP/RRC/TIA-801) to transfer assistance data and position results. [47]

In summary, SUPL v3.0 enhancements compared to v2.0 include the following[48]:

- Improved location performance - accuracy and availability are improved.
- Improved Indoor Location Accuracy addresses the special requirements arising from indoor location issues. An example of such is the support for floor level information as well as the use of relative instead of global coordinates.

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[46] There are no CDMA networks in the UK to date

[47] http://wireless.agilent.com/rfcomms/e6965a/SUPL_System_Overview.htm

[48] Secure User Plane Location Requirements Candidate Version 3.0 – 26 Jan 2010, Open Mobile Alliance, OMA-RD-SUPL-V3_0-20100126-C

- Improved location for IP Emergency Calls
  - supports additional emergency call scenarios;
  - enables location support after IP emergency call release as required in some regulatory environments (e.g. Japan);
  - introduces improvements to SUPL INIT transport (reduction of latency and elimination of transport restrictions) and security.
- Triggered location enhancement provides improvements to existing trigger capabilities and adds new capabilities such as triggers based on location change and/or velocity.
- SUPL Enabled Terminal to SUPL Enabled Terminal Location supports communication between terminals to continuously obtain absolute and/or relative location and measurements of other SUPL terminals for both immediate and triggered location requests.
- Authentication enhancements enables authentication of SIM-less devices (with SUPL subscription) in an IP network. The current security solution includes 3GPP Generic Bootstrapping Architecture (GBA), which requires a shared secret between the SIM and the HLR/HSS and hence clearly is not feasible for emerging device types eg WiFi tablet with GPS.
- Privacy Enhancements aims at aligning privacy management with other Location Enablers.
- Additional Access Networks aims to expand the coverage (applicability) of SUPL to other types of wireless and wireline access networks – e.g. fixed broadband access, private WiFi access.
- Support for Extended Location Information enables the delivery of, for instance, sensor-derived information including motion state, SUPL terminal orientation information.

5.8.2 OMA SUPL LPPe

LPPe is the OMA supported variant of LPP and is supported in SUPL 3.0, which will be the primary transport protocol of LPPe. It is in particular targeted at commercial applications such as navigation requiring continuous positioning updates.

LPPe supports:

- Capability exchange and location-information exchange reversed mode;
- Periodic assistance data;

- Periodic (continuous) location information reporting;
- Segmented assistance-data transfer procedure;
- Measurement scheduling/windowing allows the server to request measurements (GNSS, ECID, TDOA).

LPPe also introduces new positioning methods and enhancements to existing ones. These include:

Additions in the A-GNSS domain include local atmosphere models.

- a localized Klobuchar model
- Troposphere models
- continuous carrier-phase (CCP) assistance for real-time kinematic applications (generally for very precise survey type applications)

Although OMA seems to be developing to support much more of the continuous modes of positioning determinations and seems to be making more use of GNSS itself for assistance data it still supports interoperability with legacy techniques on terrestrial networks. For example:

- E-OTD and OTDOA-IPDL for GSM and UTRA networks, respectively, are supported;
- ECID methods. These cover GSM, UTRA, LTE, and WLAN networks both in mobile device-assisted and mobile device-based modes;
- Support for box containers for vendors and operators to carry their own proprietary assistance data.

Table 5.7: Comparison of SUPL (U-plane) and C-Plane approaches

Characteristic	SUPL (U-Plane)	C-Plane
Implementation cost	Less cumbersome and hence cheaper to implement for LBS providers. Need not use the MNO network if other positioning technologies are availalble.. Can potentially use other sources of assistance data and/or positioning determination methods eg WiFi networks and public internet for communications of positioning information to server	Very expensive to retro-fit to 2G and 3G mobile networks, may be cheaper in LTE networks
Protocols	Uses Packet Switched network (TCP/IP) capability. Terminal must support TCP/IP Later releases of SUPL may use SMS [tbc]	Uses the MNO for assistance data & network based positioning determination and communication Requires updates to several network elements to handle all of the standard

Characteristic	SUPL (U-Plane)	C-Plane
		protocols
Initiation	Supports MO location. SUPL v2 supports MT location	Supports MO (user) & MT(user/third party) and network initiated location
Legacy terminals	SUPL enabled terminal needed Cannot locate legacy terminals	Supports legacy terminals
Emergency		Highly reliable available and secure. Supports location of emergency calls

5.9 Impact of technical architectures on potential organisational structures

In order to determine the potential organisational structures that can support emergency service location it is necessary to take a closer look at the technical architectures.

Support for a SUPL based Location application

In order to support this, the handset must be:

- IP based
- Contain a SUPL agent
- Contain the MLB application (client)
- Contain a GPS or A-GPS chipset
- Requires a data subscription service
- In credit, or be associated with post-pay subscription (if user is out of credit the MNO needs to implement a mechanism to allow a data bearer service to be used)
- Able to roam on other national networks (where home network has no coverage).

Organisations such as Spime inc supply SUPL clients to chip manufacturers such as Qualcomm, a market leader in the supply of chips to mobile handhelds. Similarly GPS chipsets are provided to the chip manufacturers such as Qualcomm. Upgraded / differential GPS chipsets will be provided to support GLONASS, QZSS etc. It is likely that the handset manufacturers, rather than the MNOs, will determine which GNSS are supported and when.

Mobile location applications (managing the emergency location information retrieval) must operate on at least one/all of the leading mobile platforms/operating systems.

For the following structures we assumed that this complexity is outsourced to a third party developer for an appropriate cost.

- A Mobile Positioning Centre (MPC) is responsible for authentication, billing, security and provisioning.
- a geo server is required to map the co-ordinates, a location based service (the application) and content. This might be the location of places the user wishes to visit eg cafes, museums etc.

A number of organisational structures could then support providing location information for mobile callers.

Support for Control Plane based location

For control plane the following is required:

- A Positioning Determination Entity (PDE). This is the SMLC/E-SMLC in the mobile networks. This is capable of both network invoked (sometimes called Push) and user invoked (sometimes called Pull) location determination.
- A Mobile Positioning Centre (MPC). This is the GMLC in mobile networks and is responsible for authentication, billing (for user plane requests), security and provisioning.
- a geo server is required to map the co-ordinates, a location based service (the application) and content. This might be the location of places the user wishes to visit eg cafes, museums etc.

Most of the complexity of this implementation falls within the mobile network.

6. Industry context

The Location Based Services (LBS) industry is perceived as a future revenue earner and so the industry context is relevant for the following reasons:

- Emergency location has been a major driver for location technologies, but LBS is now a major enabler for many commercial activities;
- This has meant that many of LBS providers and enablers eg Google have built up and maintain significant sophisticated databases linking mobile device properties with location;
- Suppliers of user mobile devices also recognise the importance of location and are working with operators and LBS providers to provide the handset capabilities needed to support better positioning.

As a result, the LBS industry is an important provider of some of the techniques for determining location. Accordingly, an assessment of the LBS industry, how it has developed over the last two years and how it is likely to progress in the future is an important part of this review. The aim is to identify developments that could be used to provide a structure for new approaches to emergency location provision.

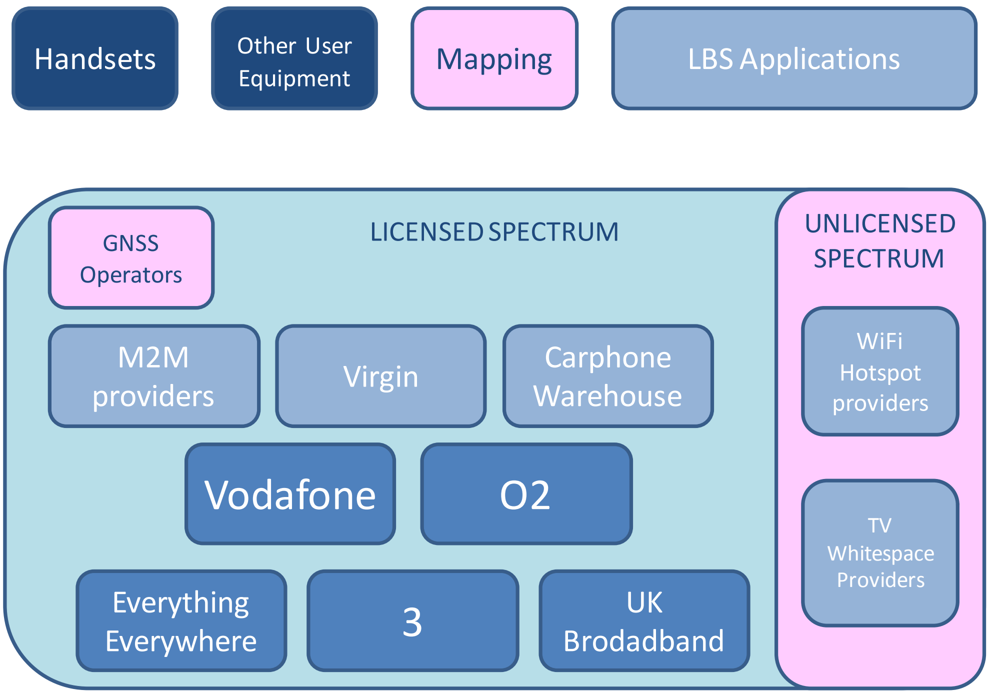
6.1 Overall industry value chain

To provide LBS requires a large number of players to interact. A network is always needed to convey positioning information from a mobile terminal to a user, to provide fallback positioning techniques for challenging environments and in some cases to support handset positioning.

Mobile networks

Within the UK there are the four national licensed mobile operators plus UK broadband who have a licence but have built little infrastructure to date. In addition to the national networks, WiFi hotspot providers can also be conveyors of location information and potentially wireless providers using TV whitespace, though in the UK this is only at the trials stage. WiFi hotspots can also provide position determination based on the location of the WiFi Access Point although these are easily moved and so the position they report will not always be reliable.

Figure 6.1: Industry Structure chart for LBS in UK



Source: MM

LBS data

LBS applications used by UK consumers require a database to associate the measured variable such as cell base station or WiFi point with a corresponding location. These databases may be based in local data centres or may be centralised to a few global locations [49]. Google for example has data centres in Europe and North America.

Mapping

LBS use mapping applications for the location of measured reference points and also to present the calculated position and uncertainty estimate to the end user.

The two key vendors in this domain are TeleAtlas and Navteq, the latter being Nokia owned.

[49] http://royal.pingdom.com/2008/04/11/map-of-all-google-data-center-locations/

In addition to the 'traditional' street mapping of buildings and transport infrastructure, maps are also being created of indoor environments such as shopping malls, stations and airports, universities, hospitals and other large structures. This will provide an improved basis for indoor positioning. Navteq for example is developing indoor maps of malls and airports and also has indoor beacons with an accuracy of 30 cm[50]

6.2 LBS industry developments

The commercial market for LBS in the UK is likely to grow rapidly with the increased penetration of smart phones and other GPS phones. Although LBS have been touted as a 'killer application', it has actually emerged more gradually as a less visible enabler and integrated element of other mobile applications.

LBS revenue forecasts made by Pyramid [May 2011][51] suggest that the LBS global revenues will be $10.3 bn by 2015. Pyramid believes about 50% of this revenue is attributable to the mobile operators. This compares with the global revenue forecast for all mobile services of Euro 871.3 bn MM 2011. This is a not insubstantial percentage of overall revenues. The most common LBS applications are navigation applications.

The main implication of the growth of LBS is a technology push to extend the range of environments in which accurate positioning information can be provided.

