

Impact of Sectorization on UMTS Radio Access Network Coverage Planning

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Abstract: In this paper, dimensioning of Universal Mobile Telecommunication Systems (UMTS) Radio Access Method (RAN) has been performed with respect to varying antenna gain of NodeB and sectorization of site layout of network sites. Three different site layouts have been configured to estimate the number of sites required to cover the deployment area. In the first site layout, Single Omni directional antenna is used, while in the second and third configuration, the network consists of a 3-sector-sites and 6-sector sites respectively. These sectorized sites replace the Omni-directional antenna with high gain directional antenna, each placed such that to cover the entire sector area. Antenna gain has been varied as per the site layout typical requirements. Thus, investigation has been carried to study the effect of sectorization and antenna gain on the number of site required to cover the deployment area for different clutter type.

Keywords: UMTS, RAN, Sectorization, Antenna gain, Site-layout

I. Introduction

Air interface dimensioning is the first step performed in order to provide first estimation of the sites volumes which has to be taken into account when deploying Universal Mobile Telephony System (UMTS) Radio Access Network (RAN). It is executed in order to calculate, for a given geographical network area and a defined minimum quality of service to be guaranteed at the cell edge, a qualified estimate of the number of sites, their density, cell ranges and areas in correspondence with the pre-defined site layouts, clutter types and simulation cases. Sectorization is the process in which a site is partitioned into multiple sectors and radio resource are used across each sectors and sites, which increases the network capacity of system and service coverage is also increased using high gain directional antenna [1]. Three cases using Omni, 3-sectorized and 6-sectorized sites have been presented shown in Figure 1.

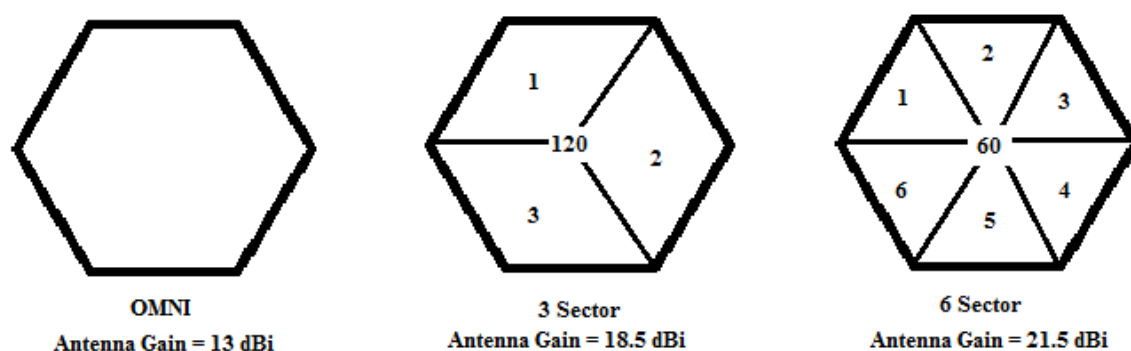


Figure 1 UMTS Network Site Layout Configuration

A cellular cell can be divided into number of geographic areas, called sectors. It may be 3 sectors, 4 sectors, 6 sectors etc. When sectorization is done in a cell, interference is significantly reduced resulting in better performance for cellular network. Sectorization is an approach which enhances capacity of the network and increases radio resource usage. In this method, cell radius does not changes but at the same time it is necessary to reduce the relative interference without decreasing the transmit power. Omni directional antenna at the NodeB is replaced by high gain directional antennas, each radiating within a specified sector.

The network relevant to the link budget works at 2100 MHz carrier frequency. The system bandwidth is configured to 5 MHz. UE power class 3 is assumed with 21 dBm power.

II. Related Work

Bo Hagerman, Davide Imbeni and Jozsef Barta considered WCDMA 6-sector deployment case study of a real installed UMTS-FDD network [2]. Romeo Giuliano, Franco Mazzenga, Francesco Vatalaro described Adaptive Cell Sectorization for UMTS Third Generation CDMA Systems [3]. Achim Wacker, Jaana Laiho-Steffens, Kari Sipila, and Kari Heiska considered the impact of the base station sectorisation on WCDMA radio network performance [4]. S. Sharma, A.G. Spilling and A.R. Nix considered Adaptive Coverage for UMTS Macro cells based on Situation Awareness [5]. Most of the works analyzed the performance considering sectors with static parameters but it is needed to analyze the performance along with all dynamic parameters, so in this paper, sectorization effect on number of sites have been shown.

