Projeto de Comunicações Móveis

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Resumo. *Este Trabalho foi feito com intuito de aprendizado adaptação de enlace e conhecimento sobre Long Term Evolution(LTE), Mapeando as possíveis taxas de transmissão dada uma SINR . Para isso foi utilizado a linguagem de programação em Python para a modelagem dos possíveis valores de SINR, com isso foram feitos gráficos para comparação entre o Release 8 e 10 do 3GPP.*

1. Introdução

Nos sistemas do 3GPP, cada um tem sua forma de calcular taxa de transmissão, aqui abordaremos sobre o LTE(*Long Term Evolution*), ou também conhecido como 4G. Para poder calcularmos a taxa de transmissão, precisamos saber quem é MCS(*Modulation and Coding Scheme*) que é quem quem vai mapear a modulação e a taxa de codificação, e o MCS é mapeado de acordo com a CQI(*Channel Quality Indicator*), que para cada faixa de SNR temos um CQI diferente, e a SNR é dada por cada usuário, e para ficar com uma melhor *throughput*,para isso usamos essa tabela:[CQI]

Table 7.1 Lookup table for mapping SINR estimate to modulation scheme and coding rate

CQI index	Modulation	Coding rate	Spectral efficiency (bps/Hz)	SINR estimate (dB)
1	QPSK	0.0762	0.1523	−6.7
2	QPSK	0.1172	0.2344	−4.7
3	QPSK	0.1885	0.3770	−2.3
4	QPSK	0.3008	0.6016	0.2
5	QPSK	0.4385	0.8770	2.4
6	QPSK	0.5879	1.1758	4.3
7	16QAM	0.3691	1.4766	5.9
8	16QAM	0.4785	1.9141	8.1
9	16QAM	0.6016	2.4063	10.3
10	64QAM	0.4551	2.7305	11.7
11	64QAM	0.5537	3.3223	14.1
12	64QAM	0.6504	3.9023	16.3
13	64QAM	0.7539	4.5234	18.7
14	64QAM	0.8525	5.1152	21.0
15	64QAM	0.9258	5.5547	22.7

Figura 1. Mapeando CQI dada SNR

De posse da tabela acima temos só que fazer um mapeamento de CQI em MCS, o qual utilizamos o da patente: [Pat]

MCS INDEX	MODULATION ORDER	TBS INDEX	SPECTRAL EFFICIENCY	COMMENTS	CODE RATE
0	2	0	0.2344	from CQI table (CQI index=2)	0.1171875
1	2	1	0.3057	Average Efficiency	0.15332031
2	2	2	0.377	from CQI table (CQI index=3)	0.18847656
3	2	3	0.4893	Average Efficiency	0.24511719
4	2	4	0.6016	from CQI table (CQI index=4)	0.30078125
5	2	5	0.7393	Average Efficiency	0.37011719
6	2	6	0.877	from CQI table (CQI index=5)	0.43847656
7	2	7	1.0264	Average Efficiency	0.51367188
8	2	8	1.1758	from CQI table (CQI index=6)	0.58789063
9	2	9	1.3262	Average Efficiency	0.66308594
10	4	9	1.3262	overlap	0.33203125
11	4	10	1.4766	from CQI table (CQI index=7)	0.36914063
12	4	11	1.69535	Average Efficiency	0.42382813
13	4	12	1.9141	from CQI table (CQI index=8)	0.47851563
14	4	13	2.1602	Average Efficiency	0.54003906
15	4	14	2.4063	from CQI table (CQI index=9)	0.6015625
16	4	15	2.5684	Average Efficiency	0.64257813
17	6	15	2.5684	overlap	0.42773438
18	6	16	2.7305	from CQI table (CQI index=10)	0.45507813
19	6	17	3.0264	Average Efficiency	0.50488281
20	6	18	3.3223	from CQI table (CQI index=11)	0.55371094
21	6	19	3.6123	Average Efficiency	0.6015625
22	6	20	3.9023	from CQI table (CQI index=12)	0.65039063
23	6	21	4.21285	Average Efficiency	0.70214844
24	6	22	4.5234	from CQI table (CQI index=13)	0.75390625
25	6	23	4.8193	Average Efficiency	0.80273438
26	6	24	5.1152	from CQI table (CQI index=14)	0.85253906
27	6	25	5.33495	Average Efficiency	0.88867188
28	6	26	5.5547	from CQI table (CQI index=15)	0.92578125
29	2	reserved			
30	4	reserved			
31	6	reserved			
32	8	27	5.7930	Average Efficiency	0.7241
33	8	28	6.0313	from CQI table (CQI index=16)	0.75390625
34	8	29	6.4141	Average Efficiency	0.8018
35	8	30	6.7969	from CQI table (CQI index=17)	0.85253906
36	8	31	7.0976	Average Efficiency	0.8872
37	8	32	7.3984	from CQI table (CQI index=18)	0.92578125
38	8	33	7.5077	Average Efficiency	0.9385
39	8	34	7.6171	from CQI table (CQI index=19)	0.9521484375

EXTENDED ACCORDING TO THE NEW CQI TABLE

Figura 2. Mapeando MCS em CQI

2. Experimento 1

No primeiro experimento foi pedido para que fosse apresentado as tabelas de taxa de pico através da formula e da tabela, com o mapeamento feito na introdução, conseguimos montar a formula da taxa de transmissão. Sabendo que a banda de 1.4Mhz são 6 PRBs, 3Mhz são 15 PRBs, 5Mhz são 25 PRBs,10Mhz são 50 PRBs e 20MHZ são 100 PRBs[cal]. A formula é:

$$Tput = mimo * prb * cp * 12 * mod * 0.75 * ca * cod/(0.5 * 10^{-3}) \qquad (1)$$

O quais:

- mimo=Número de antenas
- prb=Número de prbs
- cp=se é prefixo normal(7) se for estendido(6)
- 12 é o numero de subportadoras
- mod= a modulação usada em $log_2(Qam)$
- 0.75 é porque 0.25 é a overhead [Ove]

- ca= é o número dos carrier aggregation, que release 8 é 1.
- cod= a taxa de codificação
- $0.5*10^{-3}$ é o tempo do slot

Com posse do calculo pela formula,só precisamos definir como se calcula pela tabela da norma do 3GPP[3GPP 2009] que é dado por esse site [cal],que é o valor dos bits do TBS index e o MCS, multiplicado por 1000. Com posse desses dados podemos montar essa tabela para o release 8.

