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LTE Network Coverage Area

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Abstract: Due to the advancement of telecommunication platform, users are now demanding new applications such as Online Gaming, mobile TV, Web 2.0, and to meet this requirement operators needed to design more flexible network. For the implementation of this network, the 3rd Generation Partnership Project (3GPP) started working on Long Term Evolution (LTE) and proposed a system which has larger bandwidths, low latency and packet optimized radio access technology. The answer to the bandwidth hungry wireless applications was LTE with its distinct access technology Orthogonal Frequency Division Multiple Access (OFDMA).With OFDMA as the radio access Technology, LTE has very promising features, like bandwidth scalability and both FDD and TDD duplexing methods. The major challenge in LTE is offering a greater coverage by providing higher data rates over wider areas. The changes and contributions of LTE make sure that the users are able to request and use more mobile applications like interactive TV, mobile video blogging, advanced games or professional services. The transition of LTE i.e from the 3rd generation (3G) to the 4th generation (4G), has achieved great capacity and high speed of mobile telephone networks.

Index Terms: Cell radius, Coverage, LTE.

I. INTRODUCTION

Along with the voice, data communication has now also become an integral part of the consumer need. People on the move with smart phones demand high speed data service. Apart from these, consumer satisfaction with greater quality of service also needs to be maintained. All these brought attention upon the scarce resource on which the technology depends upon – Frequency Spectrum. The evolution of the technology from the 1st to the 4th generation networks have all been based upon more and more efficient use of the frequency spectrum over the capacity and throughput offered. The work on 3GPP LTE [4] Release 8 started in 2004. The development of LTE was driven by certain aspects. First the wire line data networks improved and higher data rates were possible. This lead to new applications and services which are often referred to as the \Web 2.0.Second, to cover the mentioned tremendous growth of mobile subscribers new technologies that are specifically designed for higher capacities are needed.

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In addition, competing standards, for instance WiMAX (IEEE802.16), were under development and the 3GPP was challenged by this competition. Furthermore, the drop of prices for data delivery made it essential for the telecommunication companies (as key partners of 3GPP) to have competing and efficient telecommunication network architecture. With the LTE technology the mobile network operators are not required to maintain an additional complex circuit-switched domain. LTE networks are superior to 3G/HSPA in terms of control plane.

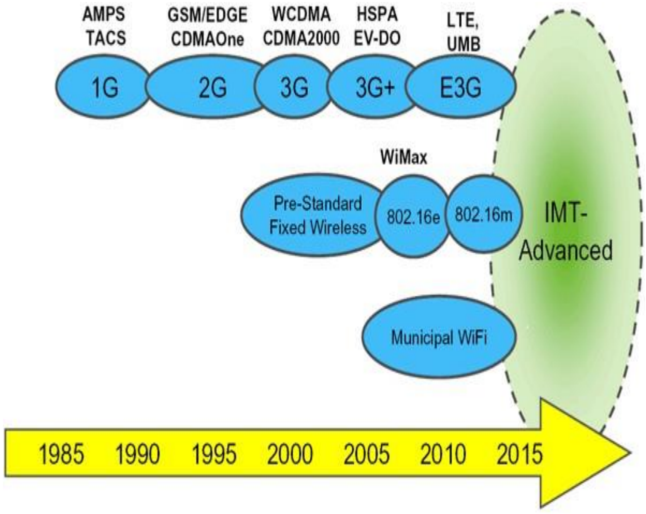

Fig. 1.Evolution of Wireless Technology

II. OKUMURA-HATA MODEL

In wireless communication, the Hata model for urban areas, also known as the Okumura–Hata model for being a developed version of the Okumura model, is the most widely used radio frequency propagation model for predicting the behaviour of cellular transmissions in built up areas. This model incorporates the graphical information from Okumura model and develops it further to realize the effects of diffraction, reflection and scattering caused by city structures. This model also has two more varieties for transmission insuburban areas and open areas. Hata Model predicts the total path loss along a link of terrestrial microwave or other type of cellular communications. It is one of the most popular radio propagation models. It is an empirical model and is based on the measurements carried out by Okumura in the Tokyo area. The measurements made were drafted in graphs and approximations were done by Hata to formulate the path loss expressions which we now refer to as Okumura-Hata model. The path loss criteria are solely depends on the propagation environment.