III. Theory

Coverage planning is performed with a link budget calculation and propagation model. Since the coverage limiting factor for macro-cells is the uplink direction, the corresponding uplink link budget calculation needs to be done in advance to calculate the maximum allowable Path loss. The calculation also includes the total interference, a sum of all possible environment or system losses and gains and the hardware parameters of NodeB and UE. Taking into account of the uplink cell load and maximum allowable path loss obtained, further, cell radius calculation based on the COST 231 propagation model has been calculated [5].

A. General Parameters

- i. **Operating Band:** In India, operating band of 2100 MHz is utilized by operators for UMTS Network.
- ii. **Channel Bandwidth:** UMTS is a single carrier system with bandwidth of 5MHz.
- iii. **Channel Model:** Vehicular A 5 at 3 km/hr is the channel model is used.

B. Transmitter Parameters

There are different transmitter parameter each for downlink and uplink. Down link transmitting end parameters is Transmitted Power per Antenna, Antenna Gain, Body Loss and Cable loss, whereas receiver parameters are User Equipment Transmitter Power per Antenna, Antenna Gain, Body Loss and MHA Insertion Loss [6].

- i. **Transmitted Power per Antenna:** In downlink, Tx Power per Antenna depends on the channel bandwidth, whereas in uplink, transmitted power depends on the UE Class.
- ii. **Antenna Gain:** It is one of the parameter generally used to balance path loss in uplink and downlink. In downlink, typical value of antenna gain ranges from 18 dBi to 22 dBi, whereas in Uplink, gain is taken as 0, if UE lies in best coverage unless value change.
- iii. **Cable Loss:** Sum of all the signal losses caused by the antenna line outside the BS cabinet. Different Signal losses are Jumper Cable Losses, Feeder Cable Losses, Feeder Connector Losses and Antenna/eNodeB Connector Loss. MHA insertion Loss in DL when MHA is used contributes typical loss of 0.5 dB.
- iv. **Body Loss:** The body loss arises from the use of UE close to body or other object in close proximity. Speech services are carried on a handheld terminal held against head. Body loss of 3dB is assumed for voice services when the UE terminals are held near the head. For Data services, UE may be place at some distance from the body with resultant lower body loss, hence in this body loss is assumed to be 0dB.
- v. **EIRP:** EIRP is abbreviated for Effective Isotropic Radiated Power from the transmitting antenna. It is the measured radiated power in a single direction.

C. Receiver Parameter

There are different receiver parameter each for downlink and uplink.

- i. **Noise Figure:** It represents the additive noise generated by the equipment hardware components. It depends on the type of device (UE or eNodeB) and frequency. Noise Figure is an indication of how much noise in a given circuit or piece of equipment add to the signal.

- ii. **Thermal Noise:** Thermal noise is a random fluctuation in voltage caused by random motion of charge carriers in any conduction medium at a temperature above absolute zero.
- iii. **Uplink Load and Interference Margin:** The coverage and capacity of CDMA systems are closely related due to the use of the same frequency and sharing of power. As the cell load increases, more interference is generated in the system resulting in a reduced coverage area. The increase and reduction in coverage area as a result of the loading is known as cell breathing/shrinking and must be taken into account when dimensioning the system.

IV. Link Budget Process and Calculations

For calculations, NSN RAN DIM Tool has been used. Link Budget is calculated for DL service rate of 384 kbps (interactive service) and UL service rate 64 kbps. Four different clutter types – Dense urban, Urban, Sub urban, and Rural have been considered. In the first site layout configuration, the network consists of a single Omni directional antenna, while in the second and third configuration, the network consists of a 3-sector-sites and 6-sector site respectively. These sectorized sites replace the Omni-directional antenna with high gain directional antenna, each placed in a way that covers the sector. Antenna gain has been varied as per the site layout requirements. RLB calculations have been carried out in the following steps:

Step 1: General Configuration Parameters for the dimensioning of UMTS RAN is presented in Table 1.

Table 1 General Parameter Configuration

General Parameters	
Operating Band	2100 MHz
Channel Bandwidth	5 MHz
Channel Model	Vehicular A 5 at 3 km/hr
UE Type	Power Class 3
Data Rate	DL - 384 kbps
	UL - 64 Kbps

Step 2: Based on the transmitting end parameter, EIRP is calculated for both DL and UL. EIRP is the amount of power being radiated from the transmitting antenna in a single direction. Table 2 and 3 presents Transmitter parameters and EIRP value for DL and UL respectively.