MCS	MIMO	35 Taxa de transmissão											
		1.4MHZ	1.4MHZ	3MHZ	3MHZ	5MHZ	5MHZ	10MHZ	10MHZ	15MHZ	15MHZ	20MHZ	20MHZ
		Equação	Tabela	Equação	Tabela	Equação	Tabela	Equação	Tabela	Equação	Tabela	Equação	Tabela
0	1x1	177.19 kbps	152.00 kbps	442.97 kbps	392.00 kbps	738.28 kbps	680.00 kbps	1.48 Mbps	1.38 Mbps	2.21 Mbps	2.09 Mbps	2.95 Mbps	2.79 Mbps
0	2x2	354.38 kbps	304.00 kbps	885.94 kbps	784.00 kbps	1.48 Mbps	1.36 Mbps	2.95 Mbps	2.77 Mbps	4.43 Mbps	4.18 Mbps	5.91 Mbps	5.58 Mbps
0	4x4	708.75 kbps	608.00 kbps	1.77 Mbps	1.57 Mbps	2.95 Mbps	2.72 Mbps	5.91 Mbps	5.54 Mbps	8.86 Mbps	8.35 Mbps	11.81 Mbps	11.17 Mbps
1	1x1	231.82 kbps	208.00 kbps	579.55 kbps	520.00 kbps	965.92 kbps	904.00 kbps	1.93 Mbps	1.80 Mbps	2.90 Mbps	2.73 Mbps	3.86 Mbps	3.62 Mbps
1	2x2	463.64 kbps	416.00 kbps	1.16 Mbps	1.04 Mbps	1.93 Mbps	1.81 Mbps	3.86 Mbps	3.60 Mbps	5.80 Mbps	5.46 Mbps	7.73 Mbps	7.25 Mbps
1	4x4	927.28 kbps	832.00 kbps	2.32 Mbps	2.08 Mbps	3.86 Mbps	3.62 Mbps	7.73 Mbps	7.20 Mbps	11.59 Mbps	10.91 Mbps	15.45 Mbps	14.50 Mbps
2	1x1	284.98 kbps	256.00 kbps	712.44 kbps	648.00 kbps	1.19 Mbps	1.10 Mbps	2.37 Mbps	2.22 Mbps	3.56 Mbps	3.37 Mbps	4.75 Mbps	4.58 Mbps
2	2x2	569.95 kbps	512.00 kbps	1.42 Mbps	1.30 Mbps	2.37 Mbps	2.19 Mbps	4.75 Mbps	4.43 Mbps	7.12 Mbps	6.74 Mbps	9.50 Mbps	9.17 Mbps
2	4x4	1.14 Mbps	1.02 Mbps	2.85 Mbps	2.59 Mbps	4.75 Mbps	4.38 Mbps	9.50 Mbps	8.86 Mbps	14.25 Mbps	13.47 Mbps	19.00 Mbps	18.34 Mbps
3	1x1	370.62 kbps	328.00 kbps	926.54 kbps	872.00 kbps	1.54 Mbps	1.42 Mbps	3.09 Mbps	2.86 Mbps	4.63 Mbps	4.39 Mbps	6.18 Mbps	5.74 Mbps
3	2x2	741.23 kbps	656.00 kbps	1.85 Mbps	1.74 Mbps	3.09 Mbps	2.83 Mbps	6.18 Mbps	5.71 Mbps	9.27 Mbps	8.78 Mbps	12.35 Mbps	11.47 Mbps
3	4x4	1.48 Mbps	1.31 Mbps	3.71 Mbps	3.49 Mbps	6.18 Mbps	5.66 Mbps	12.35 Mbps	11.42 Mbps	18.53 Mbps	17.57 Mbps	24.71 Mbps	22.94 Mbps
4	1x1	454.68 kbps	408.00 kbps	1.14 Mbps	1.06 Mbps	1.89 Mbps	1.80 Mbps	3.79 Mbps	3.62 Mbps	5.68 Mbps	5.35 Mbps	7.58 Mbps	7.22 Mbps
4	2x2	909.35 kbps	816.00 kbps	2.27 Mbps	2.13 Mbps	3.79 Mbps	3.60 Mbps	7.58 Mbps	7.25 Mbps	11.37 Mbps	10.70 Mbps	15.16 Mbps	14.45 Mbps
4	4x4	1.82 Mbps	1.63 Mbps	4.55 Mbps	4.26 Mbps	7.58 Mbps	7.20 Mbps	15.16 Mbps	14.50 Mbps	22.73 Mbps	21.41 Mbps	30.31 Mbps	28.90 Mbps
5	1x1	559.62 kbps	504.00 kbps	1.40 Mbps	1.32 Mbps	2.33 Mbps	2.22 Mbps	4.66 Mbps	4.39 Mbps	7.00 Mbps	6.71 Mbps	9.33 Mbps	8.76 Mbps
5	2x2	1.12 Mbps	1.01 Mbps	2.80 Mbps	2.64 Mbps	4.66 Mbps	4.43 Mbps	9.33 Mbps	8.78 Mbps	13.99 Mbps	13.42 Mbps	18.65 Mbps	17.52 Mbps
5	4x4	2.24 Mbps	2.02 Mbps	5.60 Mbps	5.28 Mbps	9.33 Mbps	8.86 Mbps	18.65 Mbps	17.57 Mbps	27.98 Mbps	26.85 Mbps	37.31 Mbps	35.04 Mbps
6	1x1	662.98 kbps	600.00 kbps	1.66 Mbps	1.54 Mbps	2.76 Mbps	2.60 Mbps	5.52 Mbps	5.16 Mbps	8.29 Mbps	7.74 Mbps	11.05 Mbps	10.30 Mbps
6	2x2	1.33 Mbps	1.20 Mbps	3.31 Mbps	3.09 Mbps	5.52 Mbps	5.20 Mbps	11.05 Mbps	10.32 Mbps	16.57 Mbps	15.47 Mbps	22.10 Mbps	20.59 Mbps
6	4x4	2.65 Mbps	2.40 Mbps	6.63 Mbps	6.18 Mbps	11.05 Mbps	10.40 Mbps	22.10 Mbps	20.64 Mbps	33.15 Mbps	30.94 Mbps	44.20 Mbps	41.18 Mbps
7	1x1	776.67 kbps	712.00 kbps	1.94 Mbps	1.80 Mbps	3.24 Mbps	3.11 Mbps	6.47 Mbps	6.20 Mbps	9.71 Mbps	9.14 Mbps	12.94 Mbps	12.22 Mbps
7	2x2	1.55 Mbps	1.42 Mbps	3.88 Mbps	3.60 Mbps	6.47 Mbps	6.22 Mbps	12.94 Mbps	12.40 Mbps	19.42 Mbps	18.29 Mbps	25.89 Mbps	24.43 Mbps
7	4x4	3.11 Mbps	2.85 Mbps	7.77 Mbps	7.20 Mbps	12.94 Mbps	12.45 Mbps	25.89 Mbps	24.80 Mbps	38.83 Mbps	36.58 Mbps	51.78 Mbps	48.86 Mbps
8	1x1	888.89 kbps	808.00 kbps	2.22 Mbps	2.09 Mbps	3.70 Mbps	3.50 Mbps	7.41 Mbps	6.97 Mbps	11.11 Mbps	10.68 Mbps	14.81 Mbps	14.11 Mbps
8	2x2	1.78 Mbps	1.62 Mbps	4.44 Mbps	4.18 Mbps	7.41 Mbps	6.99 Mbps	14.81 Mbps	13.94 Mbps	22.22 Mbps	21.36 Mbps	29.63 Mbps	28.22 Mbps
8	4x4	3.56 Mbps	3.23 Mbps	8.89 Mbps	8.35 Mbps	14.81 Mbps	13.98 Mbps	29.63 Mbps	27.87 Mbps	44.44 Mbps	42.72 Mbps	59.26 Mbps	56.45 Mbps
9	1x1	1.00 Mbps	936.00 kbps	2.51 Mbps	2.34 Mbps	4.18 Mbps	4.01 Mbps	8.35 Mbps	7.99 Mbps	12.53 Mbps	11.83 Mbps	16.71 Mbps	15.84 Mbps
9	2x2	2.01 Mbps	1.87 Mbps	5.01 Mbps	4.69 Mbps	8.35 Mbps	8.02 Mbps	16.71 Mbps	15.98 Mbps	25.06 Mbps	23.66 Mbps	33.42 Mbps	31.68 Mbps
9	4x4	4.01 Mbps	3.74 Mbps	10.03 Mbps	9.38 Mbps	16.71 Mbps	16.03 Mbps	33.42 Mbps	31.97 Mbps	50.13 Mbps	47.33 Mbps	66.84 Mbps	63.36 Mbps
10	1x1	1.00 Mbps	936.00 kbps	2.51 Mbps	2.34 Mbps	4.18 Mbps	4.01 Mbps	8.37 Mbps	7.99 Mbps	12.55 Mbps	11.83 Mbps	16.73 Mbps	15.84 Mbps
10	2x2	2.01 Mbps	1.87 Mbps	5.02 Mbps	4.69 Mbps	8.37 Mbps	8.02 Mbps	16.73 Mbps	15.98 Mbps	25.10 Mbps	23.66 Mbps	33.47 Mbps	31.68 Mbps
10	4x4	4.02 Mbps	3.74 Mbps	10.04 Mbps	9.38 Mbps	16.73 Mbps	16.03 Mbps	33.47 Mbps	31.97 Mbps	50.20 Mbps	47.33 Mbps	66.94 Mbps	63.36 Mbps
11	1x1	1.12 Mbps	1.03 Mbps	2.79 Mbps	2.66 Mbps	4.65 Mbps	4.39 Mbps	9.30 Mbps	8.76 Mbps	13.95 Mbps	12.96 Mbps	18.60 Mbps	17.57 Mbps
11	2x2	2.23 Mbps	2.06 Mbps	5.58 Mbps	5.33 Mbps	9.30 Mbps	8.78 Mbps	18.60 Mbps	17.52 Mbps	27.91 Mbps	25.92 Mbps	37.21 Mbps	35.14 Mbps
11	4x4	4.47 Mbps	4.13 Mbps	11.16 Mbps	10.66 Mbps	18.60 Mbps	17.57 Mbps	37.21 Mbps	35.04 Mbps	55.81 Mbps	51.84 Mbps	74.42 Mbps	70.27 Mbps
12	1x1	1.28 Mbps	1.19 Mbps	3.20 Mbps	2.98 Mbps	5.34 Mbps	4.97 Mbps	10.68 Mbps	9.91 Mbps	16.02 Mbps	15.26 Mbps	21.36 Mbps	19.85 Mbps
12	2x2	2.56 Mbps	2.38 Mbps	6.41 Mbps	5.97 Mbps	10.68 Mbps	9.94 Mbps	21.36 Mbps	19.82 Mbps	32.04 Mbps	30.53 Mbps	42.72 Mbps	39.70 Mbps
12	4x4	5.13 Mbps	4.77 Mbps	12.82 Mbps	11.94 Mbps	21.36 Mbps	19.87 Mbps	42.72 Mbps	39.65 Mbps	64.08 Mbps	61.06 Mbps	85.44 Mbps	79.39 Mbps
13	1x1	1.45 Mbps	1.35 Mbps	3.62 Mbps	3.37 Mbps	6.03 Mbps	5.74 Mbps	12.06 Mbps	11.45 Mbps	18.09 Mbps	16.99 Mbps	24.12 Mbps	22.92 Mbps
13	2x2	2.89 Mbps	2.70 Mbps	7.24 Mbps	6.74 Mbps	12.06 Mbps	11.47 Mbps	24.12 Mbps	22.90 Mbps	36.18 Mbps	33.98 Mbps	48.23 Mbps	45.84 Mbps
13	4x4	5.79 Mbps	5.41 Mbps	14.47 Mbps	13.47 Mbps	24.12 Mbps	22.94 Mbps	48.23 Mbps	45.79 Mbps	72.35 Mbps	67.97 Mbps	96.47 Mbps	91.68 Mbps
14	1x1	1.63 Mbps	1.54 Mbps	4.08 Mbps	3.88 Mbps	6.80 Mbps	6.46 Mbps	13.61 Mbps	12.96 Mbps	20.41 Mbps	19.08 Mbps	27.22 Mbps	25.46 Mbps
14	2x2	3.27 Mbps	3.09 Mbps	8.17 Mbps	7.76 Mbps	13.61 Mbps	12.91 Mbps	27.22 Mbps	25.92 Mbps	40.83 Mbps	38.16 Mbps	54.44 Mbps	50.91 Mbps