6.3 LTE rollout

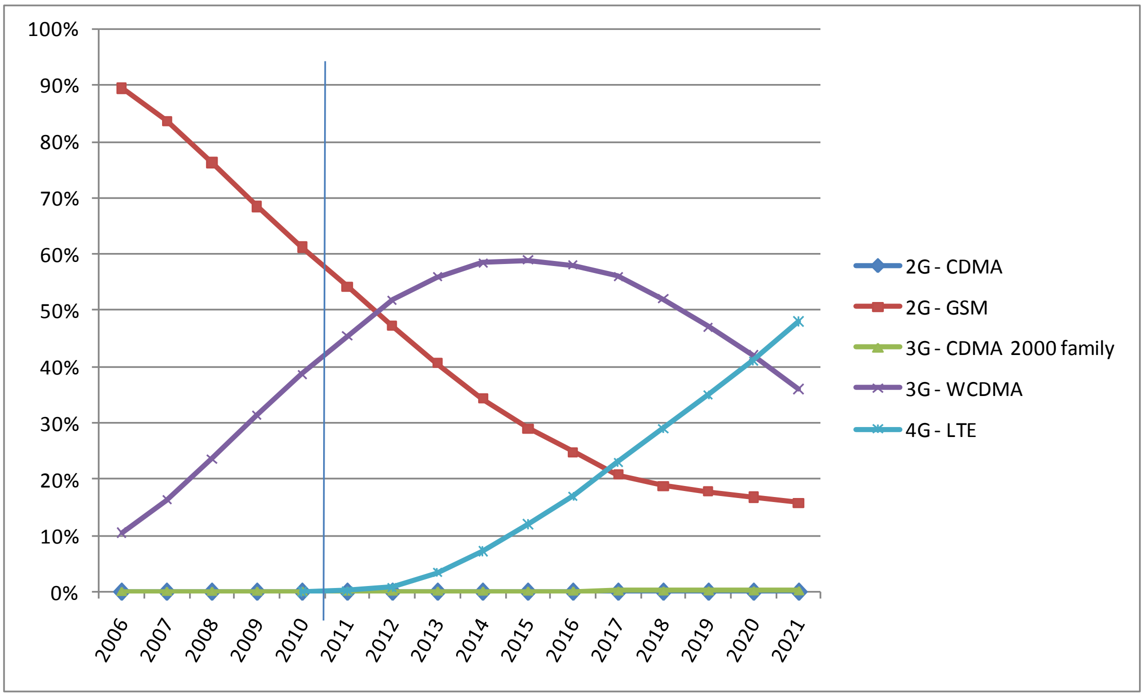
It is anticipated that LTE rollout will be happening in the UK potentially starting this year on 1800 MHz and then continuing in the subsequent years. Figure 6.2 below shows the forecast penetration by technology for Western Europe as a whole. This represents an opportunity to add additional equipment to sites at reduced rollout costs eg. LMU required for UTDOA and also a potential opportunity to take advantage of a greater number of positioning technologies integrated within LTE. Although Figure 6.2 shows that LTE penetration for Europe as a whole is unlikely to exceed 50% before 2021, the UK is likely to be faster than this with 50% coverage possible between 2015 and 2017. By that time, a much greater proportion of emergency calls is likely to come from

[50] http://www.indoorlbs.com/2011/04/nokia-indoor-navigation.html

[51] http://www.pyramidresearch.com/store/Report-Location-Based-Services.htm#sf

mobile devices and so whatever measures can be provided though LTE will require an alternative means which can fully support legacy devices.

Figure 6.2: Western Europe – forecast shares by technology type



Source: MM based on wireless intelligence data

6.4 Organisations involved in various LBS

6.4.1 Status and development of WiFi and network location services

Service provider organisations include AeroScout, Apple, Combain, Ekahau, Fraunhofer Institute, Google, Navizon, Redsky, Skyhook Wireless, and others are likely. A note of each provider's distinguishing features is set out below, and a summary list is provided in Table 6.1. In addition to these where the emphasis is on the provision and maintenance of databases linking location to measurable variables, there are also providers such as Truposition who offer specific technology implementations, in this example U-TDOA.

Table 6.1: Summary of established WPS location providers

WPS provider	Scope	Intended purpose	Method	Source of location data
Apple	Devices running iOS worldwide	Apple-only LBS	Hybrid	Stealthily crowdsourced
Combain	Worldwide	Commercial LBS	Hybrid	Crowdsourced (provenance unknown)
Google	Populated areas worldwide	Commercial LBS	Hybrid	Originally wardriving, now stealthily crowdsourced
Navizon	Worldwide	Commercial LBS	Hybrid	Openly crowdsourced
Skyhook Wireless	Populated areas in North America, Europe, Asia, and Australia	Commercial LBS	Hybrid	Wardriving
Fraunhofer Institute -Awiloc	Populated areas in Germany, spreading into Europe	Commercial LBS	WiFi on-device	Site survey
Redsky	Customers' buildings within the United States	Compliance with enterprise E911 laws; person tracking	WiFi	Manual access point location entry
AeroScout	Customers' buildings	Person and asset tracking	WiFi	Site survey
Ekahau	Customers' buildings, mostly hospitals	Person and asset tracking	WiFi	Site survey

These location providers clearly partition into three types:

- Those enabling tracking of specific people and assets within particular buildings or campus areas, for use within a company or organisation.
- Those providing a geolocation service for open access worldwide (via published APIs or embedded software) e.g. Combain, Fraunhofer Institute, Google, Skyhook Wireless
- Those providing a geolocation service for closed access worldwide e.g. Apple

It is particularly notable that there is no published non-proprietary standard geolocation method in widespread use yet. The closest practical implementation of an open standard method would appear to be the W3C HTML5 geolocation API for use by mobile web browsers[52]. By default this uses Google's geolocation service to respond to queries[53], but over time other geolocation service providers may also choose to offer their services via this API if a suitable business model can be found.

[52] http://dev.w3.org/geo/api/spec-source.html

[53] http://webscannotes.com/?page_id=425

Though the focus of the HTML5 geolocation API is squarely upon commercial location-based services, the W3C suggests that it may be useful to VoIP telephony applications when placing emergency calls:

"Some user agents will have prearranged trust relationships that do not require such [permission-requesting] *user interfaces. For example, while a Web browser will present a user interface when a Web site performs a geolocation request, a VOIP telephone may not present any user interface when using location information to perform an E911 function."*[54]

6.4.1.1 AeroScout

AeroScout markets enterprise software and tags which use existing WiFi access points to track the real-time location and status of equipment and people within buildings and campuses. The company invented the first WiFi active tag, and the system can also track handsets and other WiFi-enabled devices. They have 800 customers worldwide in healthcare, manufacturing, mining, oil & gas, logistics and other industries. AeroScout's differentiator is that the enterprise location server calculates positions using either received signal strength or time difference of arrival, for indoor and outdoor locations respectively.

AeroScout's location server has been chosen by Cisco to be embedded into their own products (marketed as the Cisco Mobility Services Engine), to power their location determination and processing.[55]

6.4.1.2 Apple

Apple began to provide location-based services using other providers' databases in January 2008, and activated their own location database in April 2010 for use by devices running iOS version 3.2 onwards.

For handsets running iOS versions 1.1.3 to 3.1, Apple used and continues to use location databases maintained by Google and Skyhook Wireless.

Apple's location database contains the positions, cell IDs, and signal strengths of cell towers, and the positions, MAC addresses and signal strengths of WiFi access points. The database is maintained by stealthy crowdsourcing from devices running iOS; information is collected

[54] http://dev.w3.org/geo/api/spec-source.html#privacy_for_uas

[55] http://www.aeroscout.com/aeroscout-engine

automatically whenever a device is turned on, and whenever a user application requests a location.

To determine a position, an iOS device reports the cell IDs and MAC addresses of detected towers and access points to Apple, and then calculates its own position based upon the known positions of those nearby transmitters as returned by Apple.

Apple does not allow other companies to access their location database[56].

6.4.1.3 Combain

Combain is headquartered in Sweden and provides a global hybrid cell ID and WiFi location service to software developers and device manufacturers for incorporation into their products. Devices advise Combain's server of which transmitter IDs are in the vicinity and their signal strengths. The server looks up the IDs in the database and calculates and reports the most likely position and estimated accuracy based on this data.

Combain embedded software can simply provide access to the positioning service or, for device manufacturers, can calculate positioning in the device, which is faster, reduces power consumption and reduces data transfer.[57]

A significant differentiator is Combain's openness. To enhance positioning accuracy in certain buildings, they allow users to manually add individual access point locations into the Combain database. If adding all WiFi spots in a building, the positioning accuracy can be improved to less than 10m, and room and building can be included with location query responses.[58]

6.4.1.4 Ekahau

Ekahau markets, primarily to hospitals, an onsite WiFi positioning server which tracks WiFi-enabled devices within a building, via any

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[56] Apple Inc.'s response to a Congressional request for information regarding its privacy policy and location-based services, July 2010, available online at http://www.wired.com/images_blogs/gadgetlab/2011/04/applemarkeybarton7-12-10.pdf

[57] http://www.combain.com/what.php

[58] http://location-api.com/

existing network of access points[59]. The differentiating feature is high location accuracy, obtained by comparing signal strength measurements with data obtained from a prior radio survey of the building. Greatest accuracy requires that a proprietary application be running on the handset[60].

6.4.1.5 Fraunhofer Institute

The Fraunhofer Institute in Germany markets geolocation tools and services, together known as Awiloc, for the intended construction of reference databases to be used throughout Europe. The distinguishing feature of the Awiloc method is that, using WiFi access point signal strength measurements, the handset can determine location independently i.e. without communicating to a remote server[61]. This ensures privacy and enables location determination without a network connection or GPS.

6.4.1.6 Google

Since 2007 Google has collected the location of 300 million WiFi hotspots by wardriving, using StreetView imagery collection cars[5]. Following privacy concerns about the inadvertent collection of the *content* of access point transmissions, Google no longer uses StreetView cars to collect WiFi location information[62]. Growth and maintenance of the access point location database is instead stealthily crowdsourced[63] from users of Google Maps on handsets running Android, Windows Mobile or Symbian S60 operating systems. An explanation of how this is done is provided by a Google representative[64]:

"... you can help provide updated info to correct Google's database using Google Maps for mobile. At this time, you cannot provide individual updates to Google's location databases, though they are being updated and improved constantly over time. Open Google Maps on an Android 2.0+, Windows Mobile, or Symbian S60 phone and

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[59] http://www.ekahau.com/products/real-time-location-system/positioning-engine.html

[60] http://www.ekahau.com/products/real-time-location-system/positioning-client.html

[61] https://idw-online.de/pages/en/news355270

[62] http://www.theregister.co.uk/2010/10/20/google_has_no_plans_to_resume_street_view_wifi_collection/

[63] User consent is initially requested: *"Allow Google's location service to collect anonymous location data. Collection will occur even when no applications are running."*

[64] https://groups.google.com/a/googleproductforums.com/d/topic/maps/kw4gEPtmrcw/discussion

enable GPS. While Maps is simultaneously connected to a GPS satellite and a cell tower or WiFi router, you will be providing updated anonymous geographic data for the cell tower or WiFi router to which you're connected. Please note that this data is anonymous and may require a significant amount of data from you and other users before changes are made to Google's location database."

The location database is used to provide handset geolocation to Google applications and to other developers' applications through the HTML5 geolocation API[65].

6.4.1.7 Navizon

Navizon relies on a community of over one million registered users to collect information about WiFi and cellular tower locations.[66] Registered users are paid[67] if their Navizon handset application maps a large number of these locations. Consequently, coverage is worldwide[68].

Yahoo and Microsoft have licensed Navizon's positioning technology for use in their mobile applications.

6.4.1.8 Redsky

Some US states have legislation requiring companies with large sites and IP phones to implement a means of locating the building and floor from which an emergency call is placed. To provide compliance for employees using WiFi phones within a building or campus, Redsky markets software known as *WiFi e911* which interfaces with enterprise Cisco, Avaya, and Nortel call servers to keep track of the links between individual WiFi devices and individual access points[69].

When a WiFi phone dials 911, the enterprise call server holds the call at a route point and requests the location reference (Emergency Location Identification Number) for the dialling number from RedSky's onsite server, which then provides the ELIN which represents the last known access point location of the phone. The enterprise call server sends the

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[65] http://googlepolicyeurope.blogspot.co.uk/2010/04/data-collected-by-google-cars.html

[66] http://www.navizon.com/howitworks.php

[67] Reimbursement is meagre compared to the cost of obtaining data by other means: US$15 for reporting 666 new or 5 000 existing cell towers, or for reporting 3 333 new or 10 000 existing access points. http://www.navizon.com/FullFeatures.asp

[68] http://navizon.typepad.com/my_weblog/2008/03/watch-our-cover.html

[69] http://www.redskye911.com/e911-products-and-services/e911-manager/wifi-e911

ELIN along with the call to the Public Safety Answering Point (PSAP) where the ELIN triggers a query to a pre-populated Private Switch Automatic Location Information (PS/ALI) database that retrieves the location record for the access point of the emergency caller.[70]

6.4.1.9 Skyhook Wireless

Skyhook claims to have the largest WPS database in the world, storing the locations of 700 million WiFi access points and cellular towers in most major metropolitan areas in North America, Europe, Asia, and Australia. The database is gathered and maintained by wardriving. [71]

Skyhook's Core Engine is embedded into the MapQuest Android app. Until April 2010, all Apple mobile devices used Skyhook.

