Determining Pinpoint of Mobile Location in Global System for Mobile Communication Network (Gsm)

[1,]Adnan Affandi, [2,]Mubashshir Husain
[1,2,]Department of Elect. & Comp. Eng.,King Abdul Aziz University,Jeddah, Saudi Arabia

Abstract:
The objective of this proposed paper is to present an extensive simple study about the mobile Location and the technologies that can enable them in conventional GSM networks, which do not require any significant changes to the network or the mobile device itself. A set of cell-based positioning techniques are proposed based on information available from the network and on accurate path loss models. We have also developed a program in matlab language for GSM vendors to use this feature without physical change in the network hardware.

Keywords: Global System For Mobile Communication, etc.

1. Introduction

In 1982, the Nordic PTT sent a proposal to Conférence Européenne des Postes et Télécommunications (CEPT) to specify a common European telecommunication service at 900 MHz. A Global System for Mobile Communications (GSM) standardization group was established to formulate the specifications for this pan-European mobile cellular radio system. During 1982 through 1985, discussions centered around whether to build an analog or a digital system. Then in 1985, GSM decided to develop a digital system. In 1986, companies participated in a field test in Paris to determine whether a narrowband or broadband solution should be employed. By May 1987, the narrowband Time Division Multiple Access (TDMA) solution was chosen. Concurrently, The terrain profile of a particular area needs to be taken into account for estimating the path loss. The terrain profile may vary from a simple curved earth profile to a highly mountainous profile. The presence of trees, buildings, and other obstacles also must be taken into account. A number of propagation models are available to predict path loss over irregular terrain.

While all these models aim to predict operators in 13 countries (two operators in the United Kingdom) signed the Memorandum of Understanding (MoU) which committed them to fulfilling GSM specifications and delivering a GSM system by July 1, 1991. This opened a large new market. In 1989 the ownership of the GSM standard was shifted to ETSI (European Telecommunications Standards Institute). ETSI has members from 54 countries inside and outside Europe, and represents administrations, network operators, manufacturers, service providers, research bodies and users. The next step in the GSM evolution was the specification of the Personal Communication Network (PCN) for the 1800 MHz frequency range. This was named the Digital Cellular System (DCS) 1800 (or GSM 1800). The Personal Communication Services (PCS) 1900 (or GSM 1900) for the 1900 MHz frequency range were also established for use in the Americas. Later GSM 800 and GSM 400 has been added. GSM 800 is using a frequency area currently being used by analog system in the Americas. GSM 400 is intended as a replacement of analog system around 450 MHz (NMT 450). This standard is not implemented by GPRS (General Packet Radio Services) is an extension of the GSM architecture. Packet data traffic runs on a new backbone IP network and is separate from the existing GSM core network that is used mainly for speech. GPRS was introduced in 2001. EDGE is a new modulation method enabling higher data bit rates introduced in R9.

2. Outdoor Propagation Models

Radio transmission in a mobile communications system often takes place over irregular terrain. signal strength at a particular receiving point or in a specific local area (called a sector), the methods vary widely in their approach, complexity, and accuracy. Most of these models are based on a systematic interpretation of measurement data obtained in the service area. Some of the commonly used outdoor propagation models are now discussed.

2.1 Longley-Rice Model

The Longley-Rice model [Ric67], [Lon68] is applicable to point-to-point communication systems in the frequency range from 40 MHz to 100 GHz, over different kinds of terrain. The median transmission loss is predicted using the path geometry of the terrain profile and the refractivity of the troposphere. Geometric optics techniques (primarily the 2-ray ground reflection model) are used to predict signal strengths within the radio horizon. Diffraction losses over isolated obstacles are estimated using the Fresnel-Kirchoff knife-edge models. Forward scatter theory is used to make troposcatter predictions over long distances, and far field diffraction losses in double horizon paths are predicted using a modified Van der Pol-Bremmer method. The Longley-Rice propagation prediction model is also referred to as the ITS irregular terrain model. The Longley-Rice model is also available as a computer program [Lon78] to calculate large-scale median transmission loss relative to free space loss over irregular terrain for frequencies between 20 MHz and 10 GHz. For a given transmission path, the program takes as its input the transmission frequency, path length, polarization, antenna heights, surface refractivity, effective radius of earth, ground conductivity, ground dielectric constant, and climate. The program also operates on path-specific parameters such as horizon distance of the antennas, horizon elevation angle, angular trans-horizon distance, terrain irregularity and other specific inputs.

