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The Impact Of Interference On UMTS/LTE Network Technology In A Highly Dense Environment

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***Abstract:** This study evaluates the impact of interference on LTE at 2600 MHz and UMTS at 2100 MHz frequency bands in a densely populated environment. This was achieved by carrying out field scanning of the environment under study using spectrum analyzer, a diabola antenna with the parameters obtained from the network operator. Also drive test was conducted to measure the received signal strength (RSS). The data obtained enabled the calculation of path loss, path loss exponent, signal to noise ratio (SNR) and channel capacity. The plots show the effect on the channel capacity as the SNR decreases with increase in distance for both LTE and UMTS. Its therefore evidently clear from the tables and the plots that the capacity of LTE network is higher than that of the UMTS and the impact of interference on LTE is also higher than that of the UMTS network in a densely populated environment.*

***Keywords:** Wireless Communication, Interference, LTE/UMTS, Signal to Noise Ratio (SNR), Path Loss (L_p)*

I. INTRODUCTION

Wireless communication technology no doubt is the highest selling commodity in the world today, there is practically no aspect of life that is optimally driven outside wireless telecommunication system, from educational sector, to banking sector, to sports and games even the local market men/women in the village operates on wireless communication system. The high demand for this system of communication complicates the already existing problem of its interference that is already inherent in the network. The network technologies considered in this study are the Universal Mobile Telecommunication System (UMTS) and Long Term Evolution (LTE). The UMTS otherwise called 3G and the LTE 4G network technology in the same network environment make the heterogeneous network under investigation. The nature of the environment where these technologies are deployed is highly populated and the magnitude of the equipment deployed constitutes the densification of the network environment considered in this study. The study is geared at evaluating the Signal to Noise Ratio (SNR) to determine the impact of interference on both UMTS and LTE technologies in a dense environment. Alma (2008). Asserted that “The uplink and downlink capacities do not have just the different values, but they are not comparable because the uplink capacity is mostly related to number of users, and the downlink capacity is related to transmitted power of Node-B. Also, the WCDMA capacity should be parted from the WCDMA throughput and link-budget, even though they are related” (p. 266).

II. THEORETICAL BACKGROUND

A. INTERFERENCE

Wireless communication system is a system with inherent interference in it. Interference is anything that has the capacity to modify or disrupt signals as it travel along a channel between a source and a receiver. Interference is a major limiting factor in the performance of cellular radio systems, because it has the capacity of modifying or degrading the quality of a transmitted signal as it travels along a channel. Sources of interference include other mobile stations (MS) within the same cell, a cell in progress in a neighboring cell, other base stations (BS) operating in the same frequency band, or any non-cellular system which inadvertently leaks energy into the cellular frequency band, interference on voice channels causes cross talk, where the subscriber hears interference in the background due to an undesired transmission. On control channels, interference leads to missed calls, drop calls and blocked calls due to errors in the digital signaling. Interference is more severe in the urban areas, due to greater high frequency (HF) noise floor and a large number of base stations (BS) and mobile stations (MS). Interference has been recognized as a major bottleneck in increasing capacity and is often responsible for drop calls.

According to Article 1.166 of the International Telecommunication Union's (2016), Radio Regulations (RR) defined interference as 'the effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radio communication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy' (p. 23).

$$y = x + \omega \qquad (1)$$

where;

y is the output of the transmitted signal power, x is input of the signal power and ω is the interference power.

B. SIGNAL TO NOISE RATIO (SNR)

Signal to noise ratio is a measurement parameter in use in the field of science and engineering that compares the level of desired signal to the level of the background noise in other words, SNR is defined as the ratio of a signal power to noise power and it is normally expressed in decibel (dB). The mathematical expression of SNR is given by equation (2).

$$SNR = 10\log_{10}\frac{Signal\ Power}{Noise\ Power}\ (dB) \qquad (2)$$

Schweber (2009) Asserted that the most important factor in determining BER is the system of signal to noise ratio (SNR). He revealed that as SNR increases, BER drops drastically. Most communication systems begin to provide reasonably good BERs when the SNR is above 20 to 30dB. Recall that signal-to-noise ratio (SNR) is defined as the ratio of average signal power to average noise power and can be expressed in decibel.