6.5 Commercial LBS Organisational Models

A large number of organisations are involved in the realisation of LBS and although they have been provided for a number of years now, the organisational structures are still evolving. The next two subsections cover the determination of position and the communication of this information and a third subsection then considers how these can be implemented.

6.5.1 Position Determination

GNSS signals are provided independently and direct to handset where supported.

MNOs play a position determination role in network based methods such as RF pattern matching, Enhanced Cell-ID/Cell-ID, UTDOA and OTDOA. They also play a role in assisted GNSS. These options and their implications are explored further below.

Specialist organisations (in the USA) have set up to provide location information of WiFi access points generally through a database. This database will be connected to the majority of WiFi access points and hence user devices over the public internet. Similarly the LBS application will be connected over the public internet. The public internet connectivity may involve a number of organisations and the traffic will traverse a number of network domains and so it will be

[70] http://www.redskye911.com/sites/default/files/resources/RedSky-WiFi-e911.pdf
[71] http://www.skyhookwireless.com/howitworks/coverage.php

difficult to attain end to end service guarantees across the end-end ecosystem. Likewise it will be difficult to attribute responsibility for accuracy of location information. This is not an issue for most LBS which only charge a small amount or are free and mostly provide consumer information.

LBS providers provide various location based or location aware services. For example, navigation, for vehicles or pedestrians, local advertising, and local interest points etc. It is technically feasible for the emergency services /call handlers to have their own LBS for emergency callers.

6.5.2 Communicating location information

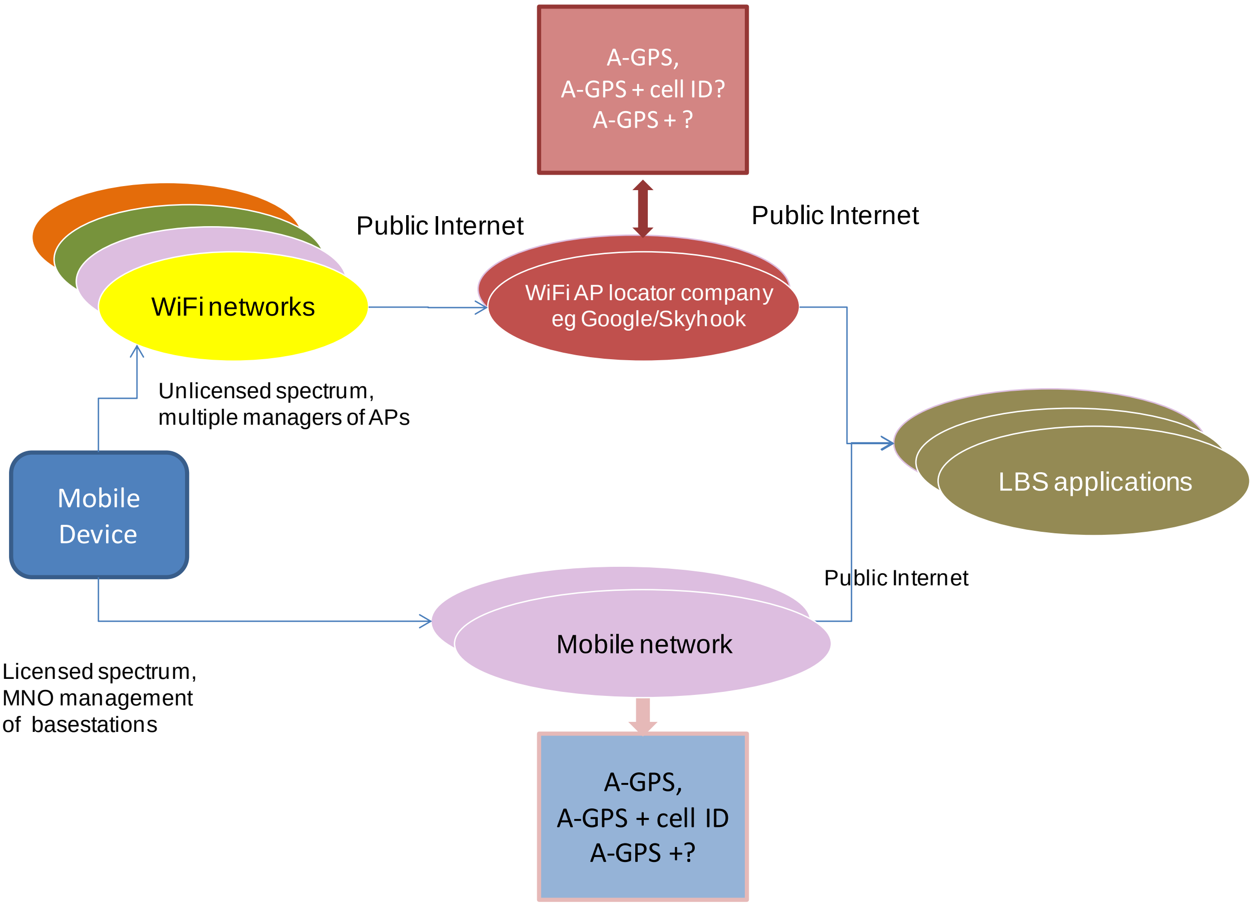
Unlicensed WiFi networks and licensed mobile networks both supply connectivity services to the end user. There are many suppliers of WiFi access points (APs) and these may be switched on or off depending on time of day eg WiFi in cafes, public houses.

In addition in some commercial scenarios the public internet may be used to convey the location information, eg between MNO and location services provider, or between WiFi access points and location services provider.

6.5.3 Model approaches

The organisational structure in Figure 6.3 shows an overview of commercial LBS and the entities involved in realising the end to end service as perceived by the user.

Figure 6.3: Commercial organisation involved in the realisation of LBS to the end user



Source: MM

Users with a GNSS handset may access the LBS using either the MNO or WiFi networks. The WiFi access provider or MNO conveys the request to the LBS who then takes responsibility for determining the user's location making use of the resource of the MNO/WiFi AP locator company. The result will depend on the position determination capabilities of the MNO and the WiFi AP locator company.

6.6 Potential Emergency Services Organisational Models

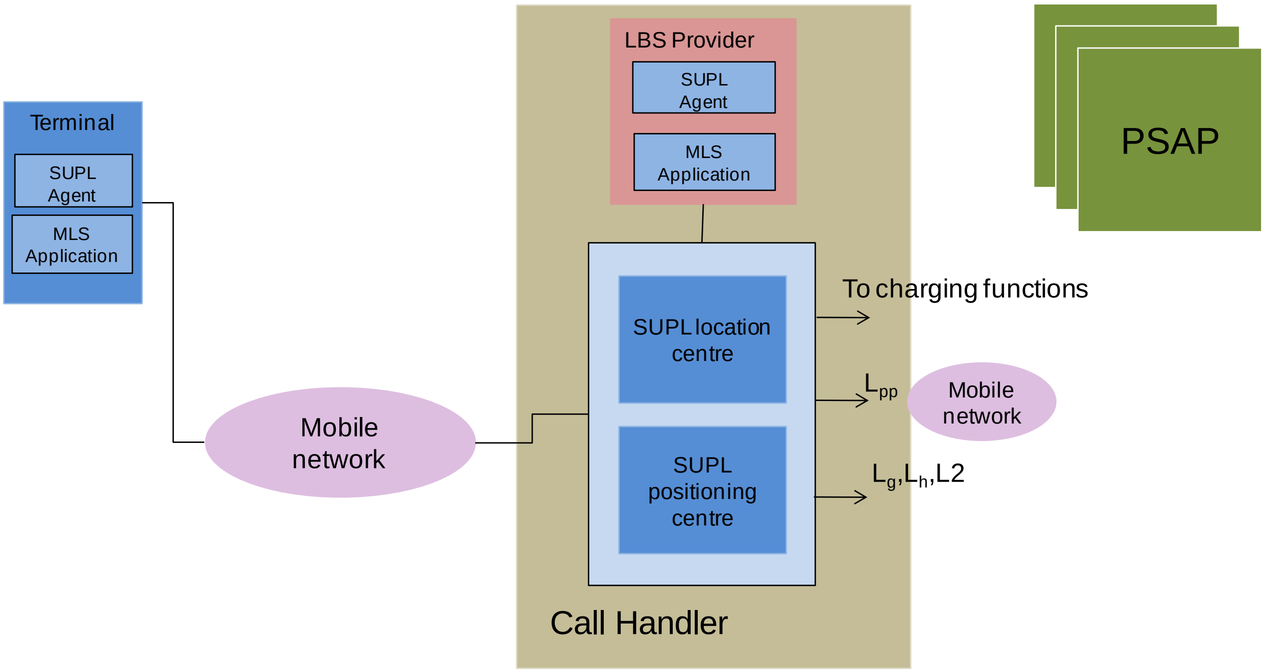
In this section we consider which organisations could provide emergency services location information and consider what the implications may be.

In structures A and B we explore opportunities for the emergency services to take advantage of technology developments ahead of MNOs' ability to integrate a complete set of position determination technologies into their networks.

6.6.1 Structure A – Call Handler

In organisational structure A (see Figure 6.4) the Call Handler is responsible for the LBS application, SUPL agent and mapping the positioning data onto the required format for the emergency services PSAP. The Mobile Network provides positioning in cases where A-GNSS is used but not where autonomous GPS is used.

Figure 6.4: Organisational structure A: Emergency Services LBS



Source: MM

SUPL uses a normal chargeable data bearer service. The user must therefore have a GPS and IP based handset with a data subscription or credit on the handset[72]. Access to a cell site supported by own network

[72] This requirement could be eliminated by special number to send location data to which is non-chargeable to end user- with payments made at wholesale level by mobile network operator or PSAP or PSAP can pay for usage.

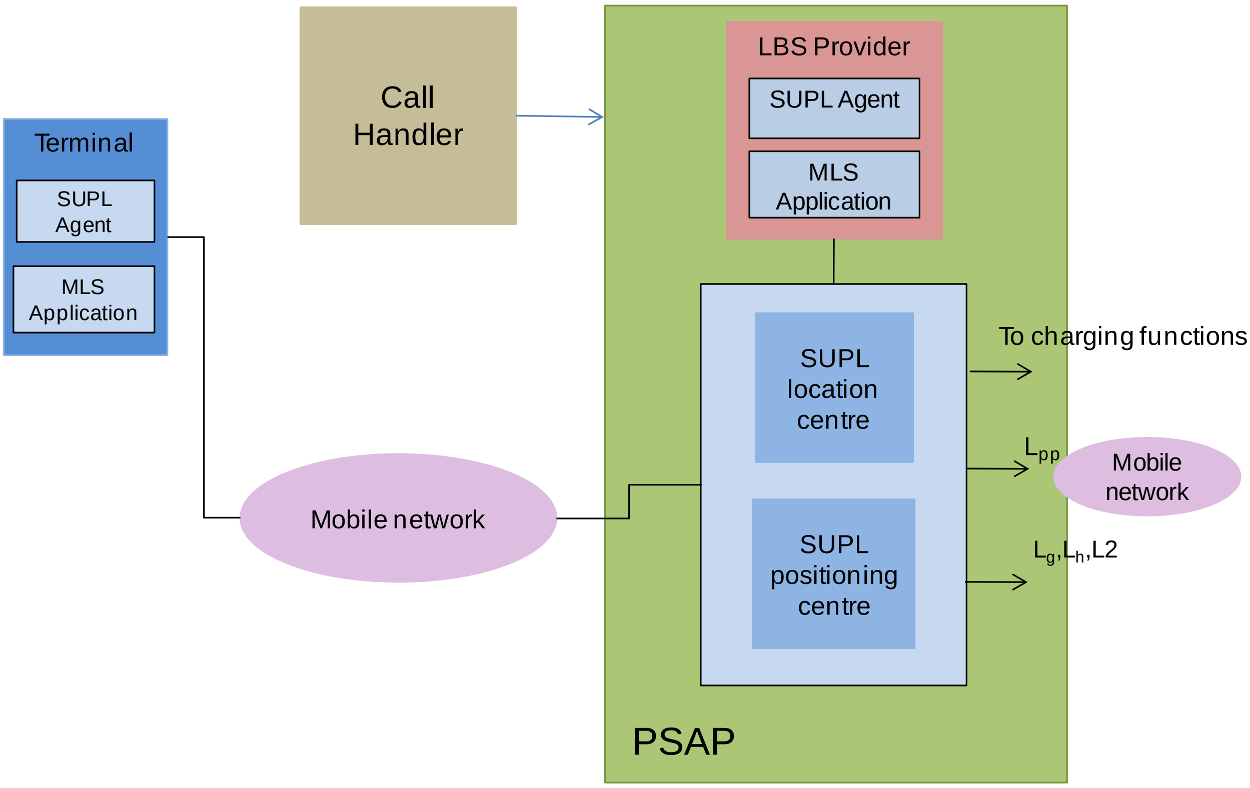
provider/national roaming partner is needed and where the MNO does not support A-GPS and LTE, the Call Handler is responsible for finding an alternate position determination method if autonomous GPS is not sufficient.