The Longley-Rice method operates in two modes. When a detailed terrain path profile is available, the path-specific parameters can be easily determined and the prediction is called a point-to-point mode prediction. On the other hand, if the terrain path profile is not available, the Longley-Rice method provides techniques to estimate the path-specific parameters, and such a prediction is called an area mode prediction. There have been many modifications and corrections to the Longley-Rice model since its original publication. One important modification [Lon78] deals with radio propagation in urban areas, and this is particularly relevant to mobile radio. This modification introduces an excess term as an allowance for the additional attenuation due to urban clutter near the receiving antenna. This extra term, called the urban factor (UF), has been derived by comparing the predictions by the original Longley-Ricé model with those obtained by Okumura [0ku68].One shortcoming of the Longley-Rice model is that it does not provide a way of determining corrections due to environmental factors in the immediate vicinity of the mobile receiver, or consider correction factors to account for the effects of buildings and foliage. Further, multipath is not considered.

2.2 Durkin's Model

The execution of the Durkin path loss simulator consists of two parts. The --first part accesses a topographic data base of a proposed service area and reconstructs the ground profile information along the radial joining the transmitter to the receiver. The assumption is that the receiving antenna receives all of its energy along that radial and, therefore, experiences no multipath propagation. In other words, the propagation phenomena that is modeled is simply LOS and diffraction from obstacles along the radial, and excludes reflections from other surrounding objects and local scatterers. The effect of this assumption is that the model is somewhat pessimistic in narrow valleys, although it identifies isolated weak reception areas rather well. The second part of the simulation algorithm calculates the expected path loss along that radial. After this is done, the simulated receiver location can be iteratively moved to different locations in the service area to deduce the signal strength contour.

2.3 Okumura Model

Okumura's model is one of the most widely used models for signal prediction in urban areas. This model is applicable for frequencies in the range 150 MHz to 1920 MHz (although it is typically extrapolated up to 3000 MHz) and distances of 1 km to 100 km. It can be used for base station antenna heights ranging from 30 m to 1000 m.

Okumura developed a set of curves giving the median attenuation relative to free space (A_{mu}), in an urban area over a quasi-smooth terrain with a base station effective antenna height (h_{te}) of 200m and a mobile antenna height (h_{re}) of 3 m. These curves were developed from extensive measurements using vertical Omni-directional antennas at both the base and mobile, and are plotted as a function of frequency in the range 100 MHz to 1920 MHz and as a function of distance from the base station in the range 1 km to 100 km. To determine path loss using Okumura's model, the free space path loss between the points of interest is first determined, and then the value of $A_{mu}(f,d)$ (as read from the curves) is added to it along with correction factors to account for the type of terrain. The model can be expressed as

$$L_{50} = L_F + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA} \quad (4.1)$$

where L_{50} is the 50th percentile (i.e., median) value of propagation path loss, L_F is the free space propagation loss, A_{mu} is the median attenuation relative to free space, $G(h_{te})$ is the base station antenna height gain factor, $G(h_{re})$ is the mobile antenna height gain factor, and G_{AREA} is the gain due to the type of environment. Note that the antenna height gains are strictly a function of height and have nothing to do with antenna patterns.

Plots of $A_{mu}(f,d)$ and G_{AREA} for a wide range of frequencies are shown in Figure 4.1 and Figure 4.2 . Furthermore, Okumura found that $G(h_{te})$ varies at a rate of 20 dB/decade and $G(h_{re})$ varies at a rate of 10 dB/decade for heights less than 3 m.

