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1. Introduction

During the RAN2#56 meeting in Riga, an LS was addressed to RAN1 requesting information on the number of guard and assisting cells required for efficient SFN operation and on the efficiency of the following radio techniques [1] for E-MBMS:

Technique 1: Normal PTP Radio Bearer

Technique 2: SFN soft combining

Technique 3: Single cell PTM - No Interference Co-ordination of neighbour cells

Technique 4: Single cell PTM – UE providing Uplink ACK/NACK feedback

Technique 5: Single cell PTM – Interference reduction by not transmitting on neighbour cells

In addition to those listed above, RAN1 has decided to investigate an additional radio technique [2]:

Technique 6: Single cell PTM - UE providing Uplink CQI and ACK/NACK feedback

In [3] results were presented for Technique 2, Technique 3 and Technique 5. This contribution builds on [3] by comparing the performance of Technique 1 with that of Technique 2 and Technique 6.

2. Network Simulations

A three ring hexagonal grid layout was simulated with dual port UE receiver operation assumed in spatially uncorrelated channels and 10MHz offered bandwidth.

Simulations involving Technique 2 use the extended cyclic prefix (CP) while simulations for all other techniques use the normal CP. In all simulations 2 of the available OFDM symbols in the subframe are used for control. Each transmission of a transport block is assumed to occupy exactly one sub-frame. Transport block payload calculations assume the presence of reference symbols on antenna 0 on all OFDM symbols eligible to transport reference symbols in a subframe (a unicast [PDSCH] RS mapping is assumed for Techniques 1 and 6, while an MBSFN RS mapping and overhead according to TS 36.211 was assumed for Technique 2). Simulations of Technique 1 and Technique 6 also assume up to 4 transmissions, spaced 5ms apart, per transport block. A CQI estimate is made 3ms before the first transmission and operates without a quantization restriction and without feedback error. The CQI estimate is then used to determine the MCS for all transmissions of a transport block which are Chase combined. The selected MCS with corresponding coded and uncoded bits in a subframe for normal CP are listed in Table 1. Also listed is the number of codewords and coded bits per codeword in a subframe due to code block segmentation.

MCS	Number of Coded Bits in a Subframe	Number of Uncoded Bits in a Subframe	Number of Codewords in a Subframe	Number of Coded bits in a Codeword
QPSK R = 1/4	13800	3450	1	13800
QPSK R = 1/2	13800	6900	2	6900
QPSK R = 3/4	13800	10350	2	6900
16QAM R = 1/2	27600	13800	3	9200
16QAM R = 5/8	27600	17250	3	9200
16QAM R = 3/4	27600	20700	4	6900
64QAM R = 5/8	41400	25875	5	8280
64QAM R = 3/4	41400	31050	6	6900

Table 1 – Modulation and coding schemes.

For Technique 1 (ptp) the selected MCS is the highest rate MCS from Table 1 that achieves a target FER of 30% or better assuming one transmission. For Technique 6 (ptm), the highest MCS that achieves a target FER of 30% or better assuming one transmission is computed for each active UE in the cell. The selected MCS is then the lowest of these per UE MCS's.

3. Results

3.1. Technique 1

The performance of Technique 1 was evaluated by carrying out multiple drops with one UE randomly located in the best 95% of UE locations in the first sector of the center cell in each drop and with all other sectors in the network acting as interferers. Any UE dropped in the 5% area in the first sector with the highest path loss is out of coverage and not considered further. The simulated rate R_{UE} for each covered UE is given by:

$$R_{UE} = \frac{\sum_{i \in S_0} D_i}{\frac{T_{subframe}}{\alpha} \sum_{i \in S_1} Nsim_i}$$

where D_i is the size of transport block i , $T_{subframe}$ is the time period of a subframe, S_0 is the set of correctly decoded transport blocks, S_1 is the set of all simulated transport blocks, $Nsim_i$ is the number of simulated transmissions for transport block i and α is the duty cycle and is the fraction of total resources available in the cell used by the simulated UE in the drop to receive the data rate R_{UE} . During simulations, values of $\alpha = \frac{1}{5}$ and $T_{subframe} = 1ms$ were used resulting in 5ms between each transmission. By considering all drops, we can create a tuple (R, CDF_R^{1pp}) , where R is the data rate required to be supported by all UEs and CDF_R^{1pp} is the cdf of the fraction of the total resources used by the UEs to support data rate R in a sector (i.e. the CDF of α).

