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Analysis and Planning of UMTS Systems

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Abstract : *The UMTS marked the beginning of a new Era that demanded, by mobile phone users, the provision of data services at high rates of transmission, that are almost always associated with the mobility of the terminal. This paper aims to present the main results obtained by the authors of the Analysis and Planning of an UMTS systems. The planning is accomplished through scientific methods and mathematical expressions implemented in Matlab software for quantitative and qualitative analysis of the parameters involved with the goal of providing better cost-effective to the end user.*
Keywords**:** *mobile systems, quality of service (QoS), UMTS.*

I. INTRODUCTION

The process of evolution of mobile telephony in the world had its beginning in in the early 1980s, with the commercialization of the first cell phone approved by the FCC (Federal Communication Commission). The mobile communications market is growing intermittently since the third generation of mobile wireless systems (3G) will continue in operation for a long period of time, as the new 4G systems requires large investments, for infrastructure and high quality coverage.

This work aims the analysis and planning of UMTS systems in order to contribute to improve the quality of service of these systems. A resume of the UMTS architecture, its elements and interfaces for understanding the convergence between fixed and mobile network is presented [1].

II. The Umts System

The 3G systems are often called Universal Mobile Telecommunications Systems – UMTS, a designation that includes all aspects of the system: applications and services, network architecture, protocols and physical layer [2].

The main advantage of UMTS systems when compared to the GSM (2G) system is the use of the spectrum dynamically by the users. In other words, in GSM systems the use of the spectrum occurs in a static way, its final capacity is limited by the number of users and the block will happen when all the sub-channels or time slots are occupied for FDMA and TDMA techniques access, respectively.

The WCDMA is designed to be used in conjunction with GSM as the CN (Core Network) of the UMTS are all based on the CN of the GSM, thus allowing handover between these systems.

The UMTS integrated several forms of communications systems, as terrestrial, satellite and indoor networks, providing high-quality multimedia services. Consequently, the UMTS requires many radio interfaces and one of the more important for this system is known as Wideband Code Division Multiple Access (WCDMA) that will be resumed in the next item.

2.1 Air Interface WCDMA

The air interface WCDMA is called by the workgroup 3rd Generation Partnership Project *(*3GPP) of Universal Terrestrial Radio Access - Time Division Duplex (UTRA FDD) and Time Division Duplex (UTRA TDD). In the FDD mode, carriers separated by 5 MHz are used for direct and reverse links while in the TDD mode a band of 5 MHz is divided in time between the direct and reverse links.

The WCDMA is also characterized by spread spectrum techniques developed originally for military applications, but woke up commercial interest due to its feature of high tolerance to interferences. The scattered signal removes the sensitivity of the original narrowband signal but some potential degradation of channels and interferences may exist.

The spread technics becomes an advantage as the demand increases because of the reuse of the spectrum. The transmitted energy remains the same, but due to bandwidth being much larger, the spectrum of the signal is below the noise of the receptor. The signal resembles noise for any recipient who does not know the structure of the signal. For this reason, it becomes difficult to detect, one of the main characteristics of the use of this technology in military applications [3].

The property of a greater tolerance to interferences means increase the tolerance to multipath. The use of Rake receivers in which multipath energy is used to advantage to improve performance through the use of various diversity techniques in space, featuring the use of smart antennas [3] .

The spreading codes used in WCDMA are called Orthogonal Variable Spreading Factor (OVSF) can vary from Spreading Factor (SF) = 4 to SF = 512 for the FDD mode of operation, while for TDD vary from SF = 2 to SF = 16 [4]. These codes are formed by a code tree, where all are orthogonal to each other. The use of OVSF codes allow various lengths of codes are orthogonal to each other.

The effective bandwidth of the WCDMA air interface is equal to 3.84 MHz, plus the guard bands grows to 5 MHz.