According to Okumura-Hata Propagation model there are four different types of propagation environment and considering each propagation environment there is a propagation model
1. Urban
2. Sub-Urban
3. Open area

III. CELL & COVERAGE ANALYSIS

A cellular radio system provides a wireless connection to the public telephone network using a system of base stations (Sometimes known as "cell sites") for any user location within the radio range of the system. In mobile cellular communication system, a number of factors affect the completion of a call from a wireless phone, like coverage area, topography, capacity and network architecture. For wireless services it is necessary to determine the extent of their coverage in the specific areas. The cell coverage area in a cellular system is defined as the percentage of area within a cell that has received power above a given minimum. Assuming some considerable noise and interference model, the SNR requirement translates to a minimum received power throughout the cell. Cell coverage mainly depends upon parameters defined by user, such as transmitting power, random shadowing and antenna configuration. Based on the average received power at the cell boundary, where the average is computed based on path loss alone, the transmit power at the base station is designed. Other non user defined parameters such as propagation environment, hills, tunnels, foliage and buildings greatly affect the overall coverage.
In order for calculating the cell radius, some basic parameters are considered as shown in Table 1. Then the following steps are followed to determine the cell radius:

A. Determination of SINR
B. Determination of Path Loss, L C. Determination of Cell radius, D
D. Determination of Coverage area, A_{cell}

A. Determination of SINR

In information theory and telecommunication engineering, the signal-to-interference-plus-noise ratio (SINR) is a quantity used to give theoretical upper bounds on channel capacity (or the rate of information transfer) in wireless communication systems such as networks. Analogous to the SNR used often in wired communications systems, the SINR is defined as the power of a certain signal of interest divided by the sum of the interference power (from all the other interfering signals) and the power of some background noise. If the power of noise term is zero, then the SINR reduces the signal-to-interference ratio (SIR). Conversely zero interference reduces the SINR to signal –to-noise ratio (SNR) which is used less often in developing mathematical models of wireless networks such as cellular networks. The complexity and randomness of certain types of wireless networks and signal propagation has motivated the use of stochastic geometry models in order to model the SINR, particularly for cellular or mobile phone networks. To determine SINR the thermal noise N_T is calculated first by using the following eq 1

$$Nt = 10 \log10(k * T * f) \qquad 1$$

where k (Boltzmann constant) =1.38 × 10^{-23} J/K, T is the temperature (300 K) and Δf is the bandwidth of the channel. We put the values of the parameters in the eq and get value of

N_T = – 104.28 dBm = 3.72 × 10^{14} W.

The SINR is calculated using Eq. 2

$$SINR = \frac{\text{Mha gain*transmitted power}}{\text{Thermal noise + interference}} = \frac{Am*Pt}{Nt + Nj} \quad ..2$$

Here let us assume that interference, Nj = 4 dB and MHA (Masthead amplifier) Gain, Am = 2 dB. Using the parameters as given in Table 1 and Eq. (1), we get SINR for uplink in Eq. (3).

$$SINR\ (UL) = -8\ (dB) \qquad 3$$

B. Determination of Path Loss

Path loss (or path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. Path loss is a major component in the analysis and design of the link budget of a telecommunication system. This term is commonly used in wireless communications and signal propagation. Path loss may be due to many effects, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption. Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas.

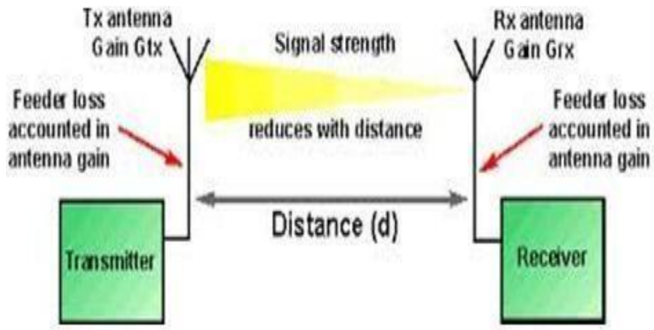

Fig. 2 Path Loss

The basic equation for path loss, L for LTE is expressed as

$$L = Pt + Gt - Lb - SINR + Gr - Lr + Nr\ (dB)$$

Using table 1 and substituting the value of SINR in Eq. (2) the pathloss for uplink is calculated
Path Loss (Uplink) = -8 Db

Parameter Values for Uplink

Parameter	*Value*
Pt, Transmitter Power	24 dBm / 0.251 W
Gt Transmitter Antenna Gain (dBi)	*0*