The cdf CDF_R^{1pp} of resources for $R \in \{128kbps, 256kbps\}$ are shown Figure 1 for deployment scenarios Case 1 and Case 3.

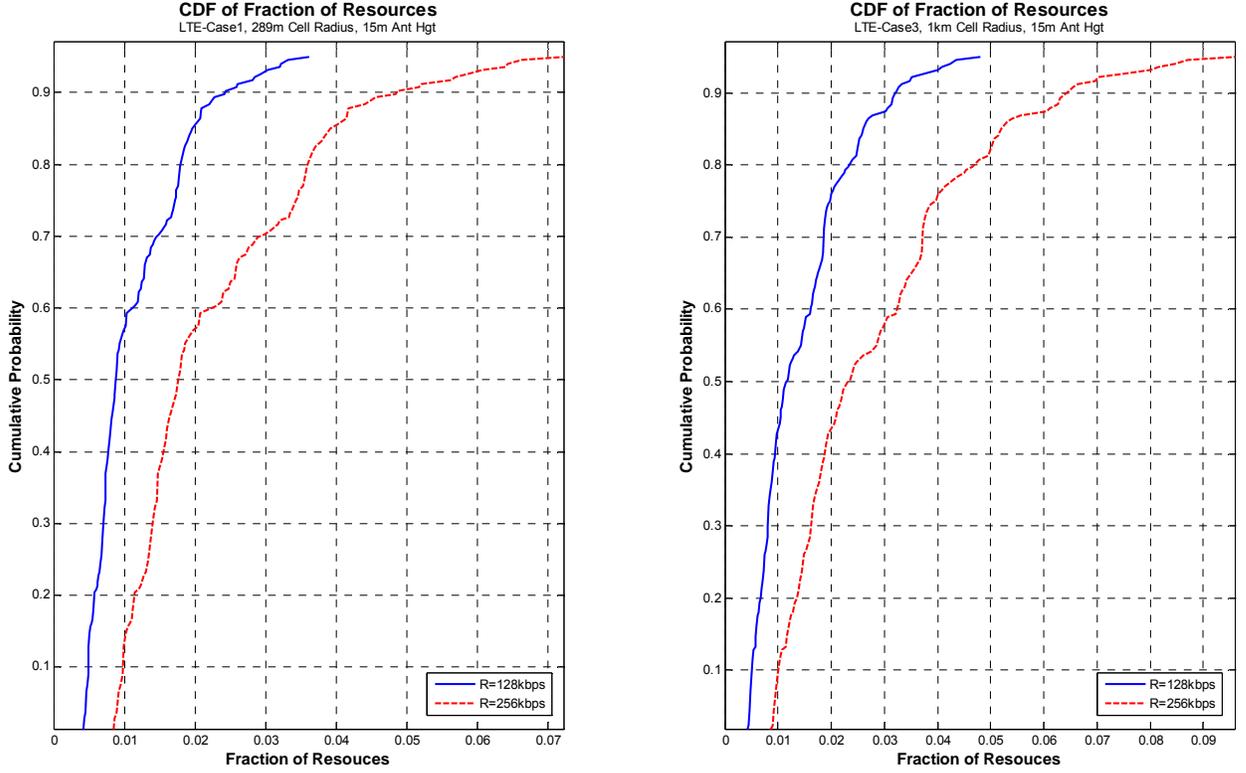


Figure 1 – CDF of fraction of resources for Technique 1 with one UE.

In order to extend the results given in Figure 1 to cases with more than one ptp user per cell, consider PDF_R^{1ptp} , the pdf form of CDF_R^{1ptp} . PDF_R^{2ptp} , the pdf of the fraction of total resources used by two UEs in a sector to support data rate R , is the convolution of PDF_R^{1ptp} with itself. Similarly the pdf of 3 or more users can be computed as necessary from which the tuples (R, CDF_R^{Xptp}) for $X \in \{1, 2, 3, 4, 5, \dots\}$ may be derived.