Table 2 Transmitter Parameter Configuration for Downlink

Transmitting End Configuration (Downlink)				
Site Layout	Omni	3-Sector	6-Sector	
Max Tx Power (Total) (dBm)	43	43	43	a
Max Tx Power (per Radio Link) (dBm)	38	38	38	
Tx Power per User (dBm)	41	41	41	
Cable Loss (dB)	0.5	0.5	0.5	b
MHA Insertion Loss (dB)	0	0	0	c
Tx Antenna Gain (dBi)	13	18.5	21.5	d
EIRP (dBm)	50.5	56	59	e = a – b – c + d

Table 3 Transmitter Parameter Configuration for Uplink

Transmitting End Configuration (Uplink)		
Site Layout	Omni/3-Sector /6-Sector	
Max Tx power	21	a
Antenna gain	0	b
Body Loss	0	c
EIRP (dBm)	21	d = a + b – c

Step 3: Receiver Parameters Loss for DL and UL are presented in Table 4 & 5. Receiver Sensitivity is calculated using the receiver end parameters. Then, Min Rx Level is calculated using Total Effective Noise power, Receiver Sensitivity and other mentioned parameters.

Table 4 Receiver Parameter Configuration for Downlink

<i>Receiving End Configuration (Downlink)</i>		
Site Layout	Omni/ 3-Sector/ 6-Sector	
Handset Noise Figure (dB)	7	f
Thermal Noise Density (dBm/Hz)	-173.83	g
Receiver Noise Density (dBm/Hz)	-166.83	$h = f + g$
Receiver Noise Power (dBm)	-100.99	$i = h + 10 \cdot \log(3840000)$
Downlink Load %	70	j (Assumption/operator provided)
Interference Margin (dB)	3.05	$k = -10 \cdot \log_{10}(1 - j \%)$
Total Effective Noise Power (dBm)	-97.94	$l = i + k$
Service Eb/No (dB)	1.96	m
Service Processing Gain (dB)	10	$n = 10 \cdot \log(3840 / (\text{Service Rate} = 384 \text{ kbps}))$
Receiver Sensitivity (dBm)	-105.98	$o = l + m - n$
Rx antenna Gain (dBi)	0	p
Body Loss (dB)	0	q
DL Fast Fade Margin (dB)	-0.81	r
SHO Gain (dB)	0	s
Gain against Shadowing (dB)	2.3	t
Min Rx Level (dBm)	-109.1	$u = o - p + q + r - s - t$

Table 5 Receiver Parameter Configuration for Uplink

<i>Receiving End Configuration (Uplink)</i>				
Site Layout	Omni	3-Sector	6-Sector	
Node B Noise Figure (dB)	2	2	2	e
Thermal Noise Density (dBm/Hz)	-173.83	-173.83	-173.83	f
Receiver Noise Density (dBm/Hz)	-171.83	-171.83	-171.83	$g = e + f$
Receiver Noise Power (dBm)	-105.99	-105.99	-105.99	$h = g + 10 \cdot \log(3840000)$
Uplink Load (%)	60	60	60	i (assumption)
Interference Margin (dB)	3.98	3.98	3.98	$j = 10 \cdot \log_{10}(1 - i \%)$
Total Effective Noise Power (dBm)	-102.01	-102.01	-102.01	$k = h + j$
Service Eb/No (dB)	2	2	2	l
Service Processing Gain (dB)	17.78	17.78	17.78	$m = 10 \cdot \log(3840 / (\text{Service Rate} = 64 \text{ kbps}))$
Receiver Sensitivity (dB)	-117.79	-117.79	-117.79	$n = k + l - m$
Rx antenna Gain (dBi)	13	18.5	21.5	o
Cable Loss (dB)	0.5	0.5	0.5	p
Benefit of using MHA (dB)	0	0	0	q
UL Fast Fade Margin (dB)	1.8	1.8	1.8	r
SHO Gain (dB)	1.5	1.5	1.5	s
Gain against Shadowing (dB)	2.1	2.1	2.1	t
Min Rx Level (dBm)	-132.1	-137.6	-140.6	$u = n - o + p - q + r - s - t$

Step 4: Limiting value (which is generally the Uplink Allowed Propagation Loss) of allowed propagation loss has been taken for the calculation of MAPL for four different clutter types.

Allowed Propagation Loss is calculated using the Transmitting and Receiving end parameters for DL and UL. Allowed propagation loss, is the value for which UL and DL needs to be balanced. MAPL calculations are presented in Table 8, 9, 10.