SNR (dB) = 10logSNR

$$SNR = Pt - Lp\ (d) - Sr$$ (cited by Alumona, et al., 2014) (4)

where P_t is the transmitted power (hardware capacity) in dBm and Sr is the receiver sensitivity in dBm, Lp is the path loss.The operators measure sensitivity, by applying a desired signal and then reduce the signal power until the quality threshold is met.

C. THE NETWORK CHANNEL CAPACITY

In WCDMA (UMTS) system, the capacity has a very important feature, it has no single fixed value system capacity in UMTS is a stochastic value that depends on several factors such as multipath propagation, orthogonality in UL/DL, thermal noise, received interference at the mobile and Node-B. UMTS capacity is basically determined by processing gain and required SNR.

Alma (2008) Posited that interference is already included in noise power density and it comprises the Multiple Access Interference (MAI), (interference of other users from observed, home cell and interference of users from the adjacent cell).

In Shannon Hartley theory, the Shannon capacity bound formula as shown in equation (5), is used to calculate the maximum amount of error-free digital data in bits/s/Hz that can be transmitted with a specified bandwidth in the presence of the noise interference.

$$\frac{C}{B} = \log_2(1 + \frac{S}{N}) \qquad (5)$$

Vieira (2008) emphasized that accurate noise interference cannot be reached in practice due to several implementation issues. To represent these loss mechanisms accurately, hence the modification of Shannon Capacity expression.

Therefore, channel capacity is an important performance metric of primary concern in the design of future digital telecommunications systems. Shannon channel capacity provides an upper bound of maximum transmission rate in a given Gaussian environment Nikos, (2005) and George, (2005), Considering a signal's transmission of bandwidth BW over the additive white Gaussian noise (AWGN) channel, the Shannon capacity is defined as;

$$C = BW \log2(1 + \gamma). \qquad (6)$$

where γ is received SNR. When the same signal is transmitted over a fading channel, the capacity can be considered as a random variable.

$$C = BW\log_2(1 + SNR) \qquad (7)$$

Where; C = Channel Capacity, BW = Bandwidth of frequency, SNR = Signal to Noise Ratio as (cited by Dabrowski, (2009)

D. PATH LOSS MODEL

Radio signals generally propagated by means of any combination of these three (3) basic propagation mechanisms; reflection, diffraction and scattering. One of the most important features of propagation is path loss. Path loss can be defined as gradual reduction in received signal strength (RSS), (power) with increase in distance between the transmitter and the receiver. The degradation (attenuation) of the signal strength (power), as the transmitter and (3) receiver (T-R) distance increases is called path loss. Path loss may occur due to the following factors; Terrain (free space loss, refraction, diffraction, reflection, aperture medium capturing loss) and absorption (penetration)), Environments (Urban or Rural, Vegetation and Foliage), Propagation and Medium (Dry or Moist air), the Distance between the transmitter and the base station and the height and location of the transmitting and receiving antenna. Path loss is expressed in the equation 8;

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$$\text{Path loss} = L_p(d_i)dB = 10\ Log\left[\frac{P_t}{P_r}\right](dB) \qquad (8)$$

Where; L_p *is known as the Path loss*, P_t is transmitted power (dBm), and *Power received* P_r *(dBm)*

PARAMETERS	WCDMA (UMTS)	HSPA /HSDPA/ HSUPA	HSPA+	LTE
Max downlink speed	384Kbps	14Mbps	28Mbps	100Mbps
Max uplink speed	128Kbps	5.7Mbps	11Mbps	50Mbps
Latency round trip time	150ms	100ms	50ms (max)	~10ms
3GPP releases	Rel 99/4	Rel 5/6	Rel 7	Rel 8/10
Approx years of initial roll out	2003/04	2005/06 (HSDPA), 2007/08 (HSUPA)	2008/09	2009/10
Access technology	CDMA	CDMA	CDMA	OFDMA/ SC-FDMA

Table 1: Comparison of UMTS, HSPA, HSPA+ and LTE (Hong, 2009 and 3GPP, 2012)

III. MATERIALS AND METHOD

The work employed an experimental research method to carry out the field measurement of networks propagation and also investigate the impact of interference on the UMTS/LTE network system users. The procedure followed in this research work is predominantly field studies which entails field measurement and data collection. The collated data is used to characterize radio environment and determine the QoS, parameter and software considered for this study. MATLAB software is the tool used to analyse the obtained data for the field measurements such as received Signal Strength (RSS) with respect to distance in kilometres (Km) to calculate Signal to Noise Ratio (SNR) and Capacity of both networks UMTS/LTE network systems.