In order to compare the performance of Technique 1 (ptp) with other techniques, it is necessary to determine the tuple $(R, \rho_{UE}, CDF_{R, \rho_{UE}}^{ptp})$ or in other words the cdf of used resources for a given user density per sector ρ_{UE} and data rate R . As a first step consider the computation of $CDF_{R, \rho_{UE}}^{ptp}$. The Poisson distribution with mean ρ_{UE} gives the distribution of UEs in a cell assuming a UE has equal probability of occupying all cells in a network. Modifying this distribution to account for the fact that only 95% of UEs are covered, the $CDF_{R, \rho_{UE}}^{ptp}$ can be computed by multiplying $CDF_{R, \rho_{UE}}^{0ptp}$ by the probability that zero user is present in a sector, $CDF_{R, \rho_{UE}}^{1ptp}$ by the probability that one user is present in a sector, $CDF_{R, \rho_{UE}}^{2ptp}$ by the probability that two users are present in a sector and so on and adding all results together. Figure 2 gives the $CDF_{R, \rho_{UE}}^{ptp}$ for $\rho_{UE} = 1$, $R \in \{128kbps, 256kbps\}$ the 95%-tile point of fractional resources used and the mean fraction of total resources used in a cell over covered UEs to support data rate $R \in \{128kbps, 256kbps\}$ for $\rho_{UE} = \{0.1, 0.5, 1, 2, 3, 5\}$.

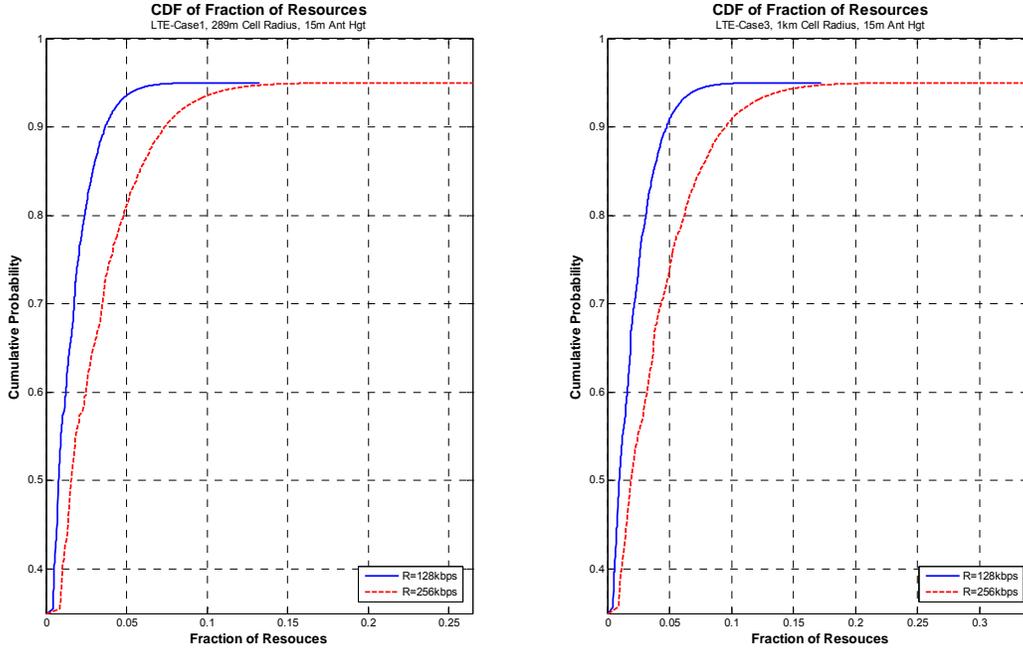


Figure 2 – CDF of fraction of resources for Technique 1 with $\rho_{UE} = 1$.

		R = 128kbps					R=256kbps				
		$\rho = 0.1$	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3.5$	$\rho = 0.1$	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3.5$
	95%tile point of fractional resources	0.009	0.026	0.037	0.058	0.085	0.017	0.052	0.075	0.116	0.169
	Mean fractional resources	0.001	0.005	0.011	0.021	0.037	0.002	0.011	0.021	0.043	0.075
	95%tile point of fractional resources	0.011	0.033	0.048	0.074	0.108	0.022	0.065	0.096	0.149	0.217
	Mean fractional resources	0.001	0.007	0.014	0.027	0.047	0.003	0.014	0.027	0.054	0.095

Table 2 – The 95%-tile point of fractional resources used and the mean fraction of total resources used for Technique 1.