2.2 Main Parameters of the System

One of the parameters for understanding the WCDMA air interface is the concept of representation of information, classified as bit, symbol and chip. The concept of the chip is related to the number of bits used in the code spreading. The chip rate has a constant value of 3.84 M chips/s for reverse link and 7.68 M chips/s for direct link, being called SCR - System Chip Rate and characterizing the asymmetry of direct and reverse links [5] . The duration of the chip to the reverse link is 2,6041 x 10^{-7}seconds.

The spreading factor indicates how many times the signal is scattered. It is a multiplier that assigns a number of chips per symbol, and is expressed by: 2^k, k = 0,1,2,...,8. The spreading factor is also called Processing Gain, and this is responsible for the robustness of the links themselves against interferences.

The adaptive modulation is also an important parameter, since the greater the range of the signal, this modulation is more robust to bit error rate of the system (QPSK - Quadrature Phase Shift Keying), but as the nearest to the station - base, this modulation will be less robust to bit error rate (64-QAM - Quadrature Amplitude Modulation), thus causing a smaller range [6].

III. Performance Of Umts Systems

To build a network, whatever its nature, with high quality and excellent ratio cost-benefit it is important to obtain information for the development of an initial network plan *(Roll-Out).* Generally, the initial parameters for the realization of a Roll–Out are:

- **Coverage Requirements** - The link budget must be performed to estimate the amount of BS that are needed in each area of the network to achieve the total desired coverage.
- **Capacity Requirements** - The estimated number users, the services in each area of the network, as well as the calculation of the capacity of the site must be performed in order to determine the required number of Base Stations (BS) to meet the demand and to avoid "congestion" in the sites.
- **Quality Site:** From the moment that the region has coverage and capacity, the inclusion of quality sites at strategic points may be required to meet specific situations classified as to "provide quality service".

To perform the calculation of link budget will be considered the following situations: a mobile terminal operating in the downlink direction and the other handset operating in the uplink direction. It is necessary to determine the following network characteristics:

- Path Loss;
- Limit of the coverage area;
- Estimation of the cell radius.

The Tables 1 and 2 show the parameters and the variables used in this work to calculate the link budget in WCDMA, related to the transmitter and to the receiver, respectively.

Table 1 - Variables and link budget parameters related to the transmitter

TRANSMITTER				
Parameters and Variables	**Units**	**Nº**	***Downlink***	***Uplink***
Data Rate Users	k bits/s	(1)	$R_{b,j}$	
Chip Rate	M chips/s	(2)	R_c =3,84 Mchips/s	
Maximum Transmit Power	W (Watts)	(3)	P_T Power transmitted by Node B	Each UE_j has output power $P_{t,j}$
β (Serving the power of common channels)		(4)	β	
Power for dedicated channels	W	(5)	$P_{cd} = (1-\beta) P_T$	
	dBm	(6)	10log [(5) / 10^{-3}]	
Loss Cable	dB	(7)	L_c	
Loss by the proximity of the body	dB	(8)	L_b	
Antenna Gain	18 dBi	(9)	G_a	
Effectively Transmitted Power	dBm	(10)		