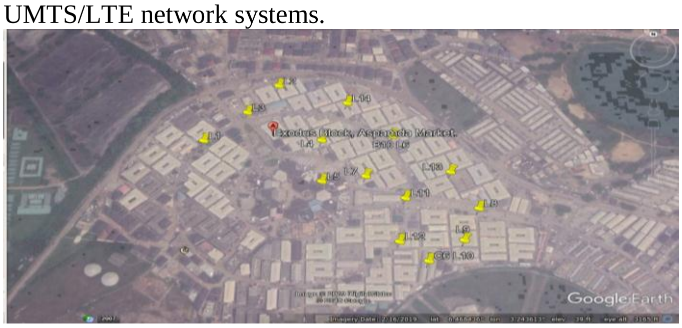

Figure 8: Google Earth of the Sites Visited for Scanning and Drive Test Measurement in the Environment under consideration

Table 2: is the expression of parameters made available by the network operators for the purpose of the field scanning in order to ascertain and confirm the reported problems of interference experienced by the network, which results into the complaints by customers and as shown by the present decline in their generated revenue respectively.

Parameters	UMTS Values	LTE Values
Operating frequency	2100 MHz	2600 MHz
Base station transmitter power	30dBm	46 dBm
Mobile transmitter power	30 dBm	30 dBm
Base station antenna height	32m	32m
Mobile station antenna height	1.5 m	1.5 m
Distance between transmitter and receiver	1-1000m	1-1000m
Receiver Sensitivity.	-110 dBm	−101.5 dBm
Building to building distance	15 m	15 m
Average building height	15m (urban)	15m (urban)
Downlink E_b/N_o	2.5 dB	2.5 dB
Uplink E_b/N_o	1 dB	1 dB

Table 2: Base Stations Parameters and Values.

A. FIELD SCANNING AND MEASUREMENT INSTRUMENTS

a. FIELD SCANNING INSTRUMENTS

The second part of the field work carried out in the process of this project work at Trade Fair (Festac Town) in Lagos is field scanning, using Spectrum Analyser (Azimuth Scanner) with a serial number 1038086, Base version V5.19, Application Version V6.55, Model number MS2725C, and a Diabola Antenna.

b. THE STEP BY STEP PROCEDURE

A step by step procedure in carrying out interference scanning test in Trade Fair (Festac Town), Lagos, using the obtained parameters from the network operator was followed. The first step is the assembling of the field equipment that is coupling the Spectrum Analyser and the Daibola Antenna. secondly, Powering ON the spectrum analyser and getting the setting right in accordance with the obtained parameters required. Thirdly, input the required obtained parameters and then start the movement within the cell to know whether the network is interfered and also to find out the source of interference if any. Finally, the scanning device captures and save the data in the device memory for processing and analysis later, after the drive scanning. The captured data is downloaded into the personal computer (PC) for analysis and interpretation. The figures 1, 2, 3, 4, 5, 6 and 7 shows some of the sources of interference as traced to the unofficially installed antennas generally known as network boosters.