3.2. Technique 6

The performance of Technique 6 was evaluated by carrying out multiple drops, each with X UE's randomly located in the first sector of the center cell with all other sectors in the network acting as interferers. Simulations were carried out for $X \in \{1, 2, 3, \dots, 10\}$.

The simulated rate for a UE j , R_j^{UE-ptm} , is defined as:

$$R_j^{UE-ptm} = \frac{\sum_{i \in S_j^0} D_i}{\frac{T_{subframe}}{\alpha} \sum_{i \in S^1} Nsim_i}$$

where D_i is the size of transport block i , $T_{subframe}$ is the time period of a subframe, S_j^0 is the set of correctly decoded transport blocks for UE $j \in S_{Drop}$, S_{Drop} is the set of UEs in the drop and $|S_{Drop}| = X$, S^1 is the set of all simulated transport blocks (and which is common to all UE's), $Nsim_i$ is the number simulated transmissions for transport block i , and α is the duty cycle used by all UEs in the sector and is the fraction of total resources used by the sector. During simulations, the values of $\alpha = \frac{1}{5}$ and $T_{subframe} = 1ms$ were used resulting in 5ms between each transmission. The supported data rate by UEs in coverage in the cell is then $R^{Cell-pm} = \min_{j \in S_{Drop}} (R_j^{UE-pm})$.

By considering all simulations of X UEs per drop, we can create a tuple (R, CDF_R^{Xpm}) , where R is the data rate required to be supported by all UEs and CDF_R^{Xpm} is the cdf of the fraction of the total resources used by the X UEs to support data rate R .

Similar to the approach used for Technique 1, the tuple $(R, \rho_{UE}, CDF_{R, \rho_{UE}}^{Xpm})$ can be computed from CDF_R^{Xpm} for $X \in \{1, 2, 3, 4, 5, \dots\}$ by using the Poisson distribution with mean ρ_{UE} and suitably modifying this distribution to account for the coverage of 95% of UE locations.

Figure 3 gives the $CDF_{R, \rho_{UE}}^{Xpm}$ for $\rho_{UE} = 1$, $R \in \{128kbps, 256kbps\}$ while, the 95%-tile point of fractional resources used and the mean fraction of total resources used in a cell over covered UEs to support data rate $R \in \{128kbps, 256kbps\}$ for $\rho_{UE} = \{0.1, 0.5, 1, 2, 3.5\}$.