Table 6 Calculation of Uplink MAPL for Omni Site Layout

<i>Allowed Propagation Loss: Uplink - Omni Site</i>					
Clutter Type	Dense Urban	Urban	Suburban	Rural	
Average Penetration Loss (dB)	20	15	10	5	v
Standard Deviation Outdoor (dB)	9	8	8	7	w
Cell Area Probability	93.00%	93.00%	93.00%	93.00%	x
Log Normal Fading Margin (dB)	6.54	6.54	6.54	6.54	y
Isotropic power required (dB)	-105.6	-110.6	-115.6	-120.6	$z = u + v + y$
Allowed Prop. Loss (dB)	126.6	131.6	136.6	141.6	MAPL = d - z

Table 7 Calculation of Uplink MAPL for 3 Sector Site Layout

<i>Allowed Propagation Loss: Uplink - 3 Sector Site</i>					
Clutter Type	Dense Urban	Urban	Suburban	Rural	
Average Penetration Loss (dB)	20	15	10	5	v
Standard Deviation Outdoor (dB)	9	8	8	7	w
Cell Area Probability	93.00%	93.00%	93.00%	93.00%	x
Log Normal Fading Margin (dB)	6.54	6.54	6.54	6.54	y
Isotropic power required (dB)	-111.1	-116.1	-121.1	-126.1	$z = u + v + y$
Allowed Prop. Loss (dB)	132.1	137.1	142.1	147.1	MAPL = d - z

Table 8 Calculation of Uplink MAPL for 6 Sector Site Layout

<i>Allowed Propagation Loss: Uplink - 6 Sector Site</i>					
Clutter Type	Dense Urban	Urban	Suburban	Rural	
Average Penetration Loss (dB)	20	15	10	5	v
Standard Deviation Outdoor (dB)	9	8	8	7	w
Cell Area Probability	93.00%	93.00%	93.00%	93.00%	x
Log Normal Fading Margin (dB)	7.18	7.18	7.18	7.18	y
Isotropic power required (dB)	-113.5	-118.5	-123.5	-128.5	$z = u + v + y$
Allowed Prop. Loss (dB)	134.5	139.5	144.5	149.5	MAPL = d - z

Step 5: Modeling is done using COST 231 Model, path loss formulas of this model are defined in equation 1 [7]. Table 6 and 7 presents UE Height and Clutter correction factors for COST 231 Model respectively. MAPL calculations and propagation modeling of LTE RAN is presented in Table 8, 9 and 10. Cell range d is calculated by solving the propagation equation for the MAPL, $MAPL = L(d)$.

$$L = 46.30 + 33.90 \cdot \log f_{(MHz)} - 13.82 \cdot \log h_{eNB(m)} - a \cdot h_{BS(m)} + s \cdot \log(d_{km}) + L_{clutter} \quad (1)$$

$$\text{where Slope Factor, } s = (47.88 + 13.9 \cdot \log f_{(MHz)} - 13.82 \cdot \log h_{BS(m)}) \cdot (1/\log 50) \quad (2)$$

Table 9 UE height Correction Factors

Clutter type	$a \cdot \left(\frac{h_{UE}}{m} \right)$
Dense urban	$3.2 \cdot \log^2 \left(11.75 \cdot \frac{h_{UE}}{m} \right) - 4.97$
Urban	
Suburban	$\frac{h_{UE}}{m} \cdot \left(1.1 \cdot \log \left(\frac{f}{MHz} \right) - 0.7 \right) - \left(1.56 \cdot \log \left(\frac{f}{MHz} \right) - 0.8 \right)$
Rural	

Table 10 Clutter Type Correction Factors

Clutter type	$L_{clutter}$
Dense urban	3
Urban	0
Suburban	$-2 \cdot \log^2\left(\frac{f}{28MHz}\right) - 5.4$
Rural	$-4.78 \cdot \log^2\left(\frac{f}{28MHz}\right) + 18.33 \cdot \log\left(\frac{f}{MHz}\right) - 40.94$

Radio Network Configuration parameters are cell area, site-to-site distance and site area. These parameters are used to obtain the site count. The cell range calculated from the link budget analysis is used as input parameter to cell area calculation. These calculations depend on site layout.

$$\begin{aligned} \text{Cell Area} = & 2.6 \times R^2 \text{ (Omni- or 6-Sectored Site)} \\ & 0.65 \times R^2 \text{ (3-Sectored Site)} \end{aligned} \quad (3)$$

$$\begin{aligned} \text{Inter-site Distance} = & 1.73 \times R \text{ (Omni- or 6-Sectored Site)} \\ & 1.5 \times R \text{ (3-Sectored Site)} \end{aligned} \quad (4)$$

$$\begin{aligned} \text{Site Area} = & 2.6 \times R^2 \text{ (Omni- or 6-Sectored Site)} \\ & 1.95 \times R^2 \text{ (3-Sectored Site)} \end{aligned} \quad (5)$$

$$\text{Site Count} = \text{Deployment Area} / \text{Site Area} \quad (6)$$

where, R is cell range in Km.

$$\text{Cell Range} = ((\text{MAPL} - (\text{Intercept Point} + \text{Clutter Correction Factor}))/\text{Slope Factor}) \quad (7)$$

Table 11 shows the parameters for propagation modeling. Table 12, 13 and 14 shows the calculation of cell range, site area and number of sites for each site layout as described above.