Figure 1: Borno Plaza Scanned Interference on LTE 2600 Downlink

Figure 2: Borno Plaza Source of Interference on LTE Downlink

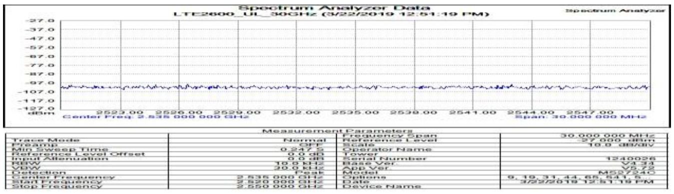

Figure 3: Borno Plaza Scanned Interference on LTE 2600 Uplink

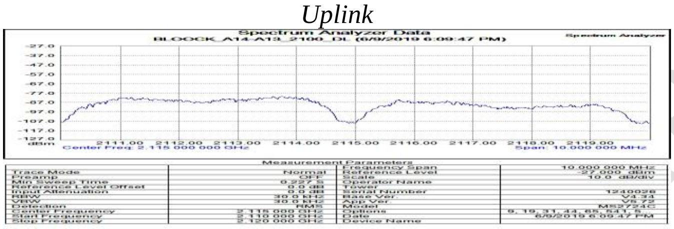

Figure 4: Borno Plaza Scanned Interference on UMTS 2100 Downlink

Figure 5: Borno Plaza Source of Interference on UMTS Downlink

Figure 6: Borno Plaza Scanned Interference on UMTS 2100 Uplink

Figure 7: Borno Plaza Source of Interference on UMTS Uplink

c. MEASUREMENT INSTRUMENTS

The instruments used for data collation consists of test mobile of TECHNO L8 LITE and INFINIX PRO 6 phone operated in the active mode and MAP76CSX GPS to determine the distance from Base Stations, the received signal strength (RSS), phone operated at 95% active mode, Global Positioning System (GPS) receiver set, binocular and digital compass, a laptop equipped with classical node software. On start-up, the software initializes the system by loading a configuration file, this specifies the mode of frequency of operation and allows the operator to work independently. The equipment used for the azimuths of the antenna was a digital compass and a set of binoculars. All readings were taken using true north. The tilts were taken using an electronic tilt meter while the height of antenna was measured using tape. Using the Net Monitor application of the mobile phone and GPS to determine the distance from base stations, the received signal strength was measured. Readings were taken at intervals of 100m spanning 0.1km (100m) ≤ d_i ≤ 2.0km (2000m) from each of the base station. Received power were observed to be unstable and fluctuated due to some building obstacles along the line of sight between the BTS and the receiver.

B. PATH LOSS CHARACTERIZATION OF THE TEST-BED ENVIRONMENT

The values established for the parameters such as path loss at a reference distance, $P_L(d_o)$, and the measured path loss. The gradual reduction of the signal strength (power), as the transmitter and receiver (T-R) distance increases is called path loss as expressed in the equation 8.

Path loss = $L_p(d_i)dB = 10\ Log\left[\frac{P_t}{P_r}\right](dB)$

Using measured data (Average received Power) from table 3. at a close-in distance, d_o of 100m mean received power is;

Power (R_{Xav}) = $P_r(dBm)$ = -54dBm

That is -54 = 10 Log P_r = -5.4

Hence $P_r = 10^{-5.4} = 3.981 \times 10^{-6}\ dB$

Transmitter power for LTE $P_t = 46W = 10\ Log\ 46$

$P_t = 16.628\ dB$

$L_p = 10\log\left(\frac{P_t}{P_r}\right) dB$

$L_p = 10\log\left(\frac{16.628}{3.981\times10^{-6}}\right) dB$

$L_p = 66.208\ dB$

Power (R_{Xav}) = $P_r(dBm)$ = -57dBm

That is -57 = 10 Log P_r = -5.7

Hence $P_r = 10^{-5.7} = 1.995 \times 10^{-6}\ dB$

Transmitter power for UMTS $P_t = 30W = 10\ Log\ 30$

$P_t = 14.77\ dB$

$L_p = 10\log\left(\frac{14.77}{1.995\times10^{-6}}\right) dB$

$L_p = 68.869\ dB$

$L_p \approx 69\ dB$

Distance (Km)	Mean R_{Xav} (dBm) LTE	Measured PL(dB)LTE	Mean R_{Xav} (dBm) UMTS	Measured PL(dB) UMTS
0.10	-54	66	-57	69
0.20	-60	72	-67	79
0.30	-82	94	-65	77
0.40	-82	94	-69	81
0.50	-87	99	-69	81
0.60	-70	82	-91	82
0.70	-72	84	-73	85
0.80	-80	92	-77	89
0.90	-88	100	-87	100
1.00	-89	101	-95	101
1.10	-89	101	-97	107
1.20	-100	112	-85	97
1.30	-95	107	-83	95
1.40	-84	96	-85	96
1.50	-97	109	-81	109
1.60	-96	108	-91	108
1.70	-80	92	-83	95
1.80	-83	95	-83	95
1.90	-98	110	-98	110
2.00	-106	118	-103	118

Table 3: LTE and UMTS Mean RSS and Mean Path Loss for the Measured Sites

a. SIGNAL-TO-NOISE RATIO (SNR) PERFORMANCE OF LTE AND UMTS FROM MEASURED DATA

Recall from equation (3) $SNR = Pt - Lp(d) - Sr,$

The values of SNRs for specified distances spanning $0.1km \leq d_i \leq 2.0km$ are evaluated using same procedure for LTE and UMTS and presented in Tables 4 and 5 that follows. distance of 0.1Km for both LTE and UMTS network systems.