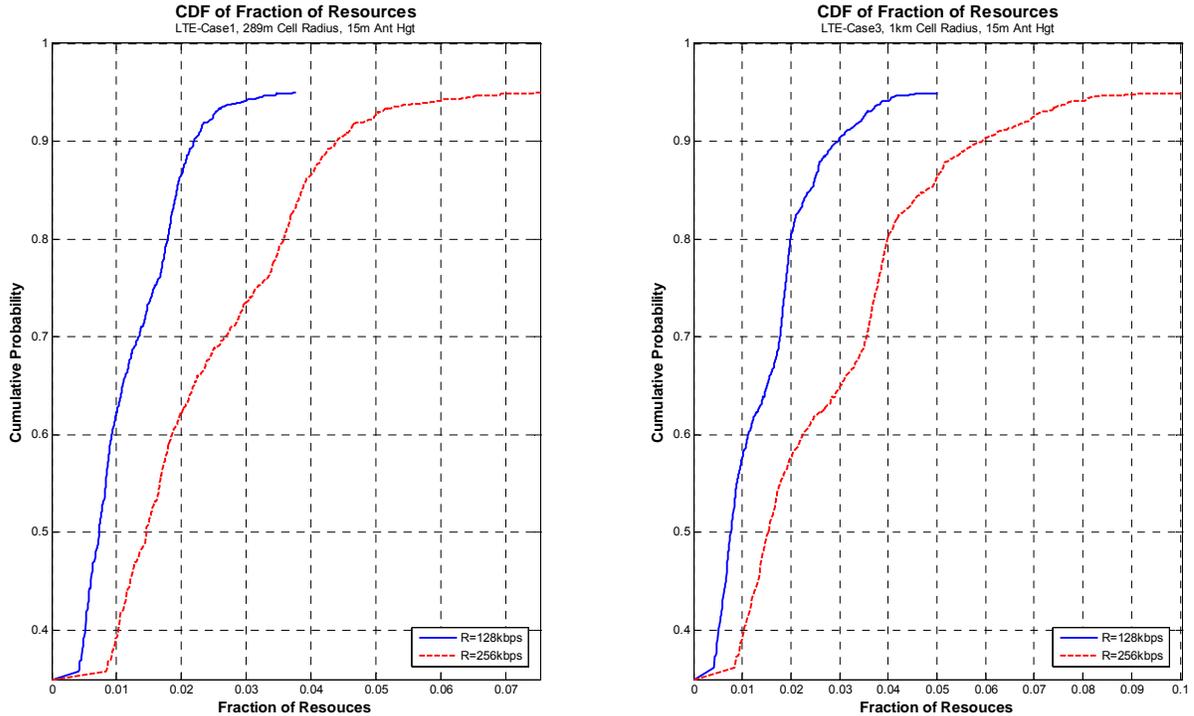


Figure 3 – CDF of fraction of resources for Technique 6 with $\rho_{UE} = 1$.

		R = 128kbps					R=256kbps				
		$\rho = 0.1$	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3.5$	$\rho = 0.1$	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3.5$
	95%tile point of fractional resources	0.008	0.019	0.022	0.026	0.03	0.017	0.039	0.044	0.051	0.059
	Mean fractional resources	0.001	0.004	0.008	0.012	0.016	0.002	0.009	0.015	0.024	0.032
	95%tile point of fractional resources	0.009	0.025	0.03	0.036	0.038	0.019	0.049	0.06	0.071	0.075
	Mean fractional resources	0.001	0.005	0.009	0.015	0.02	0.002	0.011	0.019	0.03	0.039

Table 3 – The 95-%tile point of fractional resources used and the mean fraction of total resources for Technique 6.

3.3. Technique 2

Assuming all available resources are dedicated to MBSFN, the coverage versus throughput plots for Case 1 and Case 3 are shown in Figure 4. The fractions of cell resources derived from these plot for coverage values $C_{MBSFN} = 0.95$ are given in Table 4 for $R \in \{128kbps, 256kbps\}$ and Case 1 and Case 3.

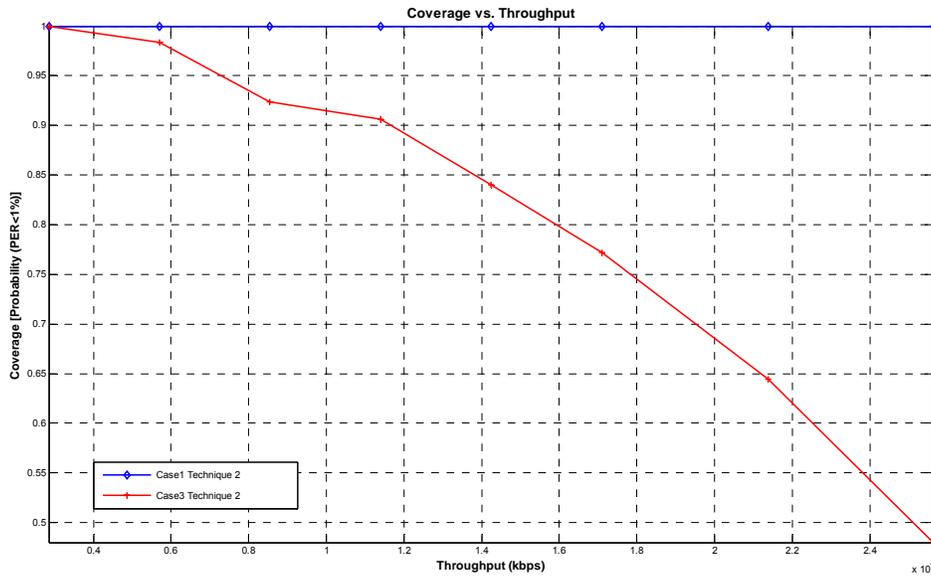


Figure 4 – Coverage versus throughput for Technique 2.

	R = 128kbps	R=256kbps
Case 1	0.005	0.010
Case 3	0.011	0.022

Table 4 – Fraction of resources for at least 95% coverage for Technique 2.

4. Discussion

The 95-%tile point of fractional resources used and the mean fraction of total resources for Technique 1 and Technique 6 are given in Table 5 and Table 6 and are compared to the fractional resources required for Technique 2 for $R \in \{128kbps, 256kbps\}$ at the 95% coverage level. Table 6 is also presented in a more visualized form of these results in Figure 5 and Figure 6.