Table 11 Parameters for Propagation Modeling

Coverage Estimation - Common Parameters	
Propagation Model	COST 231
Height of eNodeB (m)	30
Height of MS Antenna (m)	1.5
Intercept Point (without Clutter Correction) (dB)	138.52
Slope1 (dB)	35.22
Slope2 (dB)	43.35

Table 12 Site Count for Omni Site Layout

Coverage Estimation - Omni Site Layout				
Clutter Type	Dense Urban	Urban	Suburban	Rural
Allowed Propagation Loss (dB)	126.6	131.6	136.6	141.6
Cell Range (Km)	0.53	0.69	0.9	1.22
Cell Area (Km ²)	0.73	1.24	2.11	3.87
Site-to-Site Distance (Km ²)	0.92	1.19	1.56	2.11
Site Area (Km ²)	0.73	1.24	2.11	3.87
Deployment Area (Km ²)	50	50	50	50
Number of Sites	69	41	24	13

Table 13 Site Count for 3 Sector Site Layout

Coverage Estimation - 3-Sector Site Layout				
Clutter Type	Dense Urban	Urban	Suburban	Rural
Allowed Propagation Loss (dB)	132.1	137.1	142.1	147.1
Cell Range (Km)	0.71	0.93	1.26	1.75
Cell Area (Km ²)	0.33	0.57	1.04	1.99
Site-to-Site Distance (Km ²)	1.07	1.4	1.89	2.63
Site Area (Km ²)	0.98	1.69	3.1	5.97
Deployment Area (Km ²)	50	50	50	50
Number of Sites	52	30	17	9

Table 14 Site Count for 6 Sector Site Layout

<i>Coverage Estimation – 6-Sector Site Layout</i>				
Clutter Type	Dense Urban	Urban	Suburban	Rural
Allowed Propagation Loss (dB)	134.5	139.5	144.5	149.5
Cell Range (Km)	0.81	1.06	1.47	2.04
Cell Area (Km ²)	1.71	2.92	5.62	10.82
Site-to-Site Distance (Km ²)	1.4	1.83	2.54	3.53
Site Area (Km ²)	1.71	2.92	5.62	10.82
Deployment Area (Km ²)	50	50	50	50
Number of Sites	30	18	9	5

V. Discussion and Results

Number of site count for different clutter types based on coverage estimation is presented in Table 12, 13 & 14. It is seen that when sectorization is performed on sites and antenna gain is varied, site count decreases. For Dense Urban 50km² area, 69 omni sites are required whereas on deploying 6 sector site configuration, number of sites reduces to 30. Number of site count for 50 Km² (Deployment Area) decreases because value of MAPL increases. If the gain of antenna is kept constant, then number of sites required to cover deployment area increases because of the sectorization. Similarly results have been presented for other clutters in table 15.

Table 15 Total Site Count for different clutters

Clutter Type	Site Layout		
	Omni	3 Sector	6 Sector
Dense Urban	69	52	30
Urban	41	30	18
Sub Urban	24	17	9
Rural	13	9	5

VI. Conclusion

Impact of sectorization has been analyzed using the above link budget results. Sectorization is the process in which a site is partitioned into multiple sectors and radio resource are used across each sectors and sites, which increases the network capacity of system and service coverage is also increased using high gain directional antenna. In this method, cell radius does not changes but at the same time it is necessary to reduce the relative interference without decreasing the transmit power. Omni directional antenna at the NodeB is replaced by high gain directional antennas, each radiating within a specified sector. Moreover increasing amount of sectorization shows that the number of users gradually increases. The coverage area also gradually increased. Maximum allowable path loss is increased as the sectorization of site is performed because of the increase in antenna gain at NodeB. In the first site layout configuration the network consists of a single Omni antenna, while in the second and third configuration, the network consists of a 3-sector-sites and 6-sector site respectively. First site configuration has the highest number of sites as compared to other two site layout configuration to cover the deployment area for different clutter type.

VI. References

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