Table 2 - Variables and link budget parameters related to the receiver

Parameters and Variables	Units	Nº	*Uplink and Downlink*
Density of Thermal Noise	dBm/Hz	(11)	10log KT, where K is the Boltzman constant.
Band	Hz	(12)	R_c em Hz
	dBHz	(13)	10log (12)
Noise Figure	dB	(14)	F_{DL}
Noise Received Power	dBm	(15)	P_N= (11) + (13) + (14)
E_b/N_0	dB	(16)	depends on the service and channel
Processing Gain	dB	(17)	G_{pj}= 10log $\left(\frac{R_c}{R_{b,j}}\right)$
sensibility	dBm	(18)	$P_{r,min}$= (15) + (38) + (16) - (17)
Gain Antenna	dBi	(19)	G_a
Gain Diversity Antenna	dB	(20)	G_{div}
Maximum Path Loss in Free Space	dB	(21)	L_0=(10) - (18) + (19) + (20) - (23)
Soft Handover Gain	dB	(22)	G_{SHO}
Fast Fading Margin	dB	(23)	$F_{Fast\ Fading}$
Slow Fading Margin (log-normal)	dB	(24)	$F_{Shadow\ Fading}$
Loss Indoor	dB	(25)	L_{indoor}
Loss inside the car	dB	(26)	L_{in-car}
Loss Outdoor	dB	(27)	$L_{outdoor}$
Path loss tolerable considering Margins, Gain and user characteristics..	dB	(28)	L_0=(21) + (22) - (24) - (25){or(26) or(27)}
Factor Activity (use)		(29)	ν_j
Orthogonality Factor (α)		(30)	DL: Are not orthogonal because the UEs are not synchronized in time. UL: ideal channel ($\alpha = 1$) pedestrian - ITU ($\alpha = 0,9$) vehicular - ITU ($\alpha = 0,6$)
Total Received Power of Own Cell	W	(31)	I_{own}
Total Received Power of Adjacent Cells	dBm	(32)	I_{other}
Total Power Received (Only the desired signal)	dBm	(33)	$P_{r,j}$
Total Received Power	dBm	(34)	DL: I_{total}= I_{own}+ I_{other}+P_N
Interference Ratio (I_{other} / I_{own})		(35)	*i* is a fixed amount to desired area
Specific load factor service		(36)	$\lambda_j^{(DL)}$ and $\lambda_j^{(UL)}$
Factor specific load cell		(37)	η_{DL} and η_{UL}
Interference Margin	dB	(38)	F_{int}
Pole Capacity (number of connections in the same time per cell)		(39)	$C_{max}^{(DL)}$ and $C_{max}^{(UL)}$
Throughput cell	k bits/s	(40)	$R_{cell}^{(DL)} = \sum_{j=1}^{N} R_{b,j}^{DL}$ $R_{cell}^{(UL)} = \sum_{j=1}^{N} R_{b,j}^{UL}$
Cell Size	km	(41)	R
Increased Noise (Noise Rise)	dB	(42)	NR_{DL} and NR_{UL}

The estimative of the cell radius allows the determination of the number of cells needed to provide the desired coverage area. Thus, for this calculation it is necessary to determine the maximum allowable path loss (L_0'), according to the most appropriate propagation model. In this work, the Okumura-Hata model for urban areas was used for determination of L_0.

IV. Simulation Of Umts System Performance

The simulation of the performance, focusing on the WCDMA air interface, has been developed in the software Matlab [1] and the variables described on Tables 1 and 2 are determined and shown in graphics of easy understanding.

4.1 Parameters Previously Established

For the simulation above mentioned, some parameters were previously established and are shown in Table 3 (related to the transmitter and receiver) and in Table 4 (Parameters previously established according to the service). The determination of the path loss was performed for the uplink in a macro cell located in an urban area.

Table 3- Parameters related to the receiver

PARAMETERS	
Height of Radio Base Station (BS)	30 m
BS Antenna Gain	18 dBi
Soft Handover Gain	3 dB
BS Noise Figure	5 dB
BS Cable loss	2 dB
Density of thermal noise	-174 dBm/Hz
Chip Rate	3,84 Mchips/s
Height of Mobile Station (MS)	1,5 m
Mobile Station Antenna Gain	0 dBi
Loss Indoor	15 dB
Fast fading - indoor	4 dB
Fast fading - outdoor	4 dB
Fast fading - inside the car	0 dB
Slow fading - indoor	4,2 dB
Slow fading - outdoor	7,3 dB
Slow fading - inside the car	7,3 dB
Loss inside the car	8 dB