$$G(h_{te}) = 20\log(\frac{h_{te}}{200})$$

1000 m $\rangle$ h_{re} $\rangle$ 10 m (4.2 a)

$$G(h_{re}) = 10\log(\frac{h_{re}}{3})$$

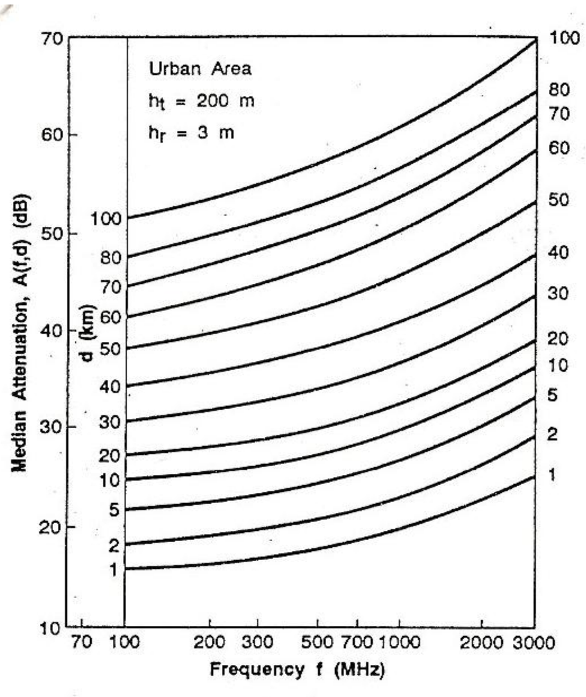
$h_{re} \leq$ 3 m (4.2 b)

$$G(h_{re}) = 20\log(\frac{h_{re}}{3})$$

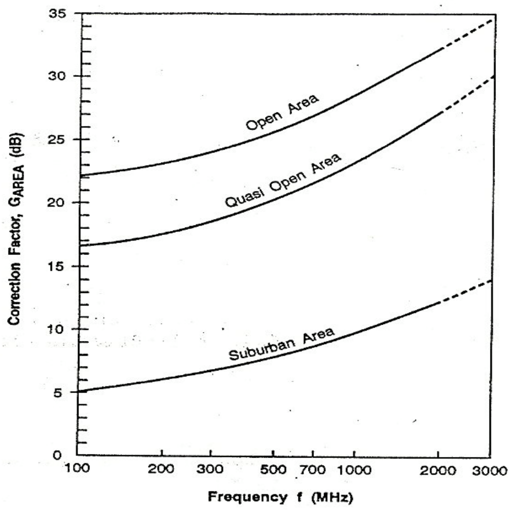
10 m $\rangle$ h_{re} $\rangle$ 3 m (4.2 c)

Other corrections may also be applied to Okumura's model. Some of the important terrain related parameters are the terrain undulation height (Δh), isolated ridge height, average slope of the terrain and the mixed land-sea parameter. Once the terrain related parameters are calculated, the necessary correction factors can be added or subtracted as required. All these correction factors are also available as Okumura curves [0ku68].Okumura's model is wholly based on measured data and does riot provide any analytical explanation. For many situations, extrapolations of the derived curves can be made to obtain values outside the measurement range, although the validity of such extrapolations depends on the circumstances and the smoothness of the curve in question.

Okumura's model is considered to be among the simplest and best in terms of accuracy in path loss prediction for mature cellular and land mobile radio systems in cluttered environments. It is very practical and has become a standard for system planning in modern land mobile radio systems in Japan. The major disadvantage with the model is its slow response to rapid changes in terrain; therefore the model is fairly good in urban and suburban areas, but not as good in rural areas. Common standard deviations between predicted and measured path loss values are around 10 dB to 14 dB.



Figaure 4.1 Median attenuation related to free space $A_{mu}(f,d)$, over a quasi-smooth terrain



Figaure 4.2 correction factor G_{AREA} , for different types of terrain

2.4 Hata Model

The Hata model [Hat9O] is an empirical formulation of the graphical path loss data provided by Okumura, and is valid from 150 MHz to 1500 MHz. Hata presented the urban area propagation loss as a standard formula and supplied correction equations for application to other situations. The standard formula for median path loss in urban areas is given by

$$L_{50}(urban)(dB) = 69.55 + 26.16\log f_c - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log d \quad (4.3)$$

where f_c is the frequency (in MHz) from 150 MHz to 1500 MHz, h_{te} is the effective transmitter (base station) antenna height (in meters) ranging from 30 m to 200 m, h_{re} is the effective receiver (mobile) antenna height (in meters) ranging from 1 m to l0 m, d is the T-R separation distance (in kin), and $a(h_{re})$ is the correction factor for effective mobile antenna height which is a function of the size of the coverage area. For a small to medium sized city, the mobile antenna correction factor is given by