14	4x4	6.53 Mbps	6.18 Mbps	16.33 Mbps	15.52 Mbps	27.22 Mbps	25.82 Mbps	54.44 Mbps	51.84 Mbps	81.65 Mbps	76.32 Mbps	108.87 Mbps	101.82 Mbps
15	1x1	1.82 Mbps	1.74 Mbps	4.55 Mbps	4.26 Mbps	7.58 Mbps	7.22 Mbps	15.16 Mbps	14.11 Mbps	22.74 Mbps	21.38 Mbps	30.32 Mbps	28.34 Mbps
15	2x2	3.64 Mbps	3.47 Mbps	9.10 Mbps	8.53 Mbps	15.16 Mbps	14.45 Mbps	30.32 Mbps	28.22 Mbps	45.48 Mbps	42.77 Mbps	60.64 Mbps	56.67 Mbps
15	4x4	7.28 Mbps	6.94 Mbps	18.19 Mbps	17.06 Mbps	30.32 Mbps	28.90 Mbps	60.64 Mbps	56.45 Mbps	90.96 Mbps	85.54 Mbps	121.27 Mbps	113.34 Mbps
16	1x1	1.94 Mbps	1.80 Mbps	4.86 Mbps	4.58 Mbps	8.10 Mbps	7.74 Mbps	16.19 Mbps	15.26 Mbps	24.29 Mbps	22.92 Mbps	32.39 Mbps	30.58 Mbps
16	2x2	3.89 Mbps	3.60 Mbps	9.72 Mbps	9.17 Mbps	16.19 Mbps	15.47 Mbps	32.39 Mbps	30.53 Mbps	48.58 Mbps	45.84 Mbps	64.77 Mbps	61.15 Mbps
16	4x4	7.77 Mbps	7.20 Mbps	19.43 Mbps	18.34 Mbps	32.39 Mbps	30.94 Mbps	64.77 Mbps	61.06 Mbps	97.16 Mbps	91.68 Mbps	129.54 Mbps	122.30 Mbps
17	1x1	1.94 Mbps	1.80 Mbps	4.85 Mbps	4.58 Mbps	8.08 Mbps	7.74 Mbps	16.17 Mbps	15.26 Mbps	24.25 Mbps	22.92 Mbps	32.34 Mbps	30.58 Mbps
17	2x2	3.88 Mbps	3.60 Mbps	9.70 Mbps	9.17 Mbps	16.17 Mbps	15.47 Mbps	32.34 Mbps	30.53 Mbps	48.51 Mbps	45.84 Mbps	64.67 Mbps	61.15 Mbps
17	4x4	7.76 Mbps	7.20 Mbps	19.40 Mbps	18.34 Mbps	32.34 Mbps	30.94 Mbps	64.67 Mbps	61.06 Mbps	97.01 Mbps	91.68 Mbps	129.35 Mbps	122.30 Mbps
18	1x1	2.06 Mbps	1.93 Mbps	5.16 Mbps	4.97 Mbps	8.60 Mbps	7.99 Mbps	17.20 Mbps	16.42 Mbps	25.80 Mbps	24.50 Mbps	34.40 Mbps	32.86 Mbps
18	2x2	4.13 Mbps	3.86 Mbps	10.32 Mbps	9.94 Mbps	17.20 Mbps	15.98 Mbps	34.40 Mbps	32.83 Mbps	51.61 Mbps	48.99 Mbps	68.81 Mbps	65.71 Mbps
18	4x4	8.26 Mbps	7.71 Mbps	20.64 Mbps	19.87 Mbps	34.40 Mbps	31.97 Mbps	68.81 Mbps	65.66 Mbps	103.21 Mbps	97.98 Mbps	137.62 Mbps	131.42 Mbps
19	1x1	2.29 Mbps	2.15 Mbps	5.73 Mbps	5.35 Mbps	9.54 Mbps	9.14 Mbps	19.08 Mbps	18.34 Mbps	28.63 Mbps	27.38 Mbps	38.17 Mbps	36.70 Mbps
19	2x2	4.58 Mbps	4.30 Mbps	11.45 Mbps	10.70 Mbps	19.08 Mbps	18.29 Mbps	38.17 Mbps	36.67 Mbps	57.25 Mbps	54.75 Mbps	76.34 Mbps	73.39 Mbps
19	4x4	9.16 Mbps	8.61 Mbps	22.90 Mbps	21.41 Mbps	38.17 Mbps	36.58 Mbps	76.34 Mbps	73.34 Mbps	114.51 Mbps	109.50 Mbps	152.68 Mbps	146.78 Mbps
20	1x1	2.51 Mbps	2.34 Mbps	6.28 Mbps	5.99 Mbps	10.47 Mbps	9.91 Mbps	20.93 Mbps	19.85 Mbps	31.40 Mbps	29.30 Mbps	41.86 Mbps	39.23 Mbps
20	2x2	5.02 Mbps	4.69 Mbps	12.56 Mbps	11.98 Mbps	20.93 Mbps	19.82 Mbps	41.86 Mbps	39.70 Mbps	62.79 Mbps	58.59 Mbps	83.72 Mbps	78.46 Mbps
20	4x4	10.05 Mbps	9.38 Mbps	25.12 Mbps	23.97 Mbps	41.86 Mbps	39.65 Mbps	83.72 Mbps	79.39 Mbps	125.58 Mbps	117.18 Mbps	167.44 Mbps	156.93 Mbps
21	1x1	2.73 Mbps	2.60 Mbps	6.82 Mbps	6.46 Mbps	11.37 Mbps	10.68 Mbps	22.74 Mbps	21.38 Mbps	34.11 Mbps	32.86 Mbps	45.48 Mbps	43.82 Mbps
21	2x2	5.46 Mbps	5.20 Mbps	13.64 Mbps	12.91 Mbps	22.74 Mbps	21.36 Mbps	45.48 Mbps	42.77 Mbps	68.22 Mbps	65.71 Mbps	90.96 Mbps	87.63 Mbps
21	4x4	10.91 Mbps	10.40 Mbps	27.29 Mbps	25.82 Mbps	45.48 Mbps	42.72 Mbps	90.96 Mbps	85.54 Mbps	136.43 Mbps	131.42 Mbps	181.91 Mbps	175.26 Mbps
22	1x1	2.95 Mbps	2.79 Mbps	7.38 Mbps	6.97 Mbps	12.29 Mbps	11.45 Mbps	24.58 Mbps	22.92 Mbps	36.88 Mbps	35.16 Mbps	49.17 Mbps	46.89 Mbps
22	2x2	5.90 Mbps	5.58 Mbps	14.75 Mbps	13.94 Mbps	24.58 Mbps	22.90 Mbps	49.17 Mbps	45.84 Mbps	73.75 Mbps	70.32 Mbps	98.34 Mbps	93.78 Mbps
22	4x4	11.80 Mbps	11.17 Mbps	29.50 Mbps	27.87 Mbps	49.17 Mbps	45.79 Mbps	98.34 Mbps	91.68 Mbps	147.51 Mbps	140.64 Mbps	196.68 Mbps	187.55 Mbps
23	1x1	3.18 Mbps	2.98 Mbps	7.96 Mbps	7.48 Mbps	13.27 Mbps	12.58 Mbps	26.54 Mbps	25.46 Mbps	39.81 Mbps	37.89 Mbps	53.08 Mbps	51.02 Mbps
23	2x2	6.37 Mbps	5.97 Mbps	15.92 Mbps	14.96 Mbps	26.54 Mbps	25.15 Mbps	53.08 Mbps	50.91 Mbps	79.62 Mbps	75.78 Mbps	106.16 Mbps	102.05 Mbps
23	4x4	12.74 Mbps	11.94 Mbps	31.85 Mbps	29.92 Mbps	53.08 Mbps	50.30 Mbps	106.16 Mbps	101.82 Mbps	159.25 Mbps	151.55 Mbps	212.33 Mbps	204.10 Mbps
24	1x1	3.42 Mbps	3.24 Mbps	8.55 Mbps	7.99 Mbps	14.25 Mbps	13.54 Mbps	28.50 Mbps	27.38 Mbps	42.75 Mbps	40.58 Mbps	57.00 Mbps	55.06 Mbps
24	2x2	6.84 Mbps	6.48 Mbps	17.10 Mbps	15.98 Mbps	28.50 Mbps	27.07 Mbps	57.00 Mbps	54.75 Mbps	85.49 Mbps	81.15 Mbps	113.99 Mbps	110.11 Mbps
24	4x4	13.68 Mbps	12.96 Mbps	34.20 Mbps	31.97 Mbps	57.00 Mbps	54.14 Mbps	113.99 Mbps	109.50 Mbps	170.99 Mbps	162.30 Mbps	227.98 Mbps	220.22 Mbps
25	1x1	3.64 Mbps	3.49 Mbps	9.10 Mbps	8.50 Mbps	15.17 Mbps	14.11 Mbps	30.34 Mbps	28.34 Mbps	45.52 Mbps	43.82 Mbps	60.69 Mbps	57.34 Mbps
25	2x2	7.28 Mbps	6.99 Mbps	18.21 Mbps	17.01 Mbps	30.34 Mbps	28.22 Mbps	60.69 Mbps	56.67 Mbps	91.03 Mbps	87.63 Mbps	121.37 Mbps	114.67 Mbps
25	4x4	14.56 Mbps	13.98 Mbps	36.41 Mbps	34.02 Mbps	60.69 Mbps	56.45 Mbps	121.37 Mbps	113.34 Mbps	182.06 Mbps	175.26 Mbps	242.75 Mbps	229.34 Mbps
26	1x1	3.87 Mbps	3.62 Mbps	9.67 Mbps	9.14 Mbps	16.11 Mbps	15.26 Mbps	32.23 Mbps	30.58 Mbps	48.34 Mbps	45.35 Mbps	64.45 Mbps	61.66 Mbps
26	2x2	7.73 Mbps	7.25 Mbps	19.34 Mbps	18.29 Mbps	32.23 Mbps	30.53 Mbps	64.45 Mbps	61.15 Mbps	96.68 Mbps	90.70 Mbps	128.90 Mbps	123.33 Mbps
26	4x4	15.47 Mbps	14.50 Mbps	38.67 Mbps	36.58 Mbps	64.45 Mbps	61.06 Mbps	128.90 Mbps	122.30 Mbps	193.36 Mbps	181.41 Mbps	257.81 Mbps	246.66 Mbps
27	1x1	4.03 Mbps	3.75 Mbps	10.08 Mbps	9.53 Mbps	16.80 Mbps	15.84 Mbps	33.59 Mbps	31.70 Mbps	50.39 Mbps	46.89 Mbps	67.18 Mbps	63.78 Mbps
27	2x2	8.06 Mbps	7.50 Mbps	20.16 Mbps	19.06 Mbps	33.59 Mbps	31.68 Mbps	67.18 Mbps	63.41 Mbps	100.78 Mbps	93.78 Mbps	134.37 Mbps	127.55 Mbps
27	4x4	16.12 Mbps	15.01 Mbps	40.31 Mbps	38.11 Mbps	67.18 Mbps	63.36 Mbps	134.37 Mbps	126.82 Mbps	201.55 Mbps	187.55 Mbps	268.73 Mbps	255.10 Mbps
28	1x1	4.20 Mbps	4.39 Mbps	10.50 Mbps	11.06 Mbps	17.50 Mbps	18.34 Mbps	34.99 Mbps	36.70 Mbps	52.49 Mbps	55.06 Mbps	69.99 Mbps	75.38 Mbps
28	2x2	8.40 Mbps	8.78 Mbps	21.00 Mbps	22.13 Mbps	34.99 Mbps	36.67 Mbps	69.99 Mbps	73.39 Mbps	104.98 Mbps	110.11 Mbps	139.98 Mbps	150.75 Mbps
28	4x4	16.80 Mbps	17.57 Mbps	41.99 Mbps	44.26 Mbps	69.99 Mbps	73.34 Mbps	139.98 Mbps	146.78 Mbps	209.97 Mbps	220.22 Mbps	279.96 Mbps	301.50 Mbps