In this scenario the call handler can ensure that a common format for positioning/location information is used by all PSAPs. This may have a future benefit in that all PSAPs could potentially use the same mapping tool and future integrations of PSAPs into regional centres would be supported with lower systems integration costs. In this case the Call Handler organisation would take responsibility for delivery of the emergency location service to the PSAP. In this structure each of the PSAPs can independently select the format of positioning / location data to suit its mapping application. This may have ramifications on any future integration of PSAPs into regional or area wide control centres.

6.6.2 Structure B - PSAP

In this structure shown in Figure 6.5 the PSAP or the Regional Emergency control room is responsible for LBS application, SUPL agent and mapping. Mobile Network provides positioning (for A-GNSS etc). Where the MNO does not have A-GPS and LTE capability the PSAP may find an alternative method for position determination. The Call Handler forwards 999/112 voice call as is currently the case.

Figure 6.5: Organisational Structure B: Emergency services Location



Source: MM

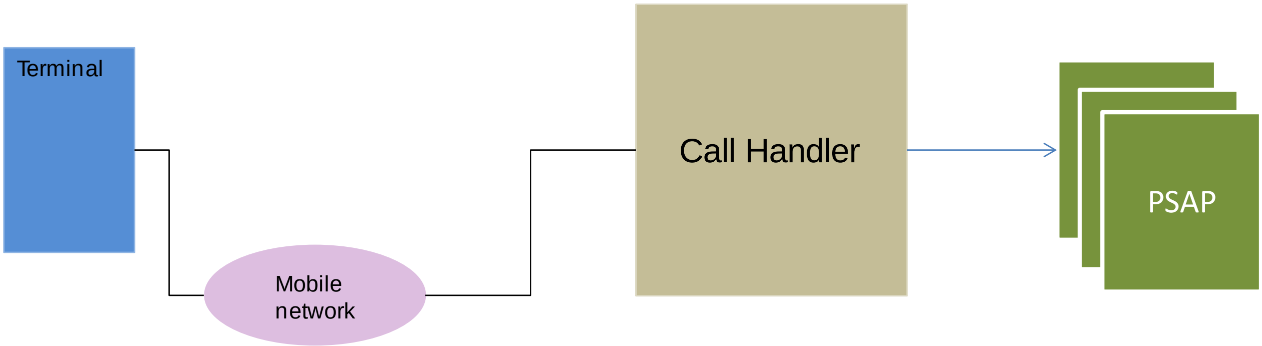
In the structure shown in Figure 6.5the PSAP would take responsibility for delivery of the emergency service location information.

6.6.3 Structure C – MNO emphasis

Mobile network responsible for determining location, passes through to Call Handler, mapping is done in the local PSAP.

In structure shown in Figure 6.6 the MNO takes responsibility for the delivery of the emergency services location information. The MNO is using a range of solutions to determine the location of the user.

Figure 6.6: Organisational Structure C: Emergency services LBS



Source: MM

6.6.4 Structure comparisons

Table 6.2 provides a comparison of the three approaches discussed above.

Table 6.2: Comparison Organisational structures

A	B	C
Single mapping format for all PSAPs managed by Call Handler	Emergency services control requests for location information	PSAP choice of mapping function
Minimal changes to existing relationships	Call Handler's role diminished/not extended	Minimal change to existing relationships
Call Handler experienced in managing location databases	PSAP/control centres need to develop expertise in location databases	Mobile networks manage the complexity of positioning determination

Source: MM

7. Emergency service technologies

It is important to consider changes in the emergency service perspective both in terms of their requirements for location information as well as their ability to productively use such information.

The aim of this chapter is therefore to update the status of the emergency services systems and usage.

7.1 Background

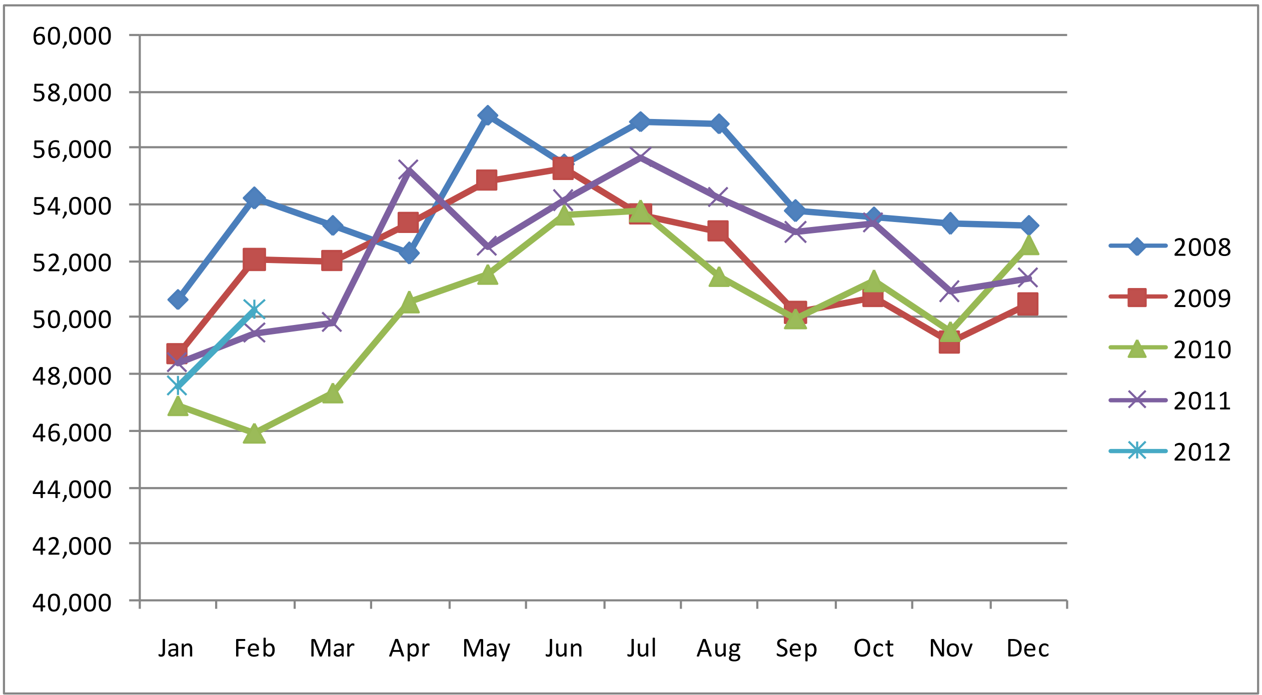
Calls to the Emergency service now total in the region of 22 million per year. Of these approximately 65% now originate from Mobile phones. Mobile callers often face issues in describing where they are located, this may be for a variety of reasons, including being in rural locations with limited landmarks, having travelled to unfamiliar areas of the country or being tourists from other countries. In this last case issues can be exacerbated by language barriers too.

Figure 7.1 shows Emergency calls connected to the EAs by the Call handling Agents. It can be seen that, the decline in call volumes and thus demand on the EA control rooms, ceased after 2010 and now continues to rise year on year. The proportion of connected calls is approximately just over 50% of the total received by the Call Handling Agents.[73]

According to the figures reported to the 999/112 Liaison Committee in April 2012, the Police and Ambulance Service currently handle about 47.5% of the calls each with the remaining 5% being connected mainly to Fire and Rescue services and with a very small proportion being for the Coastguard.

[73] "An analysis of data on the number and handling of 999 and 112 calls"- a summary report normally issued between 999 Liaison Committee meetings, 2nd April 2012, Simon Beresford.

Figure 7.1: Number of Emergency calls Connected to EAs by the Call Handling Agents[74]



Source: Simon Beresford

7.2 PSAP

7.2.1 Research undertaken with Emergency Authority Representatives

As part of the study interviews were undertaken with representatives of the three main Emergency Services. In the previous study discussions were undertaken with control room managers concerning the perceived accuracy and reliability of the information they received and how the information was used by them. In this update study, focus was moved to place more emphasis on the strategic direction of the services and the benefits and barriers for the use of information with a much greater accuracy. Interviews were conducted as follows:

- Steve West – Chief Executive of Association of Ambulance Chief Executives;

[74] An analysis of data on the number and handling of 999 and 112 calls"- a summary report normally issued between 999 Liaison Committee meetings, 2nd April 2012, Simon Beresford.

- Dave Webb – Chief Fire Officers Association Strategic Lead on Operational Communications;
- In addition, Rod Stacey-Marks lead on 999 for Association of Chief Police Officers distributed a survey form to suitable representatives to collect the views of the Police community. Surveys were returned by Durham, Essex, Gwent, Humberside, Kent, Leicestershire, Lincolnshire, Merseyside, Northumbria, Surrey, Sussex, Thames Valley, Warwickshire, and Wiltshire. Results are given against the questions asked in Section 7.2.2.3 below.

7.2.2 Uptake and use of location information

7.2.2.1 Ambulance

The Ambulance control rooms all receive both ALSEC and EISEC information. This is used to pre-populate the Computer Aided Dispatch system (CAD) for fixed line calls and ambulances are initially dispatched to the address provided. For fixed line calls the address availability enables a potentially automated dispatch of a resource but for mobile callers interrogation to determine the location adds extra steps and increases the time for call handling and attendance at the scene. To assist the dispatcher, the location information received for mobile callers is plotted on the GIS and for critical calls the ambulance is initially dispatched by populating the satellite navigation system with the grid reference provided without address information. The call details from the CAD are also sent to the in vehicle Mobile Data Terminal (MDT).

Not surprisingly the Ambulance service finds that the information for landline callers is very reliable but for Mobile callers it is not. The Ambulance service also noted a particular issue where roamers are concerned as often these are tourists unfamiliar with the area or in rural areas where coverage from a home network is not available. In these situations callers often cannot describe their location and the non-availability of an automated position costs vital time locating the casualty.

7.2.2.2 Fire

In the Fire and Rescue Services it was found that very few changes have been made to control room equipment and systems in the years between the first study into this area and this update study due to the uncertainties around the FiReControl project. However there is currently a programme of change-out and reorganisation of FRS control rooms starting to take place.

In line with the previous study it was stated that Fire and Rescue Services (FRS) that subscribe to the ALSEC and EISEC services use it for confirmation of location in conjunction with information gained by caller interrogation and also for call challenge purposes. It was felt that the information concerning location of callers from mobile telephones is currently not of a sufficient accuracy to support location of callers and incidents.

Now all UK FRS use Mobile Data terminals in their vehicles however only about 50% of English FRS use the MDT for mobilisation and messaging between the vehicle and the control room, the others use mainly for risk information. It is likely these systems will be enhanced in the control room upgrades currently beginning to proceed. Scottish and Welsh FRS all use MDTs including messaging capabilities.