$SNR = 46 - 66 - (-101.5)$ (9)

$SNR = 46 - 66 + 101.5.$

$SNR(dBm) = 81.5dBm.$

But recall from equation (3) we have;

$SNR(dB) = 10logSNR$

$SNR(dB) = 10log\ (81.5)$

For LTE $SNR(dB) = 19.11dB$ and for UMTS $SNR(dB) = 18.51dB$

b. THE NETWORK CHANNEL CAPACITY FOR BOTH LTE AND UMTS NETWORK SYSTEM

Channel Capacity can be defined as the maximum possible data rate under given set of conditions. Bandwidth can be defined as a set of or range of frequencies where most energy is concentrated. The Bandwidth of the system used to carry out this study was 10MHz and the SNR was calculated and tabulated in table 4 and 5 at 19.11 dB and 18.51dB for LTE and UMTS respectively, while we now calculate for the channel capacity of LTE and UMTS, for the entire distance covered from 0.1km to 2.0km. This research work was calculated using Shannon capacity formula as shown in equation (7). The Bandwidth and SNR at various distance of LTE and UMTS are already known. Applying the values in the equation it yields, other capacities are calculated the same way and their values are shown in the tables 4 and 5 respectively.

$C = BW\log_2(1 + SNR)$

$C = 10 \times 10^6 \log_2(1 + 19.11).$

$C = 43.29\ Mbps$ *for LTE Network Technology and* $C = 42.9\ Mbps$ *for UMTS network Technology at a distance of 0.1Km.*

D(Km)	Channel Capacity (Mbps)	SNR (dBm)	SNR (dB)
0.1	43.3	81.5	19.11
0.2	43.1	75.5	18.78
0.3	42.0	53.5	17.28
0.4	42.0	53.5	17.28
0.5	41.8	51	17.07
0.6	42.8	68	18.38

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0.7	42.6	66	18.19
0.8	42.2	58	17.63
0.9	41.7	50	16.98
1.0	41.6	49	16.90
1.1	41.6	49	16.90
1.2	40.7	38	15.79
1.3	41.2	43	16.33
1.4	42.0	54	17.32
1.5	41.0	41	16.13
1.6	41.1	42	16.23
1.7	42.2	58	17.63
1.8	42.0	55	17.40
1.9	40.9	40	16.02
2.0	40.0	32	15.05

Table 4: LTE Network Channel Capacity and SNR with respect to Distance

D(Km)	Channel Capacity (Mbps)	SNR (dBm)	SNR (dB)
0.1	42.9	71	18.51
0.2	42.4	61	17.85
0.3	42.5	63	18.01
0.4	42.2	59	17.70
0.5	42.2	59	17.70
0.6	40.6	37	15.70
0.7	42,0	55	17.40
0.8	41,8	51	17.07
0.9	41.0	41	16.13
1.0	40.2	33	15.19
1.1	40.2	33	15.19
1.2	41.2	43	16.33
1.3	41.3	45	16.53
1.4	41.2	43	16.33
1.5	41.5	47	16.72
1.6	41.0	37	15.70
1.7	41.3	45	16.53
1.8	41.3	45	16.53
1.9	39.0	25	13.97
2.0	38.5	22	13.42

Table 5: UMTS (WCDMA) Network Channel Capacity and SNR with respect to Distance

IV. RESULTS AND DISCUSSION

A. COMPARISON OF LTE SNR AND UMTS SNR WITH INCREASE DISTANCE

The comparison of LTE and UMTS was done using MATLAB software and the values as obtained in tables 4 and 5 of SNR with respect to distance. The plot that LTE is better than UMTS, with LTE at 19.11dB upper end and UMTS at 18.51dB on the lower end of the plot with respect to distance. Looking vividly at the graph it shows that LTE network has a better SNR both at the upper and at lower distance compared to UMTS therefore, has a lower BER and considered as a better network option compared to UMTS in urban areas.