E para o release 10 foi acrescentado o *carrier aggregation* [Car] e o mimo 8x8,mas para a tabela não ficar tão grande foi colocado o carrier aggregation igual a 5 em cima de 20Mhz, que é o de 100Mhz.

MCS	MIMO	Taxa de Transmissão													
		1.4MHZ Equação	1.4MHZ Tabela	3MHZ Equação	3MHZ Tabela	5MHZ Equação	5MHZ Tabela	10MHZ Equação	10MHZ Tabela	15MHZ Equação	15MHZ Tabela	20MHZ Equação	20MHZ Tabela	100MHZ Equação	100MHZ Tabela
0	1x1	177.19 kbps	152.00 kbps	442.97 kbps	392.00 kbps	738.28 kbps	680.00 kbps	1.48 Mbps	1.38 Mbps	2.21 Mbps	2.09 Mbps	2.95 Mbps	2.79 Mbps	14.77 Mbps	13.96 Mbps
0	2x2	354.38 kbps	304.00 kbps	885.94 kbps	784.00 kbps	1.48 Mbps	1.36 Mbps	2.95 Mbps	2.77 Mbps	4.43 Mbps	4.18 Mbps	5.91 Mbps	5.58 Mbps	29.53 Mbps	27.92 Mbps
0	4x4	708.75 kbps	608.00 kbps	1.77 Mbps	1.57 Mbps	2.95 Mbps	2.72 Mbps	5.91 Mbps	5.54 Mbps	8.86 Mbps	8.35 Mbps	11.81 Mbps	11.17 Mbps	59.06 Mbps	55.84 Mbps
0	8x8	1.42 Mbps	1.22 Mbps	3.54 Mbps	3.14 Mbps	5.91 Mbps	5.44 Mbps	11.81 Mbps	11.07 Mbps	17.72 Mbps	16.70 Mbps	23.62 Mbps	22.34 Mbps	118.12 Mbps	111.68 Mbps
1	1x1	231.82 kbps	208.00 kbps	579.55 kbps	520.00 kbps	965.92 kbps	904.00 kbps	1.93 Mbps	1.80 Mbps	2.90 Mbps	2.73 Mbps	3.86 Mbps	3.62 Mbps	19.32 Mbps	18.12 Mbps
1	2x2	463.64 kbps	416.00 kbps	1.16 Mbps	1.04 Mbps	1.93 Mbps	1.81 Mbps	3.86 Mbps	3.60 Mbps	5.80 Mbps	5.46 Mbps	7.73 Mbps	7.25 Mbps	38.64 Mbps	36.24 Mbps
1	4x4	927.28 kbps	832.00 kbps	2.32 Mbps	2.08 Mbps	3.86 Mbps	3.62 Mbps	7.73 Mbps	7.20 Mbps	11.59 Mbps	10.91 Mbps	15.45 Mbps	14.50 Mbps	77.27 Mbps	72.48 Mbps
1	8x8	1.85 Mbps	1.66 Mbps	4.64 Mbps	4.16 Mbps	7.73 Mbps	7.23 Mbps	15.45 Mbps	14.40 Mbps	23.18 Mbps	21.82 Mbps	30.91 Mbps	28.99 Mbps	154.55 Mbps	144.96 Mbps
2	1x1	284.98 kbps	256.00 kbps	712.44 kbps	648.00 kbps	1.19 Mbps	1.10 Mbps	2.37 Mbps	2.22 Mbps	3.56 Mbps	3.37 Mbps	4.75 Mbps	4.58 Mbps	23.75 Mbps	22.92 Mbps
2	2x2	569.95 kbps	512.00 kbps	1.42 Mbps	1.30 Mbps	2.37 Mbps	2.19 Mbps	4.75 Mbps	4.43 Mbps	7.12 Mbps	6.74 Mbps	9.50 Mbps	9.17 Mbps	47.50 Mbps	45.84 Mbps
2	4x4	1.14 Mbps	1.02 Mbps	2.85 Mbps	2.59 Mbps	4.75 Mbps	4.38 Mbps	9.50 Mbps	8.86 Mbps	14.25 Mbps	13.47 Mbps	19.00 Mbps	18.34 Mbps	94.99 Mbps	91.68 Mbps
2	8x8	2.28 Mbps	2.05 Mbps	5.70 Mbps	5.18 Mbps	9.50 Mbps	8.77 Mbps	19.00 Mbps	17.73 Mbps	28.50 Mbps	26.94 Mbps	38.00 Mbps	36.67 Mbps	189.98 Mbps	183.36 Mbps
3	1x1	370.62 kbps	328.00 kbps	926.54 kbps	872.00 kbps	1.54 Mbps	1.42 Mbps	3.09 Mbps	2.86 Mbps	4.63 Mbps	4.39 Mbps	6.18 Mbps	5.74 Mbps	30.88 Mbps	28.68 Mbps
3	2x2	741.23 kbps	656.00 kbps	1.85 Mbps	1.74 Mbps	3.09 Mbps	2.83 Mbps	6.18 Mbps	5.71 Mbps	9.27 Mbps	8.78 Mbps	12.35 Mbps	11.47 Mbps	61.77 Mbps	57.36 Mbps
3	4x4	1.48 Mbps	1.31 Mbps	3.71 Mbps	3.49 Mbps	6.18 Mbps	5.66 Mbps	12.35 Mbps	11.42 Mbps	18.53 Mbps	17.57 Mbps	24.71 Mbps	22.94 Mbps	123.54 Mbps	114.72 Mbps
3	8x8	2.96 Mbps	2.62 Mbps	7.41 Mbps	6.98 Mbps	12.35 Mbps	11.33 Mbps	24.71 Mbps	22.85 Mbps	37.06 Mbps	35.14 Mbps	49.42 Mbps	45.89 Mbps	247.08 Mbps	229.44 Mbps
4	1x1	454.68 kbps	408.00 kbps	1.14 Mbps	1.06 Mbps	1.89 Mbps	1.80 Mbps	3.79 Mbps	3.62 Mbps	5.68 Mbps	5.35 Mbps	7.58 Mbps	7.22 Mbps	37.89 Mbps	36.12 Mbps
4	2x2	909.35 kbps	816.00 kbps	2.27 Mbps	2.13 Mbps	3.79 Mbps	3.60 Mbps	7.58 Mbps	7.25 Mbps	11.37 Mbps	10.70 Mbps	15.16 Mbps	14.45 Mbps	75.78 Mbps	72.24 Mbps
4	4x4	1.82 Mbps	1.63 Mbps	4.55 Mbps	4.26 Mbps	7.58 Mbps	7.20 Mbps	15.16 Mbps	14.50 Mbps	22.73 Mbps	21.41 Mbps	30.31 Mbps	28.90 Mbps	151.56 Mbps	144.48 Mbps
4	8x8	3.64 Mbps	3.26 Mbps	9.09 Mbps	8.51 Mbps	15.16 Mbps	14.40 Mbps	30.31 Mbps	28.99 Mbps	45.47 Mbps	42.82 Mbps	60.62 Mbps	57.79 Mbps	303.12 Mbps	288.96 Mbps
5	1x1	559.62 kbps	504.00 kbps	1.40 Mbps	1.32 Mbps	2.33 Mbps	2.22 Mbps	4.66 Mbps	4.39 Mbps	7.00 Mbps	6.71 Mbps	9.33 Mbps	8.76 Mbps	46.63 Mbps	43.80 Mbps
5	2x2	1.12 Mbps	1.01 Mbps	2.80 Mbps	2.64 Mbps	4.66 Mbps	4.43 Mbps	9.33 Mbps	8.78 Mbps	13.99 Mbps	13.42 Mbps	18.65 Mbps	17.52 Mbps	93.27 Mbps	87.60 Mbps
5	4x4	2.24 Mbps	2.02 Mbps	5.60 Mbps	5.28 Mbps	9.33 Mbps	8.86 Mbps	18.65 Mbps	17.57 Mbps	27.98 Mbps	26.85 Mbps	37.31 Mbps	35.04 Mbps	186.54 Mbps	175.20 Mbps
5	8x8	4.48 Mbps	4.03 Mbps	11.19 Mbps	10.56 Mbps	18.65 Mbps	17.73 Mbps	37.31 Mbps	35.14 Mbps	55.96 Mbps	53.70 Mbps	74.62 Mbps	70.08 Mbps	373.08 Mbps	350.40 Mbps
6	1x1	662.98 kbps	600.00 kbps	1.66 Mbps	1.54 Mbps	2.76 Mbps	2.60 Mbps	5.52 Mbps	5.16 Mbps	8.29 Mbps	7.74 Mbps	11.05 Mbps	10.30 Mbps	55.25 Mbps	51.48 Mbps
6	2x2	1.33 Mbps	1.20 Mbps	3.31 Mbps	3.09 Mbps	5.52 Mbps	5.20 Mbps	11.05 Mbps	10.32 Mbps	16.57 Mbps	15.47 Mbps	22.10 Mbps	20.59 Mbps	110.50 Mbps	102.96 Mbps
6	4x4	2.65 Mbps	2.40 Mbps	6.63 Mbps	6.18 Mbps	11.05 Mbps	10.40 Mbps	22.10 Mbps	20.64 Mbps	33.15 Mbps	30.94 Mbps	44.20 Mbps	41.18 Mbps	220.99 Mbps	205.92 Mbps