7.2.2.3 Police

With the support of ACPO, a questionnaire was distributed to obtain the views of the Police Forces, particularly with respect to the information currently provided to Control Rooms and the opportunities and benefits that would be derived from improvements. It also sought to explore any perceived challenges and barriers to take-up and usage of location information by the Police Forces.

Responses were received from: Durham, Essex, Gwent, Humberside, Kent, Leicestershire, Lincolnshire, Merseyside, Northumbria, Surrey, Sussex, Thames Valley, Warwickshire, and Wiltshire.

Table 7.1 summarises significant areas of the responses:

Table 7.1: Summary of responses to ACPO questionnaire

Question	Response
Is the information made available by the call handling agent / operator in a timely way?	Forces reported obtaining the location information either from EISEC or verbally from the call handler, possibly by the use of a scripted process
How and when is the information used by your emergency call handlers?	Six forces mentioned the use of the information in assisting with finding lost, or uncertain callers or for silent calls or those refusing to provide a location. Four forces said they used the callers no to provide previous call history.
What systems currently support locating callers, eg maps, GIS etc. given the information provided by operators?	Nine Forces indicated that their Incident management system plots geographical location onto a mapping system but two said the coordinates were manually entered into GIS system. One force commented that the GIS could only be used for postal addresses.
What systems currently support mobile	Four forces reported that Sat Nav was used in vehicle to locate incidents but

Question	Response
resources locating an incident? Are there any plans for developing this area?	an equal number indicated that the resources would be guided verbally by the emergency operator and use of local knowledge. There were reports of ongoing development projects in the use of MDTs and in-vehicle mapping systems.
How reliable is the information? Is it currently useful to support location of callers and incidents?	Forces commented that the information was reliably provided but that it was of insufficient accuracy and Provides an Indication only. Comments were also received that the accuracy is less in rural areas and that there were issues with use in large urban areas. One force noted that additional information for roaming handsets is needed. Only one force said that the accuracy provided is generally fit for purpose.
How is this related to any targets, for example in terms of attendance times at incidents or possible incidents averted controlled etc.?	Forces commented that the location information contributes to meeting dispatch and arrival targets which in turn leads to increased public satisfaction.
What opportunities and benefits could be derived from improved accuracy of location for mobile callers?	A number of different areas were cited here : • Potential benefits surround the ability to locate lost / hoax / missing from home silent callers x 3 • Cutting down search areas and thus emergency service resources x 4 • Improved arrival times x 6 • Allowing nearest resource to attend • Early and quick identification of location would be greatly accepted • potentially life saving x 2 • Increased arrests • Greater protection for vulnerable people when they are away from their home addresses.
What would be the challenges and barriers for take-up and usage of improved accuracy by the Police Forces?	Five forces noted the requirement for enabling or altering existing IT systems although one commented that their C&C will already accept more accurate data. It was noted that there may be Human Rights implications and it would be necessary to ensure information could only be used in emergency situations. Other forces noted they may face human resistance to change and the need for training for Control room staff. They also pointed out that improvements must be value for money and timely and simple to use. One respondent felt that there is probably a need for a mandate by OFCOM to the Mobile service providers and by government to the emergency services before there is full uptake of technology that should be in place.
What development programs are currently in place to support or that would be enhanced by better location accuracy?	Respondents noted that trials of mobile data terminals and new or improvements to mapping systems.
What change programmes would be needed to accept information that is more accurate?	Respondents commented that required change programmes would be dependant on the format that the information would be received in. Some noted that they would need to integrate the improved data into control room systems such as ICCS or mapping systems. One force commented that the introduction of Mobile C&C and Mapping to mobile resources would be required. One Force commented that they would not need any changes if the information was still passed to them verbally One respondent felt the government would need to mandate all parties to make it happen.

7.2.3 Perceived Benefits to Improved Location Accuracy

Ambulance service said that improvements in the accuracy of the location information for mobile callers could offer substantial benefits in terms of time to reach patients and the outcomes for them

The Ambulance service perceived that improvements in the accuracy of the location information with which they are supplied with concerning mobile callers could offer substantial benefits in terms of time to reach patients and the outcomes for them. Currently the Ambulance Services have a target of 480 seconds from receipt of the call at the switchboard to reaching the patient; however the process of revising the national performance standards is in progress. This will mean an altered response based on the clinical information and the ambulance services will need confidence in the location information in order to deliver successfully to the revised standards.

The outcome for patients could be significantly affected by accuracy improvements that lead to quicker dispatch of resources to the correct location as statistics show that for survival of cardiac arrest a 1 minute delay in attendance is attributed with 20% higher mortality rates.

The Association of Ambulance Services Chief Executives has written to OFCOM to reinforce the Ambulance services' need for improvements in this area stating they can’t stress enough how important it is for the Ambulance services in light of the fact that calls to Ambulance services are now totalling 8 million a year and this number is growing with 55% now from Mobile Telephones.

Fire and Rescue Services set local targets which are likely to include time to reach the incident. However it is not felt that the location information from mobile callers currently contributes to achieving this kind of target. If location information received about mobile callers was of a similar accuracy to that expected by users who are looking directly at the screen of the smartphone and used by the apps local to the phone such as maps and navigation then the service feels this would open up many possibilities for speeding up location of incidents amongst other things. Accuracy of location would also mean that a greater reliance on the data for filtering duplicate calls and use in call challenge could also be made, with these strategies being important to ensure optimal use of the service’s resources. Using improved information for location of incidents would be especially beneficial for tourists or calls from rural areas away from buildings and landmarks. Numbers of calls to Fire and Rescue Services are now greater from Mobile phones than from Landlines and the proportion is increasing year on year.

During consultations as part of this study, when asked about the Fire Services need to accurately know the location of callers to the Emergency services from Mobile telephones, Dave Webb, CFOA Strategic Lead on Operational Communications suggested it was surprising that this is not provided and thought that it should be, particularly as it is expected by the public.

Improving the accuracy of the location could not only reduce the call handling time, which is on average about 30 seconds longer for mobile calls according to BT research, but could also help to significantly reduce the cost of conducting searches. Research, again done by BT, indicates this is currently of the order of £5million because there are about 36,500 critical incidents a year where long searches are needed. In these circumstances the Emergency Services can spend in excess of 30 minutes trying to find the incident. Depending on the extent and terrain of the search area hourly costs can be in the order of £300 for land teams, £1000 for a boat and £9,000 for a helicopter.

7.2.4 Barriers to uptake

The Emergency services foresee limited barriers to takeup and use of information providing improved accuracy of location for mobile emergency callers as long as the information continues to be provided in the same EISEC and ALSEC formats.

The Ambulance services noted that there would be a need to convert between OS grid reference to a gazetteer premises address based format but discussions with Control Room systems suppliers indicate this is standard functionality.

Regarding the UK Fire Services, there is currently a programme of change-out and reorganisation of FRS control rooms starting to take place in England following the cancellation of the FiReControl Project. There is thus an opportunity to include any changes required to support these improvements.

7.2.5 Implications for Control Room Systems

Vendors indicated that minor changes like a second query of the database once the improved location was likely to be available should not present a problem

Discussions were undertaken with suppliers of control room equipment to establish the impact of improved location accuracy on their systems and the ability of the EAs to make full use of the improved information. The assumption was made that the information would continue to be presented as now by EISEC and ALSEC. Vendors indicated that minor changes like a second query of the database once the improved location was likely to be available should not present a problem. Discussion also surrounded the processing of the grid reference within the EA's systems to present the operator with a short list of addresses adjacent to the indicated position. This is not functionality that would currently be used because the list of addresses within the area provided by the mobile location query would be so long. However if the radius of the area was only a few metres then only a few addresses would be relevant. Vendors we spoke to indicated that conversion of the OS grid reference to a postcode and use of that to query the EAs premises level gazetteer to present the address list to the operator would be standard functionality for their product requiring only configuration rather than modifications.

7.2.6 Conclusions regarding Emergency Authority Requirements

In the two years since the last study, EAs need for improved accuracy of position for mobile emergency callers has matured and they now see it is fundamental for them to improve their response times to incidents and also one of the key things that will enable them to use their resources more efficiently, both in terms of call handling and operational issues such as searching for casualties.

Barriers to takeup of improvement by the end user EAs are low assuming current supporting data exchange formats and processes remain unchanged.

7.3 Call Handling Agents

As part of the study interviews were undertaken with representatives of the two call handlers that handle emergency calls made from Mobile phones in the UK. From BT an interview was conducted with Mr John Medland, 999/112 Policy Manager, and from Cable and Wireless the participants were Mr Justin Hornby, Senior Regulatory Manager, Mr Paul Rosbotham, and Mr Jonathan Welton.

7.3.1 Changes since the previous study

7.3.1.1 The BT Emergency Call Handling Service

Currently of the emergency calls connected to EAs about 92% are via the BT call handling service.

BT remains the call handling agents for all the UK Mobile Network Operators apart from T-Mobile, that is Orange, 3, Vodafone and O2. Although it is possible that Calls from Orange mobiles may in the future be handled by Cable and Wireless plans for any transition are as yet unclear. Currently of the emergency calls connected to EAs about 92% are via the BT call handling service.

As the FrameStream product has been withdrawn EA's have migrated to delivery over the BT IPClear product with ISDN as the backup. However there are a few smaller EAs where ISDN is the primary delivery route.

The EISEC information for fixed lines has been enhanced by inclusion of a flag to denote a Multi-site location i.e. where the line is likely to be to a PBX and BT cannot tell what is behind. This enables the call handling agent to query the caller's location before passing the call and this flag is also available to the EA.

Orange still only has 1 mobile location server instead of the recommendation of at least 2 (as per the other operators) however they have said they will be getting a second server to improve this.

The Emergency SMS Service

Emergency SMS has also been introduced and BT provide this service for all mobile networks. The voice part of the call is then forwarded to the call handling operator relevant to the originating network. The service uses the standard SMS service and so is a best efforts rather than guaranteed delivery – part of the reason for the registration process is that the message that it must not be assumed that assistance is on its way until a response to that effect is received is reinforced at that stage.

When SMS messages are sent to '999' or '112' they go to an SMS aggregator, which BT support on 2 servers, and these generate a call based on the 18000 service to the text relay centre and from there a 999 voice call is placed to the appropriate EA with, for BT handled calls, the location made available verbally and via the EISEC service.

As the BT centre will not receive the auto cell id to route the call, for calls where BT is the call handling agent, the location for SMS calls is found by the BT operator centre placing a query on the mobile location centre using the CLI of the message. The grid reference found is then used to match for the EA. This is in place of the zone code which is used for voice calls as that obviously is not available for SMS receipts. For calls where the call handling agent is Cable and Wireless location of the mobile is not available and so is manually requested from the caller.