Table 4- Parameters previously established according the service

PARAMETERS	Voice	Data Real Time (RT)	Data Non-Real Time (NRT)
Eb/N0- uplink	5 dB	1,5 dB	1 dB
Eb/N0- downlink	7 dB	3,5 dB	3,5 dB
Maximum transmit power of the terminal	21 dBm	24 dBm	24 dBm
Loss due to the proximity of the body	3 dB	0 dB	0 dB
Mobile Station Antenna Gain	0 dBi	2 dBi	2 dBi
User Data Rate	12.2 kbits/s	144 kbits/s	384 kbits/s

4.2 Numerical and Graphical Analysis of Performance

The input parameters for the simulation performed by the authors [1] are shown in Tables 3 and 4. Increasing the noise by 3 dB, the interactive simulation resulted in a total received noise equal to -100 dBm, considering the interference margin. In practical terms, for calculations of radio-links with typical threshold of -65 dBm, it can be concluded that for the increased noise of 3 dB the system will be still operating under favorable conditions.

In this work, three classes of service for computational simulations were classified: voice services, data services in real time and data services in non-real time. The values of the variables are shown in Table 4. The frequencies used for simulation are 850 MHz and 2100 MHz.

For the frequency of 850 MHz the processing gain obtained by simulation is 24.97 dB for voice services, so we conclude that the processing gain for the reverse link - 3.84 Mchips/s - will be higher for lower bits rates, such as voice services - 12.2 kbits/s. For a bit rate of 2 Mbits/s, the processing gain for the reverse link is 2.8 dB [7], characterizing the robustness against interference in an unfavorable situation.

For ***Voice Services***, the path loss tolerable considering margins, gains and features of the user (with no load) is 145.8 dB. The radius of the cell calculated is 3.7 km for the frequency of 850 MHz, using the Okumura - Hata prediction model [8]. The height of the Mobile equal to 1.5 m and the height of the Base Station equal to 30m (the correction factor is equal to zero).

For ***Data Services***, the **path loss** tolerable considering margins, gains and features of user (with no load) is 134.69 dB (real time) and 138.83 dB (non real-time). The following results for the radius of the cell, based on the prediction of Okumura-Hata model for a frequency of 2100 MHz, were obtained: 0.91 km (real time) and 1.2 km (non real-time). The first is the result of the simulation in a typical environment indoor and then, the cell will cover a smaller area.

The **load factor in the uplink** for 25 users of voice, 15 users of data services in real time and 15 users of data services in non real-time is 2.5, and it was obtained an increase on the thermal noise of 5.16 dB due to multiple access interference.

The **load factor in the downlink** for base station transmission power of 30 watts is 3.3. This value is higher compared to uplink load factor (2.5) due to the addition of the orthogonality factor α. The increase on the thermal noise of 3.7 dB is due to multiple access interference.

The α factor is applied in orthogonal codes in the downlink to separate the users. In other words, with no multipath propagation, the orthogonally remains when the signal from the base station is received by the mobile terminal. However, if there is sufficient delay spread by radio channel, the mobile will identify which part of the signal from the base station is multiple access interference.

For orthogonality equal to 1, the signal of the users are perfectly orthogonal. The α factor ranges from 0.4 to 0.9 in multipath channels.

Using the parameters described in section 4.1, a comparative graphical analysis between the load factors of uplink and downlink for voice services, as shown in Figure 1, illustrate that the load factor for both is directly proportional to the number of users. However, the coefficients of variation are different due to the orthogonally factor α in the downlink mathematical equation. We can conclude from the numerical and graphical analysis that the noise is higher in the uplink than in the downlink for voice services.