6	8x8	5.30 Mbps	4.80 Mbps	13.26 Mbps	12.35 Mbps	22.10 Mbps	20.80 Mbps	44.20 Mbps	41.28 Mbps	66.30 Mbps	61.89 Mbps	88.40 Mbps	82.37 Mbps	441.98 Mbps	411.84 Mbps
7	1x1	776.67 kbps	712.00 kbps	1.94 Mbps	1.80 Mbps	3.24 Mbps	3.11 Mbps	6.47 Mbps	6.20 Mbps	9.71 Mbps	9.14 Mbps	12.94 Mbps	12.22 Mbps	64.72 Mbps	61.08 Mbps
7	2x2	1.55 Mbps	1.42 Mbps	3.88 Mbps	3.60 Mbps	6.47 Mbps	6.22 Mbps	12.94 Mbps	12.40 Mbps	19.42 Mbps	18.29 Mbps	25.89 Mbps	24.43 Mbps	129.45 Mbps	122.16 Mbps
7	4x4	3.11 Mbps	2.85 Mbps	7.77 Mbps	7.20 Mbps	12.94 Mbps	12.45 Mbps	25.89 Mbps	24.80 Mbps	38.83 Mbps	36.58 Mbps	51.78 Mbps	48.86 Mbps	258.89 Mbps	244.32 Mbps
7	8x8	6.21 Mbps	5.70 Mbps	15.53 Mbps	14.40 Mbps	25.89 Mbps	24.90 Mbps	51.78 Mbps	49.60 Mbps	77.67 Mbps	73.15 Mbps	103.56 Mbps	97.73 Mbps	517.78 Mbps	488.64 Mbps
8	1x1	888.89 kbps	808.00 kbps	2.22 Mbps	2.09 Mbps	3.70 Mbps	3.50 Mbps	7.41 Mbps	6.97 Mbps	11.11 Mbps	10.68 Mbps	14.81 Mbps	14.11 Mbps	74.07 Mbps	70.56 Mbps
8	2x2	1.78 Mbps	1.62 Mbps	4.44 Mbps	4.18 Mbps	7.41 Mbps	6.99 Mbps	14.81 Mbps	13.94 Mbps	22.22 Mbps	21.36 Mbps	29.63 Mbps	28.22 Mbps	148.15 Mbps	141.12 Mbps
8	4x4	3.56 Mbps	3.23 Mbps	8.89 Mbps	8.35 Mbps	14.81 Mbps	13.98 Mbps	29.63 Mbps	27.87 Mbps	44.44 Mbps	42.72 Mbps	59.26 Mbps	56.45 Mbps	296.30 Mbps	282.24 Mbps
8	8x8	7.11 Mbps	6.46 Mbps	17.78 Mbps	16.70 Mbps	29.63 Mbps	27.97 Mbps	59.26 Mbps	55.74 Mbps	88.89 Mbps	85.44 Mbps	118.52 Mbps	112.90 Mbps	592.59 Mbps	564.48 Mbps
9	1x1	1.00 Mbps	936.00 kbps	2.51 Mbps	2.34 Mbps	4.18 Mbps	4.01 Mbps	8.35 Mbps	7.99 Mbps	12.53 Mbps	11.83 Mbps	16.71 Mbps	15.84 Mbps	83.55 Mbps	79.20 Mbps
9	2x2	2.01 Mbps	1.87 Mbps	5.01 Mbps	4.69 Mbps	8.35 Mbps	8.02 Mbps	16.71 Mbps	15.98 Mbps	25.06 Mbps	23.66 Mbps	33.42 Mbps	31.68 Mbps	167.10 Mbps	158.40 Mbps
9	4x4	4.01 Mbps	3.74 Mbps	10.03 Mbps	9.38 Mbps	16.71 Mbps	16.03 Mbps	33.42 Mbps	31.97 Mbps	50.13 Mbps	47.33 Mbps	66.84 Mbps	63.36 Mbps	334.20 Mbps	316.80 Mbps
9	8x8	8.02 Mbps	7.49 Mbps	20.05 Mbps	18.75 Mbps	33.42 Mbps	32.06 Mbps	66.84 Mbps	63.94 Mbps	100.26 Mbps	94.66 Mbps	133.68 Mbps	126.72 Mbps	668.39 Mbps	633.60 Mbps
10	1x1	1.00 Mbps	936.00 kbps	2.51 Mbps	2.34 Mbps	4.18 Mbps	4.01 Mbps	8.37 Mbps	7.99 Mbps	12.55 Mbps	11.83 Mbps	16.73 Mbps	15.84 Mbps	83.67 Mbps	79.20 Mbps
10	2x2	2.01 Mbps	1.87 Mbps	5.02 Mbps	4.69 Mbps	8.37 Mbps	8.02 Mbps	16.73 Mbps	15.98 Mbps	25.10 Mbps	23.66 Mbps	33.47 Mbps	31.68 Mbps	167.34 Mbps	158.40 Mbps
10	4x4	4.02 Mbps	3.74 Mbps	10.04 Mbps	9.38 Mbps	16.73 Mbps	16.03 Mbps	33.47 Mbps	31.97 Mbps	50.20 Mbps	47.33 Mbps	66.94 Mbps	63.36 Mbps	334.69 Mbps	316.80 Mbps
10	8x8	8.03 Mbps	7.49 Mbps	20.08 Mbps	18.75 Mbps	33.47 Mbps	32.06 Mbps	66.94 Mbps	63.94 Mbps	100.41 Mbps	94.66 Mbps	133.88 Mbps	126.72 Mbps	669.38 Mbps	633.60 Mbps
11	1x1	1.12 Mbps	1.03 Mbps	2.79 Mbps	2.66 Mbps	4.65 Mbps	4.39 Mbps	9.30 Mbps	8.76 Mbps	13.95 Mbps	12.96 Mbps	18.60 Mbps	17.57 Mbps	93.02 Mbps	87.84 Mbps
11	2x2	2.23 Mbps	2.06 Mbps	5.58 Mbps	5.33 Mbps	9.30 Mbps	8.78 Mbps	18.60 Mbps	17.52 Mbps	27.91 Mbps	25.92 Mbps	37.21 Mbps	35.14 Mbps	186.05 Mbps	175.68 Mbps
11	4x4	4.47 Mbps	4.13 Mbps	11.16 Mbps	10.66 Mbps	18.60 Mbps	17.57 Mbps	37.21 Mbps	35.04 Mbps	55.81 Mbps	51.84 Mbps	74.42 Mbps	70.27 Mbps	372.09 Mbps	351.36 Mbps
11	8x8	8.93 Mbps	8.26 Mbps	22.33 Mbps	21.31 Mbps	37.21 Mbps	35.14 Mbps	74.42 Mbps	70.08 Mbps	111.63 Mbps	103.68 Mbps	148.84 Mbps	140.54 Mbps	744.19 Mbps	702.72 Mbps
12	1x1	1.28 Mbps	1.19 Mbps	3.20 Mbps	2.98 Mbps	5.34 Mbps	4.97 Mbps	10.68 Mbps	9.91 Mbps	16.02 Mbps	15.26 Mbps	21.36 Mbps	19.85 Mbps	106.80 Mbps	99.24 Mbps
12	2x2	2.56 Mbps	2.38 Mbps	6.41 Mbps	5.97 Mbps	10.68 Mbps	9.94 Mbps	21.36 Mbps	19.82 Mbps	32.04 Mbps	30.53 Mbps	42.72 Mbps	39.70 Mbps	213.61 Mbps	198.48 Mbps
12	4x4	5.13 Mbps	4.77 Mbps	12.82 Mbps	11.94 Mbps	21.36 Mbps	19.87 Mbps	42.72 Mbps	39.65 Mbps	64.08 Mbps	61.06 Mbps	85.44 Mbps	79.39 Mbps	427.22 Mbps	396.96 Mbps
12	8x8	10.25 Mbps	9.54 Mbps	25.63 Mbps	23.87 Mbps	42.72 Mbps	39.74 Mbps	85.44 Mbps	79.30 Mbps	128.17 Mbps	122.11 Mbps	170.89 Mbps	158.78 Mbps	854.44 Mbps	793.92 Mbps
13	1x1	1.45 Mbps	1.35 Mbps	3.62 Mbps	3.37 Mbps	6.03 Mbps	5.74 Mbps	12.06 Mbps	11.45 Mbps	18.09 Mbps	16.99 Mbps	24.12 Mbps	22.92 Mbps	120.59 Mbps	114.60 Mbps
13	2x2	2.89 Mbps	2.70 Mbps	7.24 Mbps	6.74 Mbps	12.06 Mbps	11.47 Mbps	24.12 Mbps	22.90 Mbps	36.18 Mbps	33.98 Mbps	48.23 Mbps	45.84 Mbps	241.17 Mbps	229.20 Mbps
13	4x4	5.79 Mbps	5.41 Mbps	14.47 Mbps	13.47 Mbps	24.12 Mbps	22.94 Mbps	48.23 Mbps	45.79 Mbps	72.35 Mbps	67.97 Mbps	96.47 Mbps	91.68 Mbps	482.34 Mbps	458.40 Mbps
13	8x8	11.58 Mbps	10.82 Mbps	28.94 Mbps	26.94 Mbps	48.23 Mbps	45.89 Mbps	96.47 Mbps	91.58 Mbps	144.70 Mbps	135.94 Mbps	192.94 Mbps	183.36 Mbps	964.69 Mbps	916.80 Mbps