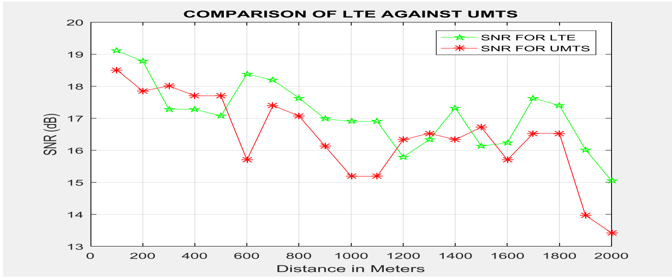

Figure 10: A Comparison of SNR LTE and UMTS Network Technologies

a. THE COMPARISON BETWEEN LTE AND UMTS CAPACITY ON THE IMPACT OF INTERFERENCE ON BOTH NETWORK TECHNOLOGIES

The impact of interference on the network channel capacity from the plots which compare the LTE and UMTS channel capacity with respect to SNR as the mobile station (MS) walked away from the base station. Interference in the LTE 2600MHz frequency band results in the loss of capacity due to the presence of intruders, in figure 11. The plot shows how the capacity decreases with increases in distance against SNR, with the capacities at 43.3Mbps, 40.0Mbps and 10.0Mbps and SNR at 19.2dB. 18.5dB and 16.0dB respectively against that of UMTS interference at 2100MHz frequency band whose capacity decreases with increase in distance against SNR in these magnitude, 42.9Mbps, 30.0Mbps and 5.0Mbps and 18.3dB, 17.5dB and 14.5dB for capacity and SNR respectively. Therefore, its evidently clear that the capacity of LTE network system is higher than that of the UMTS and the impact of interference on LTE is also higher than that of the UMTS network technology in a densely populated environment.

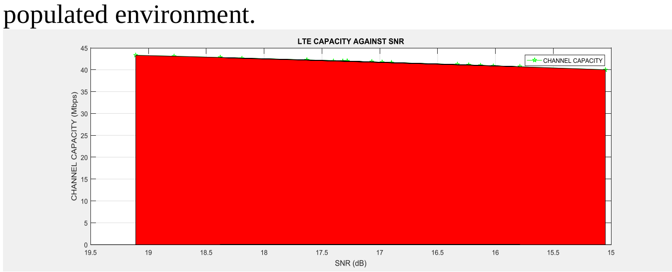

Figure 11: A Plot of Channel Capacity against SNR of an LTE Network Technology

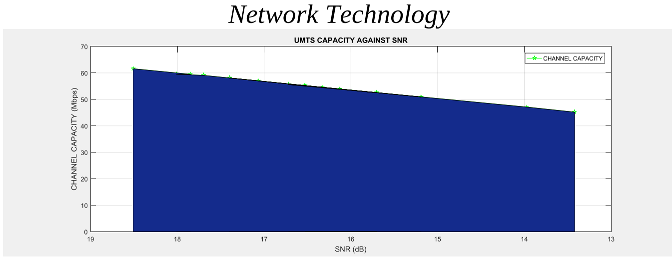

Figure 12: A Plot of Channel Capacity against SNR of an UMTS Network Technology

V. CONCLUSION

The aim of this paper is to evaluate the impact of interference in the network channel capacity for both LTE and UMTS network. To do this, the path loss was calculated from

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the received signal strength (RSS) with increase in distance (Km). The path loss enables the determination of signal to noise ratio (SNR), and the calculations of a channel capacity. From the MATLAB plots shown for the comparison between LTE SNR and UMTS SNR with respect to distance, it was clearly found that interference is very high in a densely populated environment, which reflected in the plots in figure 11 and 12 showing how much impact it has on both networks, but obviously more on UMTS. The LTE channel capacity was seen to be higher from the plots and also LTE has higher SNR from calculation, so this conforms to the known theory that the higher the SNR of the mobile station MS the higher the channel capacity.

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