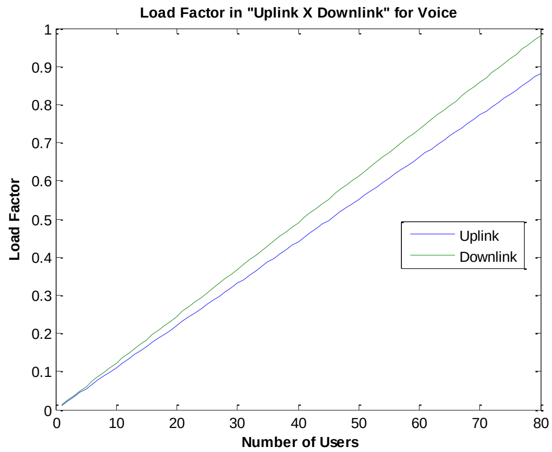

Figure 1. Load Factor in "uplink x downlink" for voice services

As shown previously, the calculation of the radius of the cells vary for different environments (outdoor, indoor and for receiving inside a car). Based on the graphic analysis seen in Figure 2, can be determined the median value of the cells radius for the three environments as a function of the number of users.

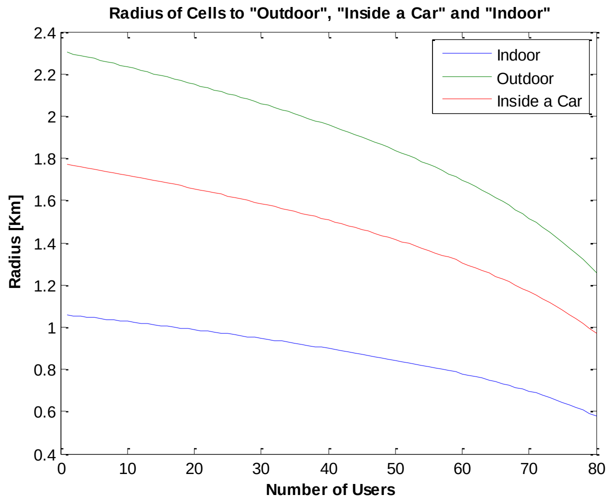

Figure 2. Radius of Cells to Outdoor, Inside a Car and Indoor.

For real-time data services, the load factor for the downlink approaches the maximum capacity (equals 1) to seven users as illustrated in Figure 3.

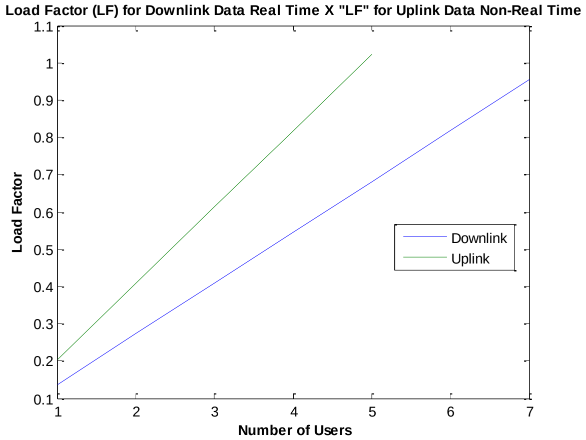

Figure 3. Load Factor for Downlink Data Real Time x Load Factor for Uplink Data in Non-Real Time.

It is important to note that the load factor for the uplink data services in non-real time is on the threshold of cell capacity as it is greater than 1. This fact, in a GSM system, block the capacity of the cell, but in UMTS systems, due to the dynamic form of spectrum allocation, this situation does not occur.

V. Conclusion

This paper aims to present the main topics of the Analysis and Planning of UMTS systems. The planning is accomplished through scientific methods and mathematical expressions implemented in Matlab software for quantitative and qualitative analysis of the parameters involved with the goal of providing better cost-effective to the end user [1]. In this way, computational simulations with real parameters used by mobile operators were performed. The analyzes of these simulations were made in order to ratify the features of 3G networks, increasing transmission rates and simultaneously reducing latency, increasing capacity per sector, reducing system complexity and equipment of the end users. This allows spectrum flexibility in existing frequency bands and new bands and finally, promote interoperability between legacy networks and existing networks.

The simulations using MATLAB software using real design situations and limit values of the input parameters, encourage future simulations with the focus no longer on the air interface developments, but in the management of the networks, thus enabling value-added services by the integration of voice, video and data.

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