14	1x1	1.63 Mbps	1.54 Mbps	4.08 Mbps	3.88 Mbps	6.80 Mbps	6.46 Mbps	13.61 Mbps	12.96 Mbps	20.41 Mbps	19.08 Mbps	27.22 Mbps	25.46 Mbps	136.09 Mbps	127.28 Mbps
14	2x2	3.27 Mbps	3.09 Mbps	8.17 Mbps	7.76 Mbps	13.61 Mbps	12.91 Mbps	27.22 Mbps	25.92 Mbps	40.83 Mbps	38.16 Mbps	54.44 Mbps	50.91 Mbps	272.18 Mbps	254.56 Mbps
14	4x4	6.53 Mbps	6.18 Mbps	16.33 Mbps	15.52 Mbps	27.22 Mbps	25.82 Mbps	54.44 Mbps	51.84 Mbps	81.65 Mbps	76.32 Mbps	108.87 Mbps	101.82 Mbps	544.36 Mbps	509.12 Mbps
14	8x8	13.06 Mbps	12.35 Mbps	32.66 Mbps	31.04 Mbps	54.44 Mbps	51.65 Mbps	108.87 Mbps	103.68 Mbps	163.31 Mbps	152.64 Mbps	217.74 Mbps	203.65 Mbps	1.09 Gbps	1.02 Gbps
15	1x1	1.82 Mbps	1.74 Mbps	4.55 Mbps	4.26 Mbps	7.58 Mbps	7.22 Mbps	15.16 Mbps	14.11 Mbps	22.74 Mbps	21.38 Mbps	30.32 Mbps	28.33 Mbps	151.59 Mbps	141.68 Mbps
15	2x2	3.64 Mbps	3.47 Mbps	9.10 Mbps	8.53 Mbps	15.16 Mbps	14.45 Mbps	30.32 Mbps	28.22 Mbps	45.48 Mbps	42.77 Mbps	60.64 Mbps	56.67 Mbps	303.19 Mbps	283.36 Mbps
15	4x4	7.28 Mbps	6.94 Mbps	18.19 Mbps	17.06 Mbps	30.32 Mbps	28.90 Mbps	60.64 Mbps	56.45 Mbps	90.96 Mbps	85.54 Mbps	121.27 Mbps	113.34 Mbps	606.38 Mbps	566.72 Mbps
15	8x8	14.55 Mbps	13.89 Mbps	36.38 Mbps	34.11 Mbps	60.64 Mbps	57.79 Mbps	121.27 Mbps	112.90 Mbps	181.91 Mbps	171.07 Mbps	242.55 Mbps	226.69 Mbps	1.21 Gbps	1.13 Gbps
16	1x1	1.94 Mbps	1.80 Mbps	4.86 Mbps	4.58 Mbps	8.10 Mbps	7.74 Mbps	16.19 Mbps	15.26 Mbps	24.29 Mbps	22.92 Mbps	32.39 Mbps	30.58 Mbps	161.93 Mbps	152.88 Mbps
16	2x2	3.89 Mbps	3.60 Mbps	9.72 Mbps	9.17 Mbps	16.19 Mbps	15.47 Mbps	32.39 Mbps	30.53 Mbps	48.58 Mbps	45.84 Mbps	64.77 Mbps	61.15 Mbps	323.86 Mbps	305.76 Mbps
16	4x4	7.77 Mbps	7.20 Mbps	19.43 Mbps	18.34 Mbps	32.39 Mbps	30.94 Mbps	64.77 Mbps	61.06 Mbps	97.16 Mbps	91.68 Mbps	129.54 Mbps	122.30 Mbps	647.72 Mbps	611.52 Mbps
16	8x8	15.55 Mbps	14.40 Mbps	38.86 Mbps	36.67 Mbps	64.77 Mbps	61.89 Mbps	129.54 Mbps	122.11 Mbps	194.32 Mbps	183.36 Mbps	259.09 Mbps	244.61 Mbps	1.30 Gbps	1.22 Gbps
17	1x1	1.94 Mbps	1.80 Mbps	4.85 Mbps	4.58 Mbps	8.08 Mbps	7.74 Mbps	16.17 Mbps	15.26 Mbps	24.25 Mbps	22.92 Mbps	32.34 Mbps	30.58 Mbps	161.68 Mbps	152.88 Mbps
17	2x2	3.88 Mbps	3.60 Mbps	9.70 Mbps	9.17 Mbps	16.17 Mbps	15.47 Mbps	32.34 Mbps	30.53 Mbps	48.51 Mbps	45.84 Mbps	64.67 Mbps	61.15 Mbps	323.37 Mbps	305.76 Mbps
17	4x4	7.76 Mbps	7.20 Mbps	19.40 Mbps	18.34 Mbps	32.34 Mbps	30.94 Mbps	64.67 Mbps	61.06 Mbps	97.01 Mbps	91.68 Mbps	129.35 Mbps	122.30 Mbps	646.73 Mbps	611.52 Mbps
17	8x8	15.52 Mbps	14.40 Mbps	38.80 Mbps	36.67 Mbps	64.67 Mbps	61.89 Mbps	129.35 Mbps	122.11 Mbps	194.02 Mbps	183.36 Mbps	258.69 Mbps	244.61 Mbps	1.29 Gbps	1.22 Gbps
18	1x1	2.06 Mbps	1.93 Mbps	5.16 Mbps	4.97 Mbps	8.60 Mbps	7.99 Mbps	17.20 Mbps	16.42 Mbps	25.80 Mbps	24.50 Mbps	34.40 Mbps	32.86 Mbps	172.02 Mbps	164.28 Mbps
18	2x2	4.13 Mbps	3.86 Mbps	10.32 Mbps	9.94 Mbps	17.20 Mbps	15.98 Mbps	34.40 Mbps	32.83 Mbps	51.61 Mbps	48.99 Mbps	68.81 Mbps	65.71 Mbps	344.04 Mbps	328.56 Mbps
18	4x4	8.26 Mbps	7.71 Mbps	20.64 Mbps	19.87 Mbps	34.40 Mbps	31.97 Mbps	68.81 Mbps	65.66 Mbps	103.21 Mbps	97.98 Mbps	137.62 Mbps	131.42 Mbps	688.08 Mbps	657.12 Mbps
18	8x8	16.51 Mbps	15.42 Mbps	41.28 Mbps	39.74 Mbps	68.81 Mbps	63.94 Mbps	137.62 Mbps	131.33 Mbps	206.42 Mbps	195.97 Mbps	275.23 Mbps	262.85 Mbps	1.38 Gbps	1.31 Gbps
19	1x1	2.29 Mbps	2.15 Mbps	5.73 Mbps	5.35 Mbps	9.54 Mbps	9.14 Mbps	19.08 Mbps	18.34 Mbps	28.63 Mbps	27.38 Mbps	38.17 Mbps	36.70 Mbps	190.85 Mbps	183.48 Mbps
19	2x2	4.58 Mbps	4.30 Mbps	11.45 Mbps	10.70 Mbps	19.08 Mbps	18.29 Mbps	38.17 Mbps	36.67 Mbps	57.25 Mbps	54.75 Mbps	76.34 Mbps	73.39 Mbps	381.69 Mbps	366.96 Mbps
19	4x4	9.16 Mbps	8.60 Mbps	22.90 Mbps	21.41 Mbps	38.17 Mbps	36.58 Mbps	76.34 Mbps	73.34 Mbps	114.51 Mbps	109.50 Mbps	152.68 Mbps	146.78 Mbps	763.38 Mbps	733.92 Mbps
19	8x8	18.32 Mbps	17.22 Mbps	45.80 Mbps	42.82 Mbps	76.34 Mbps	73.15 Mbps	152.68 Mbps	146.69 Mbps	229.01 Mbps	219.01 Mbps	305.35 Mbps	293.57 Mbps	1.53 Gbps	1.47 Gbps
20	1x1	2.51 Mbps	2.34 Mbps	6.28 Mbps	5.99 Mbps	10.47 Mbps	9.91 Mbps	20.93 Mbps	19.85 Mbps	31.40 Mbps	29.30 Mbps	41.86 Mbps	39.23 Mbps	209.30 Mbps	196.16 Mbps
20	2x2	5.02 Mbps	4.69 Mbps	12.56 Mbps	11.98 Mbps	20.93 Mbps	19.82 Mbps	41.86 Mbps	39.70 Mbps	62.79 Mbps	58.59 Mbps	83.72 Mbps	78.46 Mbps	418.61 Mbps	392.32 Mbps
20	4x4	10.05 Mbps	9.38 Mbps	25.12 Mbps	23.97 Mbps	41.86 Mbps	39.65 Mbps	83.72 Mbps	79.39 Mbps	125.58 Mbps	117.18 Mbps	167.44 Mbps	156.93 Mbps	837.21 Mbps	784.64 Mbps
20	8x8	20.09 Mbps	18.75 Mbps	50.23 Mbps	47.94 Mbps	83.72 Mbps	79.30 Mbps	167.44 Mbps	158.78 Mbps	251.16 Mbps	234.37 Mbps	334.88 Mbps	313.86 Mbps	1.67 Gbps	1.57 Gbps