Table 7.2: Emergency Authorities Subscribing to the EISEC Service as at April 2012

POLICE	AMBULANCE TRUSTS	FIRE	COASTGUARD
CAMBRIDGESHIRE	EAST OF ENGLAND*	AVON	ALL
CENTRAL SCOTLAND	EAST MIDLANDS*	BUCKINGHAMSHIRE	
CLEVELAND*	GREAT WESTERN*	CAMBRIDGESHIRE (inc SUFFOLK)	
CUMBRIA	ISLE OF WIGHT	CHESHIRE	
DERBYSHIRE	LONDON*	CLEVELAND*	
DEVON & CORNWALL	NORTHERN IRELAND	CORNWALL*	
DORSET*	NORTH EAST*	CUMBRIA*	
DUMFRIES & GALLOWAY	NORTH WEST*	DEVON & SOMERSET	
DURHAM*	SCOTTISH*	DORSET	
ESSEX*	SOUTH CENTRAL*	DUMFRIES & GALLOWAY	
FIFE	SOUTH EAST COAST	ESSEX	
GRAMPIAN	SOUTH WESTERN	GRAMPIAN	
GREATER MANCHESTER	STAFFORDSHIRE	HAMPSHIRE*	
HAMPSHIRE*	WELSH*	HERTFORDSHIRE	
HERTFORDSHIRE	WEST MIDLANDS*	HUMBERSIDE	
HUMBERSIDE	YORKSHIRE*	KENT	
KENT		LONDON*	
LANCASHIRE		LOTHIAN & BORDERS	
LINCOLNSHIRE*		MERSEYSIDE	
LOTHIAN & BORDERS		MID & WEST WALES*	
MERSEYSIDE*		NORFOLK*	
METROPOLITAN*		NORTH WALES*	
NORFOLK		NORTH YORKSHIRE*	
NORTH WALES		NORTHERN IRELAND	
NORTH YORKSHIRE		SOUTH WALES*	
NORTHAMPTON SHIRE		SHROPSHIRE	
NORTHERN*		STAFFORDSHIRE*	
NORTHERN IRELAND		STRATHCLYDE*	
NOTTINGHAMSHIRE*		SURREY (inc IoW)	
SOUTH YORKSHIRE		TAYSIDE	

POLICE	AMBULANCE TRUSTS	FIRE	COASTGUARD
STAFFORDSHIRE		WARWICKSHIRE	
STRATHCLYDE*		WEST MIDLANDS	
SUFFOLK		WEST SUSSEX	
SURREY*		WEST YORKSHIRE	
SUSSEX*			
THAMES VALLEY*			
TAYSIDE			
WARWICKSHIRE			
WEST MERCIA			
WEST MIDLANDS			
WEST YORKSHIRE			
WILTSHIRE*			
ASTERIX * INDICATES MLG			

Table 7.2 shows the updated list of EAs subscribing to the BT EISEC Service. There are 127 EAs in total and 92 of these now subscribe to EISEC (72%) however out of the 187 Emergency control rooms run by these EAs 150 have access to the EISEC information (80%).

7.3.1.2 The Cable and Wireless Emergency Call Handling Service

Currently of the emergency calls connected to EAs about 7.5% are via the Cable and Wireless call handling service.

Only minor changes have taken place to this service with Cable and Wireless still handling calls for T-Mobile only. There is currently a migration process ongoing to enable T-mobile to use a greater range of cell-ids. These cell Ids are used as part of the stage 1 look-up to reference the location to the correct Emergency Authority. Currently of the emergency calls connected to EAs about 7.5% are via the cable and wireless call handling service.

7.3.2 Opportunities and Challenges

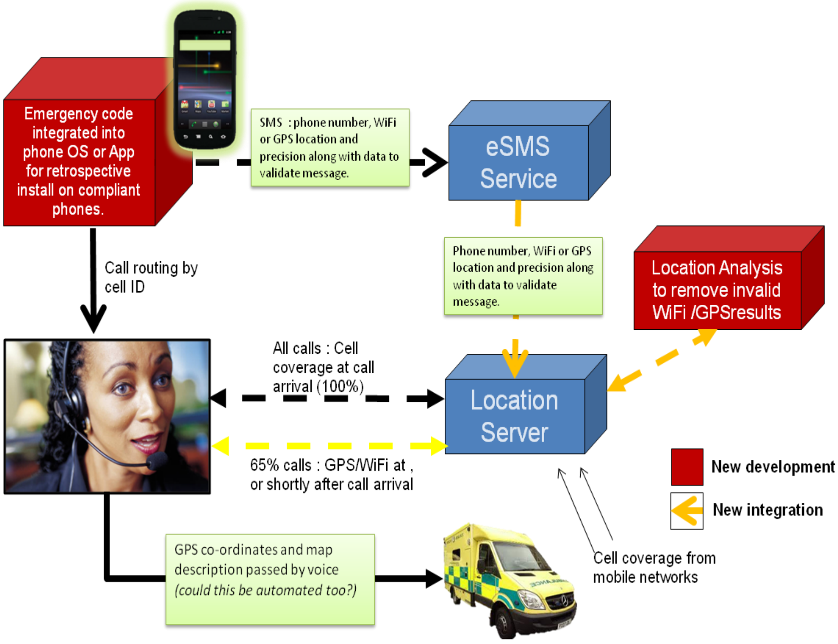
7.3.2.1 BT Trial of their ‘Emergency Location App’

BT identified an opportunity arising from the prevalence of smartphones and their inherent location features, as discussed above. A limited trial was conducted to leverage the functionality already available in the handsets and taking advantage of their existing SMS platform to determine the effectiveness for supplementing the existing cell location without requiring any changes by the Mobile network operators.

BT built an App which if, '999' or '112' is dialled, the requests the phone's WiFi and GPS position using the Android APIs.

BT built an App which monitored the number being dialled, the idea was that when this matched with the emergency number, '999' or '112', the App would request the phone's WiFi and GPS position using the Android APIs. After a configurable time it would send the best location according to source, time and precision using an SMS message to a pre-defined configurable destination.

Figure 7.2: High Level Architecture for BT Emergency Location APP



Source: Discussions with BT

Position is forwarded as an SMS to the emergency SMS server but flagged differently to an emergency SMS message.

This would then be forwarded as an SMS to the SMS server but flagged differently to an emergency SMS message. Figure 7.2 illustrates the proposed high level architecture[75].

19 triallists with a variety of Android handsets made test calls, in seven types of location – Countryside, Village, Rural within a car, Urban, Motorway, House and Office. The results were logged including the location and precision reported in the message from the handset and the actual location of the caller. The accuracy was then calculated as the distance between the reported location and the actual location.

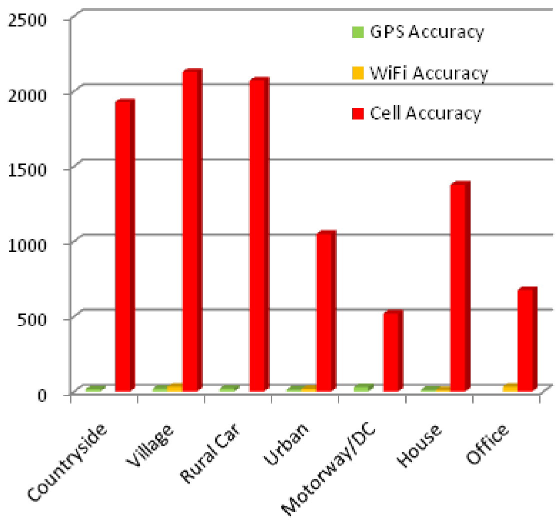
[75] BT presentation "Trial Report – Emergency Location App" at EENA Conference April 2012, John Medland, BT Senior Product Manager 999/112

The results of this small scale trial were encouraging as illustrated in Table 7.3 and Figure 7.3 below[76].

Table 7.3: Results from Trial of BT Emergency Location App

Location Type	GPS Accuracy	WiFi Accuracy	Cell Accuracy
Countryside	13		1926
Village	18	32	2126
Rural Car	18		2069
Urban	13	17	1049
Motorway/DC	29		519
House	9	9	1376
Office		32	675

Figure 7.3: Results of BT Emergency Location App



Source: BT

In order to achieve the best location information for a particular call, the method included comparison of the SMS derived location with the cell coverage derived location and, where the former fell within the area of the latter, to replace the network derived location information with the SMS derived location. The trial found that using this methodology

[76] BT presentation "Trial Report – Emergency Location App" at EENA Conference April 2012, John Medland, BT Senior Product Manager 999/112

receipt of the GPS/WiFi position data from the handset dramatically improved the accuracy for 65% of the calls.

Although the trial was considered successful in proving the possibility of enhancing cell location with handset originating GPS or WiFi position, there were some challenges discovered during the trial.

Because of the possible delay before the EISEC database has been populated with the most accurate information, it may be necessary for the EA control room systems to re-interrogate the EISEC after a short period of time.

An issue was discovered with some common handsets that meant if one of the two emergency numbers was dialled the location apps were shutdown and only the voice call could proceed. This meant the testing was undertaken using a dummy alternative number in place of 999 or 112.

It is also unlikely that this route would work for either Limited Service state roamers due to the persisting lack of CLI to perform the lookup in the EISEC/ALSEC database, or Full roamers due to constraints in the SMS delivery mechanisms.

Even for the GPS results, EAs would need to be aware that the caller may be just outside the predicted area, still providing a very small search area.

Feedback from EAs concerning the App has been very positive as it is seen as a way of achieving improvements very rapidly for a good proportion of callers, especially those in rural areas

Feedback from EAs concerning the App has been very positive as it is seen as a way of achieving improvements very rapidly for a good proportion of callers, especially those in rural areas. There was a discussion on the topic included as part of the BAPCO 2012 '999 futures' closed session. In addition to discussing the base proposal, attendees also proposed that the app could, in time, contain features to allow a user to program the app with relevant information such as pre-existing medical conditions for sending to the Emergency Agencies at the time of a call and possibly allow the user to subscribe to feeds concerning civil contingency type events.

8. Regulation and standards

Developments in other European countries and in the US and implications for UK approaches

The main aim of this chapter is to examine developments in other European countries and in the US and to consider what implications this may have for UK approaches.

In a European context, the chapter considers EU wide thinking and emerging regulation and proceeds to examine how this is being implemented in those European countries thought to be at the most advanced stage.

For the US, the latest FCC developments are considered using the available documentation and the implications for the UK set out.

The chapter covers regulations and standards directly applicable to emergency location. Accordingly, wider standards and regulation such as LTE developments are considered within the appropriate technology sections.

8.1 EU developments

8.1.1 The Regulatory Position

In December 2010 the European Emergency Number Association published a position paper on the provision of mobile caller-location information for emergency callers[77]. The paper sets out the view that improvements should be addressed as a priority and that The Universal Service Directive (2009/136/EC) provides the legal framework for the competent regulatory authorities to "lay down criteria for the accuracy and reliability of the caller-location information provided" and enables the Commission to "adopt technical implementing measures" to ensure effective access to "112" services in the Member States[78]. It also expresses the view that EU countries are falling behind the US on implementation of a solution to the issue and proposes that the Commission should act to ensure caller location throughout Europe to specific performance standards.

[77] "EENA Position Paper on the provision of mobile caller-location information in the context of calls to the European emergency number 112", EENA, Brussels, December 2010

[78] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:337:0011:0036:EN:PDF

New requirement that caller location information is made available free of charge to the authority handling emergency calls as soon as the call reaches that authority

The European Regulatory arrangements under article 26 on the "Single European emergency call number" of the Universal Service Directive (2002/22/EC) were revised on 26 May 2011 by the Citizens' Rights Directive (2009/136/EC)[79]. Included in the new provisions is the requirement that caller location information is made available free of charge to the authority handling emergency calls as soon as the call reaches that authority. This is now an obligation with the previously included "technical feasibility" phrase no longer present. The new provisions confirm that "Competent regulatory authorities shall lay down criteria for the accuracy and reliability of the caller location provided".

Consultations regarding possible standardisation for 112 Apps are on-going at present

EGEA (Expert Group on Emergency Access) has been established as a subgroup under the Communication Committee (COCOM). It is the main Consultation platform for the 112 related initiatives of the Commission such as consultation with Member States for identification of standardisation needs. Consultations regarding possible standardisation for 112 Apps are on-going at present[80].

8.1.2 The COCOM Report

The European Commission Communications Committee published a working document entitled "*Implementation of the European emergency number 112 – Results of the fifth data-gathering round*"[81] in March 2012. It was based on responses to a questionnaire which was distributed in June 2011 with replies submitted during October 2011. There were 31 responses which were from the 27 Member States plus Croatia, Iceland, Liechtenstein and Norway.

The questions of interest to this study enquired about the current state of requirements laid down by the NRA for accuracy and reliability of mobile emergency caller location and the current state of implementation for categories of caller including mobile callers on their home networks, national and international roamers and also SIM free callers. The current state of regulation by NRAs is summarised in Table 8.1.