95-%tile point of fractional resources for Techniques 1/6, fractional resources for Technique 2		R = 128kbps					R=256kbps				
		$\rho = 0.1$	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3.5$	$\rho = 0.1$	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3.5$
Case 1	Technique 1	0.008	0.025	0.037	0.058	0.085	0.017	0.051	0.074	0.116	0.169
	Technique 6	0.008	0.019	0.022	0.026	0.03	0.017	0.039	0.044	0.051	0.059
	Technique 2	0.005	0.005	0.005	0.005	0.005	0.010	0.010	0.010	0.010	0.010
Case 3	Technique 1	0.010	0.032	0.048	0.074	0.108	0.021	0.065	0.096	0.148	0.217
	Technique 6	0.009	0.025	0.03	0.036	0.038	0.019	0.049	0.06	0.071	0.075
	Technique 2	0.011	0.011	0.011	0.011	0.011	0.022	0.022	0.022	0.022	0.022

Table 5 – The 95-%tile point of fractional resources for Techniques 1 and 6 and fractional resources for Technique 2

Mean fractional resources for Techniques 1/6, fractional resources for Technique 2		R = 128kbps					R=256kbps				
		$\rho = 0.1$	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3.5$	$\rho = 0.1$	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3.5$
Case 1	Technique 1	0.001	0.005	0.011	0.021	0.037	0.002	0.011	0.021	0.043	0.075
	Technique 6	0.001	0.004	0.008	0.012	0.016	0.002	0.009	0.015	0.024	0.032
	Technique 2	0.005	0.005	0.005	0.005	0.005	0.010	0.010	0.010	0.010	0.010
Case 3	Technique 1	0.001	0.007	0.014	0.027	0.047	0.003	0.014	0.027	0.054	0.095
	Technique 6	0.001	0.005	0.009	0.015	0.02	0.002	0.011	0.019	0.03	0.039
	Technique 2	0.011	0.011	0.011	0.011	0.011	0.022	0.022	0.022	0.022	0.022

Table 6 – The mean fractional resources for Techniques 1 and 6 and fractional resources for Technique 2

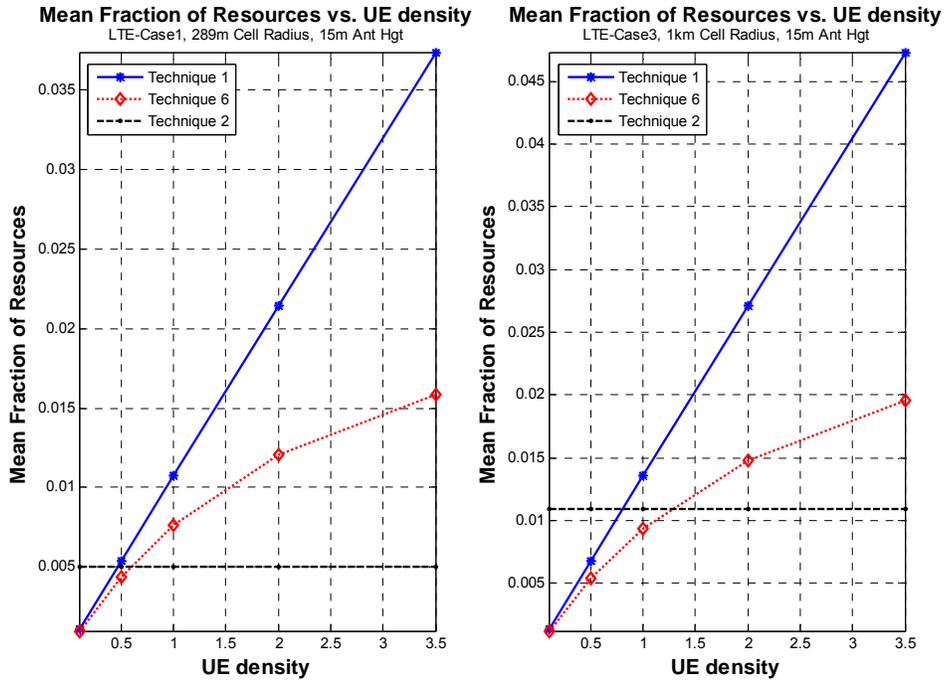


Figure 5 – The mean fractional resources for Techniques 1 and 6 and fractional resources for Technique 2 for R = 128kbps