21	1x1	2.73 Mbps	2.60 Mbps	6.82 Mbps	6.46 Mbps	11.37 Mbps	10.68 Mbps	22.74 Mbps	21.38 Mbps	34.11 Mbps	32.86 Mbps	45.48 Mbps	43.82 Mbps	227.39 Mbps	219.08 Mbps
21	2x2	5.46 Mbps	5.20 Mbps	13.64 Mbps	12.91 Mbps	22.74 Mbps	21.36 Mbps	45.48 Mbps	42.77 Mbps	68.22 Mbps	65.71 Mbps	90.96 Mbps	87.63 Mbps	454.78 Mbps	438.16 Mbps
21	4x4	10.91 Mbps	10.40 Mbps	27.29 Mbps	25.82 Mbps	45.48 Mbps	42.72 Mbps	90.96 Mbps	85.54 Mbps	136.43 Mbps	131.42 Mbps	181.91 Mbps	175.26 Mbps	909.56 Mbps	876.32 Mbps
21	8x8	21.83 Mbps	20.80 Mbps	54.57 Mbps	51.65 Mbps	90.96 Mbps	85.44 Mbps	181.91 Mbps	171.07 Mbps	272.87 Mbps	262.85 Mbps	363.82 Mbps	350.53 Mbps	1.82 Gbps	1.75 Gbps
22	1x1	2.95 Mbps	2.79 Mbps	7.38 Mbps	6.97 Mbps	12.29 Mbps	11.45 Mbps	24.58 Mbps	22.92 Mbps	36.88 Mbps	35.16 Mbps	49.17 Mbps	46.89 Mbps	245.85 Mbps	234.44 Mbps
22	2x2	5.90 Mbps	5.58 Mbps	14.75 Mbps	13.94 Mbps	24.58 Mbps	22.90 Mbps	49.17 Mbps	45.84 Mbps	73.75 Mbps	70.32 Mbps	98.34 Mbps	93.78 Mbps	491.70 Mbps	468.88 Mbps
22	4x4	11.80 Mbps	11.17 Mbps	29.50 Mbps	27.87 Mbps	49.17 Mbps	45.79 Mbps	98.34 Mbps	91.68 Mbps	147.51 Mbps	140.64 Mbps	196.68 Mbps	187.55 Mbps	983.39 Mbps	937.76 Mbps
22	8x8	23.60 Mbps	22.34 Mbps	59.00 Mbps	55.74 Mbps	98.34 Mbps	91.58 Mbps	196.68 Mbps	183.36 Mbps	295.02 Mbps	281.28 Mbps	393.36 Mbps	375.10 Mbps	1.97 Gbps	1.88 Gbps
23	1x1	3.18 Mbps	2.98 Mbps	7.96 Mbps	7.48 Mbps	13.27 Mbps	12.58 Mbps	26.54 Mbps	25.46 Mbps	39.81 Mbps	37.89 Mbps	53.08 Mbps	51.02 Mbps	265.41 Mbps	255.12 Mbps
23	2x2	6.37 Mbps	5.97 Mbps	15.92 Mbps	14.96 Mbps	26.54 Mbps	25.15 Mbps	53.08 Mbps	50.91 Mbps	79.62 Mbps	75.78 Mbps	106.16 Mbps	102.05 Mbps	530.82 Mbps	510.24 Mbps
23	4x4	12.74 Mbps	11.94 Mbps	31.85 Mbps	29.92 Mbps	53.08 Mbps	50.30 Mbps	106.16 Mbps	101.82 Mbps	159.25 Mbps	151.55 Mbps	212.33 Mbps	204.10 Mbps	1.06 Gbps	1.02 Gbps
23	8x8	25.48 Mbps	23.87 Mbps	63.70 Mbps	59.84 Mbps	106.16 Mbps	100.61 Mbps	212.33 Mbps	203.65 Mbps	318.49 Mbps	303.10 Mbps	424.66 Mbps	408.19 Mbps	2.12 Gbps	2.04 Gbps
24	1x1	3.42 Mbps	3.24 Mbps	8.55 Mbps	7.99 Mbps	14.25 Mbps	13.54 Mbps	28.50 Mbps	27.07 Mbps	42.75 Mbps	40.58 Mbps	57.00 Mbps	55.06 Mbps	284.98 Mbps	275.28 Mbps
24	2x2	6.84 Mbps	6.48 Mbps	17.11 Mbps	15.98 Mbps	28.50 Mbps	27.07 Mbps	57.00 Mbps	54.75 Mbps	85.49 Mbps	81.15 Mbps	113.99 Mbps	110.11 Mbps	569.95 Mbps	550.56 Mbps
24	4x4	13.68 Mbps	12.96 Mbps	34.20 Mbps	31.97 Mbps	57.00 Mbps	54.14 Mbps	113.99 Mbps	109.50 Mbps	170.99 Mbps	162.30 Mbps	227.98 Mbps	220.22 Mbps	1.14 Gbps	1.10 Gbps
24	8x8	27.36 Mbps	25.92 Mbps	68.39 Mbps	63.94 Mbps	113.99 Mbps	108.29 Mbps	227.98 Mbps	219.01 Mbps	341.97 Mbps	324.61 Mbps	455.96 Mbps	440.45 Mbps	2.28 Gbps	2.20 Gbps
25	1x1	3.64 Mbps	3.50 Mbps	9.10 Mbps	8.50 Mbps	15.17 Mbps	14.11 Mbps	30.34 Mbps	28.34 Mbps	45.52 Mbps	43.82 Mbps	60.69 Mbps	57.34 Mbps	303.43 Mbps	286.68 Mbps
25	2x2	7.28 Mbps	6.99 Mbps	18.21 Mbps	17.01 Mbps	30.34 Mbps	28.22 Mbps	60.69 Mbps	56.67 Mbps	91.03 Mbps	87.63 Mbps	121.37 Mbps	114.67 Mbps	606.87 Mbps	573.36 Mbps
25	4x4	14.56 Mbps	13.98 Mbps	36.41 Mbps	34.02 Mbps	60.69 Mbps	56.45 Mbps	121.37 Mbps	113.34 Mbps	182.06 Mbps	175.26 Mbps	242.75 Mbps	229.34 Mbps	1.21 Gbps	1.15 Gbps
25	8x8	29.13 Mbps	27.97 Mbps	72.82 Mbps	68.03 Mbps	121.37 Mbps	112.90 Mbps	242.75 Mbps	226.69 Mbps	364.12 Mbps	350.53 Mbps	485.49 Mbps	458.69 Mbps	2.43 Gbps	2.29 Gbps
26	1x1	3.87 Mbps	3.62 Mbps	9.67 Mbps	9.14 Mbps	16.11 Mbps	15.26 Mbps	32.23 Mbps	30.58 Mbps	48.34 Mbps	45.35 Mbps	64.45 Mbps	61.66 Mbps	322.26 Mbps	308.32 Mbps
26	2x2	7.73 Mbps	7.25 Mbps	19.34 Mbps	18.29 Mbps	32.23 Mbps	30.53 Mbps	64.45 Mbps	61.15 Mbps	96.68 Mbps	90.70 Mbps	128.90 Mbps	123.33 Mbps	644.52 Mbps	616.64 Mbps
26	4x4	15.47 Mbps	14.50 Mbps	38.67 Mbps	36.58 Mbps	64.45 Mbps	61.06 Mbps	128.90 Mbps	122.30 Mbps	193.36 Mbps	181.41 Mbps	257.81 Mbps	246.66 Mbps	1.29 Gbps	1.23 Gbps
26	8x8	30.94 Mbps	28.99 Mbps	77.34 Mbps	73.15 Mbps	128.90 Mbps	122.11 Mbps	257.81 Mbps	244.61 Mbps	386.71 Mbps	362.82 Mbps	515.62 Mbps	493.31 Mbps	2.58 Gbps	2.47 Gbps
27	1x1	4.03 Mbps	3.75 Mbps	10.08 Mbps	9.53 Mbps	16.80 Mbps	15.84 Mbps	33.59 Mbps	31.70 Mbps	50.39 Mbps	46.89 Mbps	67.18 Mbps	63.78 Mbps	335.92 Mbps	318.88 Mbps
27	2x2	8.06 Mbps	7.50 Mbps	20.16 Mbps	19.06 Mbps	33.59 Mbps	31.68 Mbps	67.18 Mbps	63.41 Mbps	100.78 Mbps	93.78 Mbps	134.37 Mbps	127.55 Mbps	671.84 Mbps	637.76 Mbps
27	4x4	16.12 Mbps	15.01 Mbps	40.31 Mbps	38.11 Mbps	67.18 Mbps	63.36 Mbps	134.37 Mbps	126.82 Mbps	201.55 Mbps	187.55 Mbps	268.73 Mbps	255.10 Mbps	1.34 Gbps	1.28 Gbps
27	8x8	32.25 Mbps	30.02 Mbps	80.62 Mbps	76.22 Mbps	134.37 Mbps	126.72 Mbps	268.73 Mbps	253.63 Mbps	403.10 Mbps	375.10 Mbps	537.47 Mbps	510.21 Mbps	2.69 Gbps	2.55 Gbps