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[79] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:337:0011:0036:En:PDF

[80] http://www.eena.org/ressource/static/files/presentation-on-the-eu-regulatory-framework---riga.pdf

[81] http://circa.europa.eu/Public/irc/infso/cocom1/library?l=/public_2012/cocom12-01_112pdf/_EN_1.0_&a=d

Table 8.1: The State of Regulation by NRAs

No Requirements for Accuracy or Reliability laid down	Requirements for Accuracy to Cell level laid down	Other
Austria	Belgium	France – Most precise that is technically possible
Bulgaria	Cyprus	
Czech Republic	Hungary	Germany - Now in implementation, mobile radio cells emergency call regulation in conjunction with technical guidelines for emergency calls.
Denmark	Ireland	
Estonia	Italy	
Finland	Netherlands	
Latvia	Portugal	Greece – best accuracy technically possible.
Lithuania	Romania	
Luxembourg	Spain	Slovenia – Rules on quality of service for the single European emergency call number 112
Malta	United Kingdom	
Poland	Norway	
Slovakia		
Croatia		Sweden – shall be as accurate and reliable as can be reasonably required.
Iceland		
Liechtenstein		

Status of Cell ID forwarding and supporting location information

All countries that responded to the COCOM survey indicated that Cell ID and/or Sector ID for the mobile caller is now made available to EAs. Excluding the United Kingdom, the existence of additional facilities to increase accuracy of mobile caller location, based on measurements and calculations (‘timing advance information’) was reported for Denmark, Italy, Poland, Finland and Norway. Estonia reported that ‘an upgrade of the system should be in place by the end of 2011. France reported that relevant postal code for the mobile caller location is given.

Liechtenstein reported using a “Highly optimized probability calculation, which is based on cell ID, field strength predictions, several calibrations and combining data from cell ID changes during the call. It has a hit rate of 95%.”

Findings were the same as those gathered previously so little has changed in recent years

The report also noted the fact that the findings were the same as those gathered previously so little has changed in recent years.

In conclusion it is notable that only Cell-ID or Sector-ID are provided in Europe despite some other countries, for example the USA, having stronger accuracy requirements. Although NRAs in member states have the ability to specify accuracy and reliability requirements this report shows that these criteria have not been defined.

8.1.3 Follow up research

Following on from the COCOM report, 19 emails were sent to contacts in 16 states who provided contact information. These were: Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Malta, Slovakia, Iceland, Liechtenstein, Belgium, Netherlands, France, Greece, Slovak Republic, Sweden and Finland. The email requested details of any policy or plans concerning regulation of the mobile caller location provisions. In particular the aim was to find out about any strategy for improving accuracy or possibly amending or strengthening the requirement for mobile network operators to provide reliable and accurate location information. The contacts were also asked about barriers to implementation or deployment of improvements and about plans to address the issues for roaming handsets.

Responses were received from Slovak Republic, Belgium, Lithuania, Finland and Estonia

Responses were received from Slovak Republic, Belgium, Lithuania, Finland and Estonia.

Lithuania

Lithuania responded that they had no current plans for improvements but that they may consider this when the eCall project is complete. They also noted their financial budget constraints.

Finland

Finland responded that their 112 call location system is based on the same location servers which the operators use for business applications. Although it is stated that the best available information should be used for 112 call location information, this requirement has not been included in regulations and there is no statistical information concerning past performance. Including a requirement for the operators to supply the best available information for 112 call location in the regulations is being considered but it is felt that because the accuracy depends on the technology (2G, 3G, 4G) and on the current status of the operator network it is very difficult to set specific values, and perhaps more difficult to verify they are being met. The value of the location information to the PSAPs was acknowledged even if accuracy is limited and it is only used to verify the caller provided information. In Finland the operators are entitled to compensation for extra costs incurred for improvements and for this reason the NRA is very hesitant to set more requirements, they feel that the operators will make improvements (e.g. A-GPS) because of business application needs and that these improvements will then be available for 112 calls without additional cost. When considering barriers to deployment, they felt that things such as the 112 call app might slow down other improvements as operators waited to see what happened. Discussion concerning how roamers could be included in the 112 call location system has taken place in the national emergency call working group but there is no solution yet.

Estonia

The Estonian contact from the COCOM report advised that ETSA (Estonian Technical Surveillance Authority) performs only supervision over the requirements specified in the Estonian Electronic Communications Act and that the requirement for service providers to provide location information is not implemented in this Act. Following this a follow up email was sent to the Ministry of Economic Affairs and Communications but no response has been received.

Slovak Republic

The Slovak Republic contact advised that they currently have a new decree at the draft stage which concerns the provision of caller identification and location to their integrated rescue system. The work is a joint exercise between the Ministry of Interior and the Telecommunications Regulatory Authority. Indicative timescales are that it is likely to come into force at the end of 2012. It will stipulate that the location data must be provided to the PSAP until 15 seconds from the beginning of the emergency call or from the request from the PSAP. The accuracy must be at least to sector level and provision for full and limited service state roamers is included. Details about communications protocols in which the information shall be transmitted are also included.

Belgium

The Belgian response advised that during 2011, certain Belgian call centres had new functionality introduced which displayed a circle for the operators to show the caller's general location, with the circle depending on the range of the receiving mobile phone antenna. The remaining eight call centres will gain this functionality in the following years with upgrades to their control room systems. There are no other caller location-functionalities planned in the near future which require mobile network operators to provide more accurate location information.

At the EENA EU Emergency Services Workshop in Riga, Latvia during April 2012 delegates were asked a number of questions concerning EU regulation during an interactive session. Amongst these one question

Support for mandatory requirements and Apps

concerned whether the Commission should propose some recommendations or mandate requirements for caller location criteria. Of the total delegates (approximately 320) 92.7 % were in favour of Mandatory requirements however this rose to 100% when considering just the attendees from the public sector[82]. When addressing a further question 64% of attendees thought that any app could be used as long as it complies with a list of standards and requirements defined at a European or international level whereas only 20% were in favour of a single app to be used all over Europe.

8.1.4 112 Applications (Apps)

112 Apps are being widely discussed in the EU and its member states. At 112 day 2012 Vice Presidents of the European Commission Neelie Kroes and Siim Kallas committed: "to ensure every European can access a 112 smartphone app, in their own language"[83]. In addition to the version trialled by BT in the UK, work is being done on a similar App in the Netherlands and the concept of an EU wide App is also being discussed[84].

In the Netherlands a proof of concept app have been used to meet communication needs for hearing impaired users and utilise GNSS information from smartphones. Further developments are planned for this[84].

EGEA foresee a staged development of a 112 EU App

EGEA foresee a staged development of a 112 EU App[84]. Version 1 of the app is timetabled for 2012 and should provide a 112 speed dial button and display 112 related information in the user's chosen language. Version 2 is timetabled for early 2014 and should additionally be capable of transferring a minimum set of data, including location. Version 3 is envisioned to contain more multimedia functionality in line with the NG112[85] work with a timeline until about 2015.

During his presentation at the 2012 EU Emergency Services Workshop, Gyula Bara from the European Commission acknowledged that "the concept of 112 Apps covers a wide range of emergency assistance applications for smartphones and other similar mobile terminal devices, from speed dial buttons to GNSS location data enhanced calls and

[82] http://www.eena.org/ressource/static/files/2012_04_20_votingsession.pdf
[83] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/12/120
[84] http://www.eena.org/ressource/static/files/chris-van-hunnik---112-help--egea.pdf
[85] http://www.eena.org/ressource/static/files/eena_ng112_ltd_v1-0_final.pdf

multimedia communication." He also reported that EGEA has given its support for the development of "endorsed" 112 Apps and provided input on the functional needs and requirements for these[86].

Standards issues with Apps - TISPAN

When looking at 112 Apps as a solution to the problem of providing locations for emergency callers from mobile handsets however it should be noted that one of the requirements for the European Standards Organisation TISPAN (Telecoms and Internet converged Services and Protocols for Advanced Network) standardisation body, working to define the architecture required under standardisation mandate 493 in support of the location enhanced emergency call service, is that "The architecture shall not be based on location information provided by an entity controlled by the user."[87] This may not be in line with the concept of the 112 App.

8.2 US FCC developments

The FCC Phase 2 Enhanced 911 emergency positioning requirements[88] mandate that the cellular network operators must ensure positioning of wireless terminals with an accuracy of:

- 50m in at least 67% of cases
- 150m in 90% of cases

These figures apply to user equipment based positioning methods principally the GPS receiver and apply within 8 years of the order (effective January 2011) with an exclusion of 15% for heavily forested areas. For network based positioning, the equivalent requirements are 100m at 67% and 300m at 90%. In all cases, the response time shall be 30s after an E911 call is placed and confidence and uncertainty data are also required.

Recent indications from the FCC suggest that they may discontinue the network positioning requirements

Recent indications from the FCC suggest that they may discontinue the network positioning requirements.

These requirements imply an availability of 95% which is difficult given that more than 50% of calls are made indoors, where GPS will not work

[86] http://www.eena.org/ressource/static/files/presentation-on-the-eu-regulatory-framework---riga.pdf

[87] http://www.eena.org/ressource/static/files/wlange.pdf

[88] Wireless E911 Location Accuracy Requirements, PS Docket 07-114, Second Report and Order, FCC 10-176, 25 FCC Rcd 18909 (2010).

predictably. This means that operators must provide a fallback method or an alternative to GPS / AGPS which does meet the requirement.

The FCC issued a proposed rulemaking document on emergency location in July of 2011. This set out to strengthen the E911 regulations and to consider how to include the increasing use of VoIP within the regulations. Some of the points which emerged from this review were as follows:

- Persisting with the joint handset / network based approach, but aiming to phase out the network based positioning standard over time;
- Requiring wireless carriers to test outdoor E911 location accuracy results periodically and to share the results with Emergency Service users;
- Seek to improve the VoIP 911 availability and location determination considering both the outbound (to PSTN) and inbound (from PSTN) situations.

The issue of VoIP is recognised as being of increasing importance, but no clear strategy has emerged at this stage in the US

The issue of VoIP is recognised as being of increasing importance, but no clear strategy has emerged at this stage in the US. One of the key questions for the medium term here is whether VoIP service providers should have to provide automatic location information (ALI). It is also recognised that such a requirement would also be likely to require the involvement of those providing the underlying network connectivity.

Another area of interest for the FCC is indoor positioning, particularly as it is noted by J D Power that indoor mobile use has increased from 40% to 56% of totals over the past 8 years. Further testing is supported though there is some resistance to this from operators who cite the difficulties and hence the cost of in-situ testing. Between the basic cell mast triangulation and the outdoor accuracy of GPS there are a number of options such as WiFi which could be used. Comments on these intermediate methods suggested that while they are capable of good accuracy in certain circumstances, they cannot be relied on to provide reliable accuracies nor is their coverage good outside urban areas.

In addition to the July documents referred to above, the FCC also produced a technical review in March 2011 which provides a good baseline review of the current state of the location technologies in a US context, and useful also for the study proposed here. This review recommended that FCC policy should "balance the continual refinement of location accuracy with the cost benefit trade offs and needs of public safety and other stakeholders" and further that the complexity of the issues will require an on-going analysis effort. It is also recommended that the FCC not mandate specific technologies but that all technologies should provide for sending their location to PSAPs if called upon to do so.