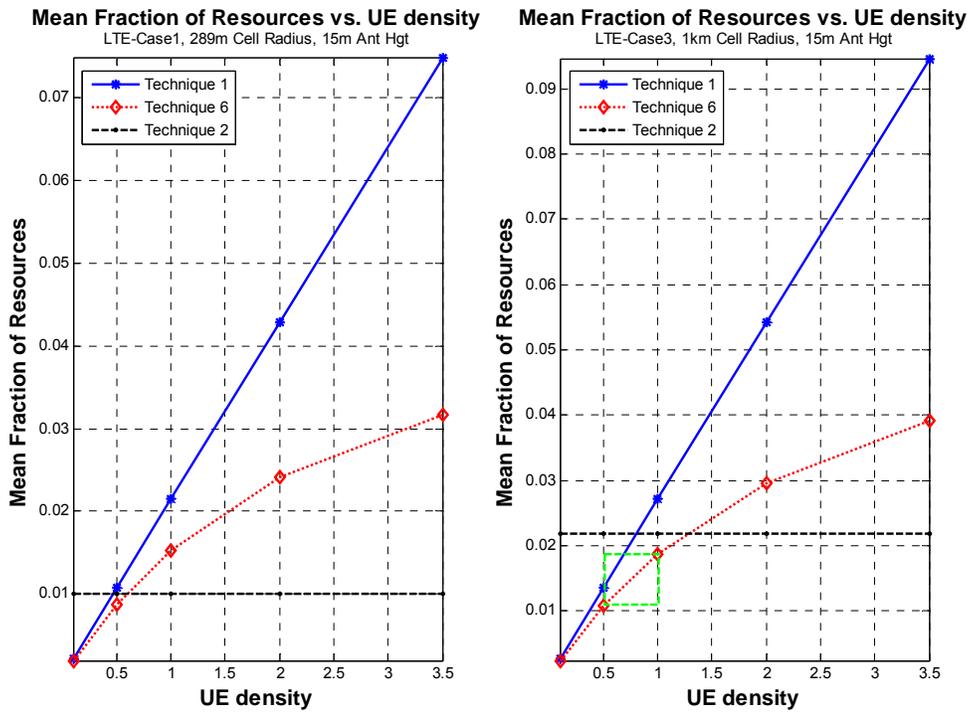


Figure 6 – The mean fractional resources for Techniques 1 and 6 and fractional resources for Technique 2 for R = 256kbps. The green box represents the area that Technique 6 is “noticeably better” than the other two techniques

Comparing the performance of the three techniques, Technique 2 offers the best performance for UE densities greater than 0.6 UEs/sector for Case 1 and 1.3 UEs/sector for Case 3. For Case 1, both Technique 1 and Technique 6 offer similar performance in the region when either technique is superior to Technique 2. Between 0.5 UEs/sector and 1.3 UEs/sector, Technique 6 does offer some advantages over Techniques 1 and 2, but the performance range in which Technique 6 offers an advantage appears quite limited.

5. Conclusions

Although Technique 6 does provide some benefit over Technique 1, it is only in Case 3 deployments and with mean UE densities (per sector) in the range of 0.5 UEs/sector to 1.3 UEs/sector that this advantage becomes apparent. Given the very limited range of UE sector densities in which this approach is superior to both Technique 1 (i.e. conventional DL-SCH ptp) and Technique 2 (MBSFN), the complexity of specifying Technique 6 (DL-SCH ptm) in addition to Technique 1 and Technique 2 does not appear worthwhile based on the current analysis, and MBMS delivery via Technique 1 (DL-SCH ptp) and Technique 2 (MBSFN) is recommended.

6. References

- [1] R2-063503, "LS on Radio efficiency for delivery of Broadcast/Multicast Services", RAN2, Riga, Latvia, Nov.6-Nov.10, 2006
- [2] R1-071213, "Response LS on Radio efficiency for delivery of Broadcast/Multicast Services", RAN1, St. Louis, U.S.A., Feb.12-Feb.16, 2007
- [3] R1-060051, "Performance of MBMS Transmission Configurations", RAN1, Sorrento, Italy, Jan.5-Jan.9, 2007