$$a(h_{re}) = (1.1\log f_c - 0.7) - (1.56\log f_c - 0.8) \quad (4.4)$$

and for a large city, it is given by

$$f_c \le 300MHz \text{ for } dB \;\; a(h_{re}) = 8.29*(\log 1.54h_{re})^2 - 1.1 \quad (4.5\text{ a})$$

$$a(h_{re}) = 3.2*(\log 11.75h_{re})^2 - 4.97 \; dB \text{ for } f_c \ge 300MHz \quad (4.5\text{ b})$$

To obtain the path loss in a suburban area the standard Hata formula in equation (4.3) is modified as

$$L_{50}(dB) = L_{50}(urban) - 2[\log(f_c/28)]^2 - 5.4 \quad (4.6)$$

And for path loss in open rural areas, the formula is modified as

$$L_{50}(dB) = L_{50}(urban) - 4.78(\log f_c)^2 - 18.33\log f_c - 40.98 \quad (4.7)$$

Although Hata's model does not have any of the path-specific corrections which are available in Okumura's model, the above expressions have significant practical value. The predictions of the Hata model compare very closely with the original Okumura model, as long as d exceeds 1 km. This model is well suited for large cell mobile systems, but not personal communications systems (PCS) which have cells on the order of 1km radius.

2.5 PCS Extension to Hata Model

The European Co-operative for Scientific and Technical research (EUROCOST) formed the COST-231 working committee to develop an extended version of the Hata model. COST-231 proposed the following formula to extend Hata's model to 2 GHz. The proposed model for path loss is [EUR91]

$$L_{50}(urban)(dB) = 46.3 + 33.9\log f_c - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log d + C_M \tag{4.8}$$

where $a(h_{re})$ is defined in equations (4.4), (4.5 a), and (4.5 b) and

C_M = 0 dB for medium sized city and suburban areas (4.9)

C_M = 3 dB for metropolitan centers

The COST-231 extension of the Hata model is restricted to the following range of parameters:

f : 1500MHz to 2000 MHz

h_{te} : 30 m to 200m

h_{re} : 1 m to l0 m

d : 1 km to 20 km

3. Locate A Mobile Position

By using Hata Model we can locate a Mobile position in the network by getting:

The Power value of Transmitting from the tower (from network data base)

The height of the tower (from network data base).

The receiving value in the mobile from the mobile (by using logical channels).

Carrier frequency (from network data base).

Mobile elevation which around 1.5 m.

Is the area urban , suburban or open rural (from network data base).

Calculate the Path loss by subtract the receiving value in the mobile (Rx) from Transmitting value from the tower (Tx).

$$L_{50} = Tx - Rx \tag{4.10}$$

Hata formula will be modifying for urban area to:

$$D = 10^{\frac{L_{50} - 69.55 - 26.16\log f_c + 13.82\log h_{te} + a(h_{re})}{44.9 - 6.55\log h_{te}}} \tag{4.11}$$

Where

$a(h_{re}) = (1.1\log f_c - 0.7) - (1.56\log f_c - 0.8)$ dB (for small city)

$a(h_{re}) = 3.2 * (\log 11.75 h_{re})^2 - 4.97$ dB (for a large city)

And for suburban area:

$$D = 10^{\frac{L_{50} - 69.55 - 26.16\log f_c + 13.82\log h_{te} + a(h_{re}) + 2[\log(f_c/28)]^2 + 5.4}{44.9 - 6.55\log h_{te}}} \tag{4.12}$$

And for open rural areas:

$$D = 10^{\frac{L_{50} - 69.55 - 26.16\log f_c + 13.82\log h_{te} + a(h_{re}) + 4.78(\log f_c)^2 + 18.33\log f_c + 40.98}{44.9 - 6.55\log h_{te}}} \tag{4.13}$$

From the above equations we can calculate the distance from the tower to the mobile for different areas (urban, suburban & open rural).after calculate the distance (D) we can create a circle as considering the position of the tower is origin of the circle and the distance D is the radius of the circle as shown below:

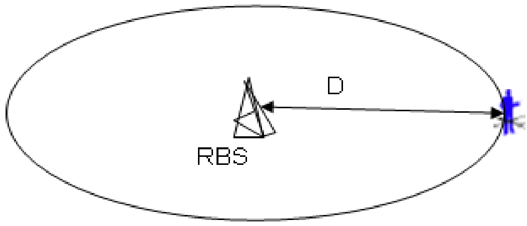


Figure 4-3 One Direction Estimation

And after repeat these process two times more for same mobile from different towers we will have three circles as shown below:

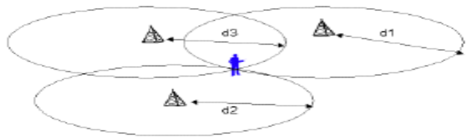


Figure 4-4 three directions estimation

The intersection between the three circles give us the location of the mobile .the intersection will be point or area depends on the receiving value (Rx) and we will locate Mobile position by placed our calculation and diagrams over good digitals Maps. These Maps programs can have them from good local vendor or use satellite Maps programs like Google earth.

4. Error and Correction

During our process maybe we will have some errors in the calculation and this is related to wrong reading values .this error in the reading values due to obstacles between the tower (transmitter) and mobile (receiver). some time no clear line of sight between RBS and MS which give us error in our estimation around 10 to 14 dB.

But we can overcome on these errors by using GSM techniques:
Handover to different towers (RBS's): we can our input by select different transmitters as we know the mobile receive from 6 different sites.
Frequency Hopping: this technique allows us to have varied frequencies to measure the mobile location because if we have a bad estimation from one frequency we will pick another one.
Take the measurement in different times or for some period to avoid the wrong estimation and take the good ones.

By these major techniques we will get a good estimation about customer location in any network. And there are a lot of techniques which are support our target.
As we know the GSM structure is very smart and always become smarter every day because it is a global system and whole the world deal with it.
We are hoping to lead the world in the development in the future.

5 .Development Of Software

Different Programs Have Been Developed In Matlab For The Simulation Of " Determining Pinpoint Of Mobile Location In Global System For Mobile Communication network (GSM)". In Fig.3 We Can See The Screenshot Of The Software.

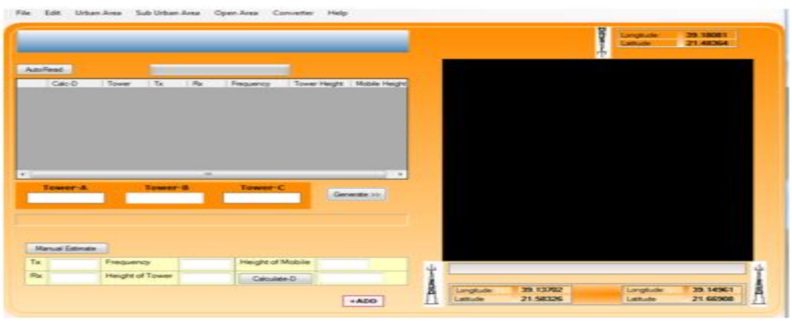


Fig 4.5

By using this simulator we can locate exact mobile location in Urban Area which is further divided into small and large city , in Sub urban area which is again divided into small and large city and finally in open area which is further divided into small and large city.

Determining pinpoint mobile location by using simulation software in Urban Area(Large City)

By using this software we demonstrated that how we can determine exact mobile location in Urban areas. Screenshot is shown in fig.4.6

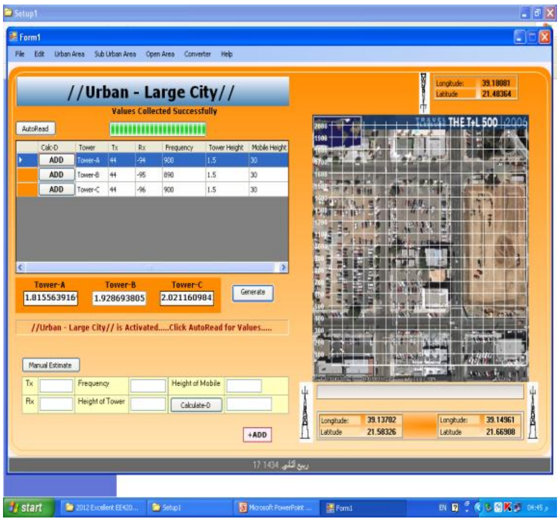


Fig 4.6

In this demonstration we have used the following values:

TValues					
Tower	**Tx**	**Rx**	**Frq**	**Hte**	**Hre**
Tower-A	44	-94	900	1.5	30
Tower-B	44	-95	890	1.5	30
Tower-C	44	-96	900	1.5	30

Where Tx=Transmitter
Rx=Receiver
Frq=Frequency
Hte = Height of Transmitter
Hre= Height of Receiver

TowerI		
Tower	**Longitude**	**Latitude**
Tower-A	39.13702	21.58326
Tower-B	39.14961	21.66908
Tower-C	39.18081	21.48364

Determining pinpoint mobile location by using simulation software in Sub-Urban Area (small city)

By using this software we demonstrated that how we can determine exact mobile location in Sub-Urban areas. Screenshot is shown in fig.4.7

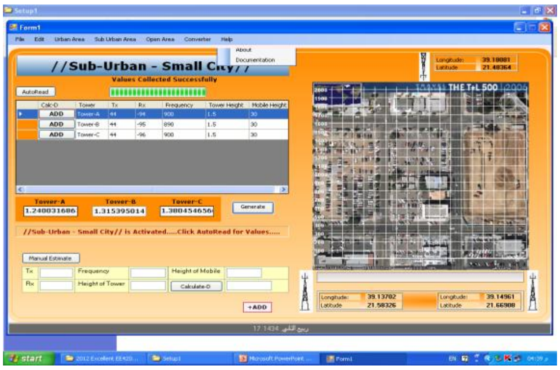


Fig 4.7

In this demonstration we have used the following values:

TValues					
Tower	**Tx**	**Rx**	**Frq**	**Hte**	**Hre**
Tower-A	44	-93	900	1.5	30
Tower-B	44	-95	890	1.5	30
Tower-C	44	-97	900	1.5	30

Where Tx=Transmitter
Rx=Receiver
Frq=Frequency
Hte = Height of Transmitter
Hre= Height of Receiver

TowerI		
Tower	**Longitude**	**Latitude**
Tower-A	39.10002	21.30003
Tower-B	39.14961	21.66908
Tower-C	39.18081	21.48364

Determining pinpoint location by using simulation software in Open Area (Large city)

By using this software we demonstrated that how we can determine exact mobile location in Open areas. Screenshot is shown in fig.

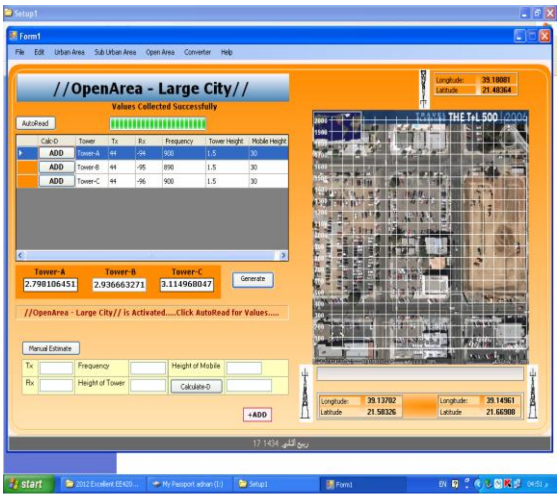


Fig 4.8

In this demonstration we have used the following values:

Towerl		
Tower	**Longitude**	**Latitude**
Tower-A	39.10002	21.30003
Tower-B	39.14961	21.66908
Tower-C	39.18081	21.48364

Where Tx=Transmitter
Rx=Receiver
Frq=Frequency
Hte = Height of Transmitter
Hre= Height of Receiver

Towerl		
Tower	**Longitude**	**Latitude**
Tower-A	39.20002	21.50234
Tower-B	39.14961	21.66908
Tower-C	39.18081	21.48364

4. Conclusion

- This research paper aims to present an extensive study about the mobile Location and the technologies that can enable them in conventional GSM networks.
- A set of cell-based positioning techniques are proposed based on information available from the network and on accurate path loss models.
- This paper creates a software methods program for GSM vendors to use this feature without physical change in the network hardware.

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