Table 2 continued from previous page

28	1x1	4.20 Mbps	4.39 Mbps	10.50 Mbps	11.06 Mbps	17.50 Mbps	18.34 Mbps	34.99 Mbps	36.70 Mbps	52.49 Mbps	55.06 Mbps	69.99 Mbps	75.38 Mbps	349.95 Mbps	376.88 Mbps
28	2x2	8.40 Mbps	8.78 Mbps	21.00 Mbps	22.13 Mbps	34.99 Mbps	36.67 Mbps	69.99 Mbps	73.39 Mbps	104.98 Mbps	110.11 Mbps	139.98 Mbps	150.75 Mbps	699.89 Mbps	753.76 Mbps
28	4x4	16.80 Mbps	17.57 Mbps	41.99 Mbps	44.26 Mbps	69.99 Mbps	73.34 Mbps	139.98 Mbps	146.78 Mbps	209.97 Mbps	220.22 Mbps	279.96 Mbps	301.50 Mbps	1.40 Gbps	1.51 Gbps
28	8x8	33.59 Mbps	35.14 Mbps	83.99 Mbps	88.51 Mbps	139.98 Mbps	146.69 Mbps	279.96 Mbps	293.57 Mbps	419.93 Mbps	440.45 Mbps	559.91 Mbps	603.01 Mbps	2.80 Gbps	3.02 Gbps

Como podemos ver as duas tabelas são bem parecidas, a única diferença é o *carrier aggregation* no release 10 que foi representado pela banda de 100 Mhz que é 5 vezes a banda de 20Mhz.E o mimo 8x8 que é 8 vezes a taxa de transmissão enquanto o release 8 o máximo é mimo 4x4 que é 4 vezes.

3. Experimento 2

No experimento 2 foi pedido para que fosse mostrado a REM(*Radio Environment Map* da SINR(*Signal-to-interference-plus-noise ratio* em um mapa com 7 erbs de raio 500m e de frequência 1900Mhz, para o calculo da SINR foi usado a formula:[SIN]

$$\frac{sinal}{interferencia + ruido} \tag{2}$$

Com isso podemos mostrar a imagem a seguir:

Figura 3.

Também foi pedido para mostrar o Gráfico das CDFs da SINR ,Taxa de transmissão e *throughput* para o melhor caso do LTE, que é a banda de 20MHZ e mimo 4x4. Com isso conseguimos mostrar para os raios especificados de 50,100,500 e 1000 metros:
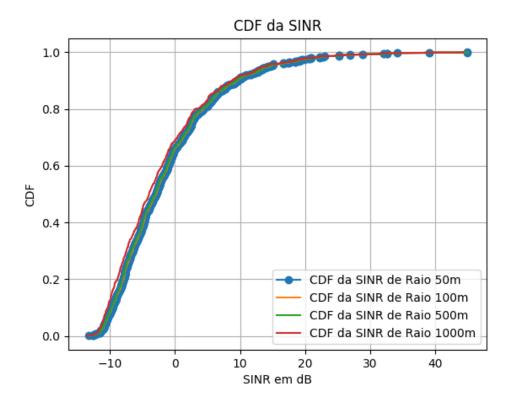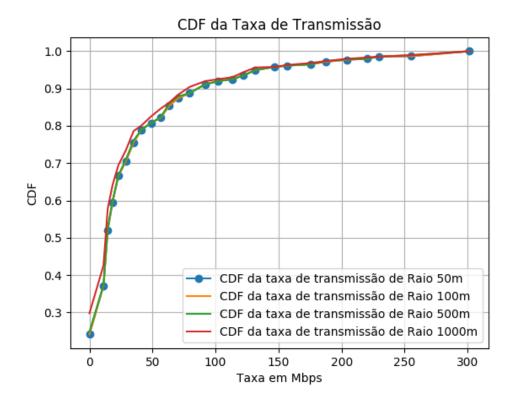
Figura 4. CDF SINR
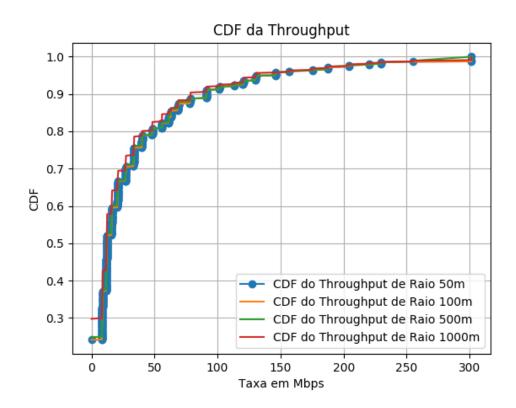

Figura 5. CDF da taxa de transmissão

Figura 6. CDF do Throughput

Os pontos em azul foram usados para diferenciar as CDFs de raio 50 e 100, porque estavam em cima do outro.lembrando que o Throughput é calculado com:

$$Tput = TaxTrans * (1 - BER) \tag{3}$$

E a BER é calculada de acordo com a modulação que o MCS usa, e a SNR efetiva que é 90% da SINR dada, e conseguimos calcular a BER pela formula para modulações M-QAM para quando $log_2(M)$ é par [Lathi 2009]:

$$Pe = \frac{4}{log_2(M)} * (1 - \frac{1}{\sqrt{M}}) * Q\left(\sqrt{\frac{3 * log_2(M) * Eb/No}{M - 1}}\right)$$

(4)

Com os gráficos em mãos podemos perceber que quanto maior o Raio maior a quantidade de pontos com uma SNR, taxa de transmissão e *throughput* mais baixa. E na taxa de transmissão e throughput podemos ver que cerca de 20% estão com 0Mbps isso é porque dada SNR 20% estão fora da área de cobertura das ERBs. E quanto menor o Raio mais se concentram com MCS mais altas, fazendo assim uma maior taxa de transmissão.

Também foi pedido para que fosse mostrado as CDFs para os melhores e piores casos do Realease 8 e Release 10, foi escolhido o raio de 500m para mostrar e temos o seguinte:
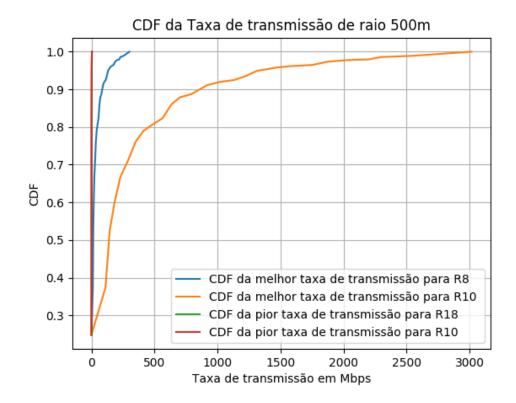
Figura 7. CDF da Taxa de Transmissão para melhores e piores casos

Como para os piores casos tem uma banda apenas de 1.4 Mhz,mimo 1x1 e prefixo cíclico estendido, e o melhor caso do release 10 tem 100Mhz de banda, mimo 8x8 e prefixo cíclico normal, é possível notar uma grande diferença a taxa de transmissão é cerca de mil vezes maior ou mais,por isso fica proximo do 0, e para o release 8 no melhor caso com 20Mhz de banda e mimo 4x4, podemos ver que chega apenas a 300Mbps, 10 vezes menos que a do release 10. Em comparação aos gráficos anteriores de gráficos o raio das ERBS não é um fator que faz tanta diferença em comparação com a quantidade de banda e mimo.

Também foi pedido para que fosse mostrado as CDFs do *carrier aggregation* do release 10 e o melhor caso do release 8 com mimo 1x1 e prefixo cíclico normal. Com isso temos a imagem seguinte
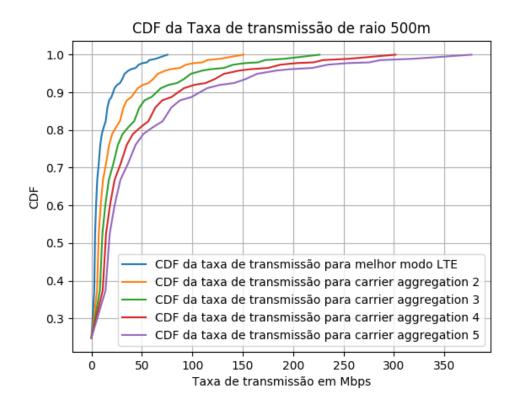
Figura 8. CDF da Taxa de Transmissão para Carrier aggregation

Com essa imagem conseguimos perceber que quanto maior o carrier aggregation maior a taxa de transmissão, e quanto a comparação com vários raios, as condições dos parâmetros são os mesmos de calcular é a taxa de transmissão que na de varios raios elas terminam no mesmo ponto, já essa do carrier aggregation não.

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