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Lb, Body Loss (dB)	*4*
hb, Base Station antenna Height (m)	*40*
Mobile Height (m)	*2*
Am, MHA Gain (dB)	2 dB / 1.58
Noise Figure(dB)	*2*
Gr, Receiver Antenna Gain (dBi)	*18*
Lr, Receiver Loss (dB)	*14*
Nr, Receiver Noise (dBm)	*-102.28*
Propagation Model	COST 231 HATA Propagation Model
Δf, Bandwidth (MHz)	*9*

Table 1

C. Determination of Cell Radius

The COST Hata model is a radio propagation model that extends the urban Hata model (which in turn is based on the Okumura model) to cover a more elaborated range of frequencies. It is the most often cited of the COST 231 models, also called the Hata Model PCS Extension. COST (COopération européenne dans le domaine de la recherche Scientifique et Technique) is a European Union Forum for cooperative scientific research which has developed this model accordingly to various experiments and researches. Using Cost 231 HATA model, we determine the cell radius of LTE. The cell radius is related by,

$D\ (km) = antilog[\{L\ (dB) - C0 - C1 - C2*\log(F_{mhz}) + 13.82*\log(H_b) + a(Hm)\}/\{44.9 - 6.55*\log(H_b)\}]$

Where C0, C1 and C2 are constants and are given as,

C0 = 0 for Suburban = 3 dB for Urban C1 = 69.55 for 150 MHz to 1000 MHZ = 46.30 for 1500 MHz to 2000 MHz C2 = 26.16 for 160 MHz to 1000 MHZ = 33.90 for 1600 MHz to 2000 MHz
F = Frequency in MHz d = Distance (cell radius) in Km Hb = Base station antenna height in meters Hm = Mobile Antenna height in meters For Urban, $a(Hm) = \{1.1 \log(F_{mhz}) - 0.7\}Hm - \{1.56 \log(F_{mhz}) - 0.8\}$

Table 2

D. Determination of Coverage Area, A $_{cell}$:

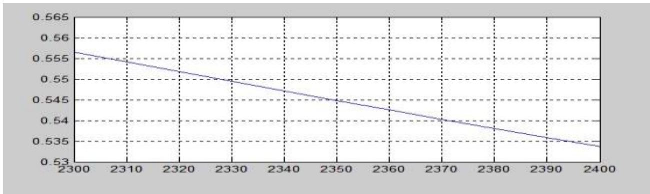
In telecommunications systems, the coverage of a radio station is the geographic area where the station can communicate. Broadcasters and telecommunications companies often produce coverage maps to indicate to users the station's intended service area. Coverage depends on many factors, such as orography (i.e. mountains) and buildings, technology, radio frequency and perhaps most importantly for two-way telecommunications the sensitivity and transmit efficiency of the consumer equipment. Some frequencies provide better regional coverage, while other frequencies penetrate better through obstacles, such as buildings in cities. The ability of a mobile phone to connect to a base station depends on the strength of the signal. That may be boosted by higher power transmissions, better antennas, taller antenna masts or alternative solutions like in-building picocells. Normal Macro- Cell signals need to be boosted to pass through buildings, which is a particular problem designing network for large metropolitan areas with modern skyscrapers, hence the current drive for small cells and micro and pico cells. Signals also do not travel deep underground, so specialized transmission solutions are used to deliver mobile phone coverage into areas such as underground parking garages and subway trains. The coverage area A_{cell} of a base station is expressed by the following formula,

$$A_{cell} = \{5.196*D^{\wedge}2\}/$$

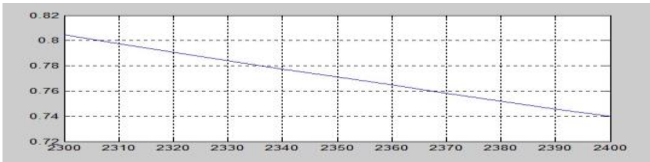
IV. RESULTS

Considering urban area

Plot of Frequency v/s Cell Radius



Plot of Frequency v/s Coverage Area



Purpose of Dimensioning or Radio Network Planning is Determining the areas that need to be covered and Computation of number of sites required to serve the target areas fulfilling the coverage and capacity requirements. LTE systems have greater Packet Delivery Ratio and Throughput AS it in above the maximum coverage is obtained when there is minimum path loss or less signal attenuation. But in case of urban area the signal is attenuated rapidly as distance from base station to mobile station rises. Optimization such as tilting and antenna redirections can improve the coverage and capacity significantly. Another way to maximize coverage area is to increase the power of Radio Base Station.

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