Appendices

Appendix A. Glossary

2G	2G refers to second generation mobile phone technology, such as GSM. The main differentiator to previous mobile telephone systems, retrospectively dubbed 1G, is that the radio signals that 1G networks use are analogue, while 2G networks are digital.
3G	3G is the third generation of mobile phone technology. It is reflected in the International Telecommunication Union (ITU) Recommendation on International Mobile Telecommunications- 2000 (IMT-2000). 3G technologies enable network operators to offer users a range of advanced services while achieving greater network capacity than 2G through improved spectral efficiency. Services include wide-area wireless voice telephony and broadband wireless data, all in a mobile environment.
3GPP	The 3rd Generation Partnership Project (3GPP) prepares, approves and maintains globally applicable technical specifications and technical reports for the evolved 3rd generation and beyond mobile system known as UMTS and LTE/E-UTRA. 3GPP also maintains the technical specifications and technical reports for GSM, including GPRS and EDGE.
A- GPS (A-GNSS)	Assisted GPS, a system where a combination of GPS and a terrestrial wireless network is used to accurately and quickly position a handset/device. A-GNSS is a generic term for the same approach
API	Application Programming Interface, allows developers to develop a system which can interface to another system, interface is well defined in its semantics, syntax etc
BTS	In a cellular system the Base Transceiver Station terminates the radio interface. Each BTS may consist of a number of TRX (Transceivers), typically between 1 and 16 in a GSM system.
CDMA	Code Division Multiple Access (CDMA) is a multiple access scheme for digital radio, to send voice, data, and signalling data between mobile phones and cell sites. CDMA channels are defined Consultation on the way forward for the future use of the band 872 - 876 MHz paired with 917 - 921 MHz 111 with codes and permit many simultaneous transmitters on the same frequency channel. CDMA is widely deployed in North America and Asia
CHA	Call Handling Agent, in UK a Call Handling Agent is used as first stage PSAP, before call is onward routed to 2nd stage PSAP
Cell-ID	The identity of a cell, held by the mobile operator, usually defined by the location of the tower and has a coverage which is known to the operator
CEPT	European Conference of Postal and Telecommunications CEPT - was established in 1959. CEPT is the European regional organisation dealing with postal and electronic communications service issues. CEPT's activities included cooperation on commercial, operational, regulatory and technical standardisation issues. CEPT currently has 45 members. www.cept.org
CGI/TA	Cell Global Identity and Timing Advance Cell Global Identity (CGI) uses the identity that each cell (coverage area of a base station) to locate the user. It is often complemented with the Timing Advance (TA) information. TA is the measured time between the start of a radio frame and a data burst. This information is already built into the network and the accuracy is good when the cells are small (a few hundred meters). For services where proximity (show me a restaurant in this area) is the desired information, this is a very inexpensive and useful method. It works with all existing terminals, which is a big advantage. The accuracy is dependent on the cell size and varies from 10m (a micro cell in a building) to 500m (in a large outdoors macro cell).
EA	Emergency Authorities
E-CGI	Enhanced Cell Global Identity
EC	The European Commission. The European Commission embodies and upholds the general interest of the European Union and is the driving force in the Union's institutional system. Its four main roles are

	to propose legislation to Parliament and the Council, to administer and implement Community policies, to enforce Community law (jointly with the Court of Justice) and to negotiate international agreements, mainly those relating to trade and cooperation. http://ec.europa.eu/atwork/index_en.htm
ECC	Electronic Communications Committee. Created by the CEPT to consider and develop policies on electronic communications activities in CEPT member countries, taking account of European and international legislation and regulations. www.ero.dk.
E-CID	Enhanced Cell ID
EGNOS	European Geostationary Navigation Overlay Service
E-OTD	Enhanced Observed Time Difference
ETSI	European Telecommunication Standards Institute. ETSI produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies. ETSI is officially recognized by Consultation on the way forward for the future use of the band 872 - 876 MHz paired with 917 - 921 MHz 112 the European Commission as a European Standards Organization and is an Organizational Partner in 3GPP. http://www.etsi.org/
EU	The European Union (EU) is a unique supernational union, made up of twenty-seven member states. It was established as the European Economic Community in 1957 by the Treaty of Rome and has undergone many changes since, most notably in 1992 by the Maastricht Treaty. Since 1957 new accessions have raised the number of member states, and powers have expanded.
EV-DO	Evolution-Data Optimized EV-DO is a telecommunications standard (cdma2000 1xEV-DO) for the wireless transmission of data through radio signals, typically for broadband Internet access. It is standardized by 3rd Generation Partnership Project 2 (3GPP2) as part of the cdma2000 family of standards and is part of IMT-2000.
eSMLC	Evolved SMLC (proposed for use in LTE networks)
FCC	Federal Communications Commission (regulatory body of US telecommunications)
FDD	Frequency Division Duplex (FDD) is a means of providing duplex (bidirectional) communications in wireless networks, FDD makes use of separate frequencies for uplink and downlink channels. FDD is used with both analogue and digital wireless technologies, including cordless telephony and cellular i.e. GSM and UMTS900.
FOMA	NTT Docomo's 3G FOMA service, deployed in the 2 GHz frequency band, uses packet data transfer speeds ranging from 64 kbps to 384 kbps to support a broad variety of applications that include Internet access, e-mail, file transfers, remote log-in and Internet phone applications. In addition, ISDN-type services functioning on a streamed basis effectively employ nx64 kbps channels to support applications such as telephony, video-conferencing and Group 4 faxing. Further, high-quality voice services at up to 12.2 kbps are also available. This is based on ATM technology
GIS	Geographic Information System
GMLC	Gateway Mobile Location Centre allows a GSM or 3G wireless network to provide positioning information to a core network, applications, billing and provisioning systems. Needs an SMLC to complete the function
GNSS	Global Navigation Satellite System
GPS	Global Positioning System. It is a specific GNSS as will be Galileo
GPRS	GPRS (General Packet Radio Service) is a mobile connectivity solution based on Internet Protocols that supports a wide range of enterprise and consumer applications. With throughput rates of up to 40 Kbit/s, it has a similar access speed to dial-up modems. Further data rate increases have been achieved with the introduction of EDGE (Enhanced Data rates for Global Evolution). http://www.gsmworld.com/technology/gprs/index.shtml
GSM	Global System for Mobile communications (GSM) is the second generation digital cellular telecommunication system implemented in the UK and many other countries across the globe. http://www.gsmworld.com/technology/gsm.shtml

HSPA	High Speed Packet Access (HSPA) is a collection of mobile telephony protocols that extend and improve the performance of the (Universal Mobile Telecommunications System) radio access network. Consultation on the way forward for the future use of the band 872 - 876 MHz paired with 917 - 921 MHz 113 Hz The hertz (symbol: Hz) is the SI (International System of Units) unit of frequency. Its base unit is cycle/s or s-1 (also called inverse seconds, reciprocal seconds). One hertz simply means one per second (typically that which is being counted is a complete cycle); 100 Hz means one hundred per second, and so on.
iDEN	US standard for mobile network (analogue)
IMT-2000	International Mobile Telecommunications-2000 is the global standard for third generation (3G) wireless communications, defined by a set of interdependent ITU Recommendations.
ITU	International Telecommunication Union. Headquartered in Geneva, Switzerland, it is an international organization within the United Nations System where governments and the private sector coordinate global telecom networks and services. http://www.itu.int kHz Kilohertz abbreviated kHz, is a unit of frequency equal to one thousand hertz (1,000 Hz).
LAN	A local area network (LAN) is a computer network covering a small physical area, like a home, office, or small group of buildings, such as a school, or an airport. The defining characteristics of LANs, in contrast to wide-area networks (WANs), include their usually higher data-transfer rates, smaller geographic range, and lack of a need for leased telecommunication lines.
LCS	Location Service
LES	Location Enabled Services
LBS	Location Based Services
LPP	LTE Positioning Protocol (suffix e = extensions)
LTE	Long Term Evolution is the name given to a project within the Third Generation Partnership Project (3GPP) to enhance the Universal Mobile Telecommunications System (UMTS) mobile phone standard. The resulting E-UTRA (Evolved Universal Terrestrial Radio Access) radio interface is based on orthogonal frequency division multiple access (OFDMA) for the downlink and single carrier frequency division multiple access (SC-FDMA) for the uplink. MHz Megahertz abbreviated MHz, is a unit of alternating current or electromagnetic wave frequency equal to one million hertz (1,000,000 Hz).
MLP	Mobile Location Protocol
MPC	Mobile Positioning Centre part of CDMA architecture (equivalent to GMLC)
MPP	Mobile Position Protocol
MVNO	Mobile Virtual Network Operator
ODFM	Orthogonal Frequency-Division Multiplexing (OFDM) is a digital multi-carrier modulation scheme, which uses a large number of closely-spaced orthogonal sub-carriers. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation) at a low symbol rate, maintaining data rates similar to conventional single-carrier modulation schemes in the same bandwidth. Consultation on the way forward for the future use of the band 872 - 876 MHz paired with 917 - 921 MHz 114
O&M	Operations & Maintenance
PDA	Personal Digital Assistant
PDE	Position Determination Equipment part of CDMA architecture (equivalent to SMLC)
PRS	Positioning Reference Signal
PSAP	Public Safety Answering Point
QoS	Quality of Service, parameter determining technical parameters such as latency, jitter etc of a telecommunications system link that determines quality perceived by user. Different applications require different quality of service levels to provide acceptable service as perceived by the user.
QZSS	Quazi Zenith Satellite System – Japanese satellite positioning system that uses highly elliptical orbits

	to provide GNSS like coverage but only at a regional rather than global level.
RFID	Radio-frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. The technology requires some extent of cooperation of an RFID reader and an RFID tag. An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader.
RSC	The Radio Spectrum Committee (RSC) was established under the Radio Spectrum Decision 676/2002/EC as part of the regulatory framework for electronic communications which entered into force on 24 April 2002. The RSC assists the European Commission in the development and adoption of technical implementing measures aimed at ensuring harmonised conditions for the availability and efficient use of radio spectrum, as well as the availability of information related to the use of radio spectrum. Once adopted by the European Commission, these Decisions are binding on Member States. http://ec.europa.eu/information_society/policy/ecomm/committees_ working_groups/index_en.htm / http://www.ofcom.org.uk/radiocomms/international/eu/
RTT	Round Trip Delay
SAS	Standalone SMLC (used in 3G networks)
SBAS	Space Based Augmentation System – regional system designed to provide operational checks and accuracy improvements to GNSS system. Regional systems include EGNOS in Europe and WAAS in the US and use a network of reference receivers which cross check satellite fixes against known positions. Checks and differential corrections Are broadcast using comms satellites
SMLC	Serving Mobile Location Centre allows a GSM or 3G wireless network to provide positioning information to a core network, applications, billing and provisioning systems. Needs a GMLC to complete the function
SLP	SUPL Location Platform
SRD	A Short Range Device (SRD) is a general term, applied to various radio devices designed to operate over short range and at low power levels. This includes alarms, telemetry and telecommand devices, radio microphones, radio local area networks and anti-theft devices with maximum powers of up to 500 mW at VHF/UHF, as well as certain microwave/Doppler devices with maximum powers of up to 5 W. SRD normally operate on a non-protected, non-interference basis.
SS7	Signalling System 7, system for control in voice networks, essential for set-up and tear down of calls etc.
SUPL	Secure user plane location, a standard that defines how location information is passed from the handset to for example a location based server, making use of user plane only, ie not using signalling/control plane
TDD	Time Division Duplexing (TDD) refers to a transmission scheme in which a common carrier is shared between the uplink and downlink, the resource being switched in time. Users are allocated one or more timeslots for uplink and downlink transmission. Consultation on the way forward for the future use of the band 872 - 876 MHz paired with 917 - 921 MHz 115
TDOA	Time Difference of Arrival
TETRA	The Terrestrial Trunked Radio (TETRA) standard (formerly known as Trans European Trunked RAdio) was developed by the European Telecommunications Standards Institute, (ETSI), as a digital alternative to analogue trunked systems. However, TETRA, with its enhanced encryption capability, has developed into a higher tier (Public Safety) product, currently mainly used by Governments, some Airports, emergency services and utilities.
TOA	Time of Arrival
TRX	A Transceiver. A device that is capable of both transmission and reception of a signal.
TTFF	Time To First Fix
UMTS	Universal Mobile Telecommunications System (UMTS) is one of the third-generation (3G) mobile technologies and is included in IMT-2000. UMTS uses a wideband code division multiple access (W-

	CDMA) radio interface. The designation UMTS900 is used to differentiate UMTS operating the band 880 – 915 MHz and 925 – 960 MHz from UMTS operating in other frequency bands.
VoIP	Voice over IP (internet protocol)
WAP	Wireless Access Protocol. WAP is an open international standard[1] for application layer network communications in a wireless communication environment. Its main use is to enable access to the Internet (HTTP) from a mobile phone or PDA.
W-CDMA	Wideband Code Division Multiple Access used in 3G technology (in Europe)
WGS-84	Standard scheme for defining a geographic location
WiFi	A telecommunications technology that provides wireless transmission of data over short distances at low power unlicensed. The technology is based on the IEEE 802.11a,b,g standards
WLAN	A local area wireless network in which a mobile user can connect to a local area network (LAN) through a wireless (radio) connection. The IEEE 802.11 group of standards specify the technologies for wireless LANs. 802.11 standards use the Ethernet protocol and CSMA/CA (carrier sense multiple access with collision avoidance) for path sharing and include an encryption method, the Wired Equivalent Privacy algorithm.
WiMAX	Worldwide Interoperability for Microwave Access, is a telecommunications technology that provides wireless transmission of data using a variety of transmission modes, from point-to-point links to portable internet access. The technology is based on the IEEE 802.16 standard