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An Application of ARQ Optimization Algorithm

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Abstract: *In a previous work [1], we presented a development with the objective of defining an algorithm able to minimize the extra amount of power utilized in the transmission of information from mobile devices in the uplink direction, relatively to the use of the technique called ARQ (Automatic Repeat Request). Although the above algorithm had been designed for use in HSPA networks, it finds application in other systems employing the ARQ technology. Here we will be analyzing an application of the algorithm, with the consequent analysis of the results obtained.*
Keywords: *ARQ, UMTS, BER, HSPA, LTE.*

I. Introduction

The main objective of this work is to test a methodology developed in a previous work [1] aiming ARQ optimization, relatively to the mean power required to transfer the information from the origin to the destination, accordingly to a given error probability.

The ARQ technology proves to be very useful for data transmission in WCDMA systems. Because this process is executed at RLC (Radio Link Control) level [2], the resultant delay does not permit its utilization for real time services [3]. This situation has changed with the introduction of HSPA systems, where some ARQ functionalities were transfered to the Physical level (PHY)[4, 5]. The main consequence was a delay reduction in the information transfer, thus allowing the ARQ utilization also for real time services. This is also the case of the LTE (Long Term Evolution) systems of the Fourth Generation.

The paper is organized as follows: after this Introduction, Section II describes the application of the theory described in Reference [1] and Section III presents the related conclusions.

II. Theory Application

Considering the results of the theory showed in Reference [1], it will be presented here an application of the developed algorithm, and described in detail in the cited reference. All the computations that follows were developed in Matlab (a product from Mathworks).

It is considered the development of an ARQ process with *n=2, 3* and *4* stages (i.e. two, three and four repetitions) for an UMTS system. In this example, the turbo code is receiving frames of N=600 bits, and the interval of interest for Eb/No is defined from -4dB to -6dB. The Tables 1, 2 and 3 show the results obtained for *n=2, 3* and *4*, respectively. The first column of these tables presents the *P(error)* (dB) variation and the subsequent colums show the corresponding x_n values (also in dB) that minimizes C_m , indicated next to the last column. Finnaly, the last column presents the mean delay time for each case.

Table 1 - *N=600* and *n=2* case

P(error) (dB)	x_1 (dB)	x_2 (dB)	x_3 (dB)	C_m (dB)	Delay (sec)
-4.0	-4.9000	-4.8000	0.8884	-2.1546	1.4107
-4.2	-4.9000	-4.8000	0.9574	-2.1411	1.4107
-4.4	-4.9000	-4.8000	1.0243	-2.1279	1.4107
-4.6	-4.9000	-4.8000	1.0896	-2.1148	1.4107
-4.8	-4.9000	-4.8000	1.1536	-2.1019	1.4107
-5.0	-4.9000	-4.8000	1.2166	-2.0890	1.4107
-5.2	-4.9000	-4.8000	1.2788	-2.0761	1.4107
-5.4	-4.9000	-4.8000	1.3407	-2.0631	1.4107
-5.6	-4.9000	-4.8000	1.4025	-2.0500	1.4107
-5.8	-4.9000	-4.8000	1.4645	-2.0367	1.4107

Table 2 - *N=600* and *n=3* case

P(error) (dB)	x_1 (dB)	x_2 (dB)	x_3 (dB)	x_4 (dB)	C_m (dB)	Delay (sec)
-4.0	-4.9000	-4.8000	-4.8000	0.6985	-2.3185	1.4402
-4.2	-4.9000	-4.8000	-4.8000	0.7750	-2.3139	1.4402
-4.4	-4.9000	-4.8000	-4.8000	0.8481	-2.3095	1.4402
-4.6	-4.9000	-4.8000	-4.8000	0.9184	-2.3052	1.4402
-4.8	-4.9000	-4.8000	-4.8000	0.9864	-2.3009	1.4402
-5.0	-4.9000	-4.8000	-4.8000	1.0526	-2.2967	1.4402
-5.2	-4.9000	-4.8000	-4.8000	1.1173	-2.2926	1.4402
-5.4	-4.9000	-4.8000	-4.8000	1.1808	-2.2884	1.4402
-5.6	-4.9000	-4.8000	-4.8000	1.2434	-2.2843	1.4402
-5.8	-4.9000	-4.8000	-4.8000	1.3055	-2.2801	1.4402
-6.0	-4.9000	-4.8000	-4.8000	1.3673	-2.2759	1.4402

Table 3 - *N=600* and *n=4* case

The Figure 1 shows the C_m values for the cases presented in the previous tables. Here it is also included, for comparison purposes, the situation with no repetition (*n=1*). It is interesting to observe that it is not feasible to increase the number of repetitions beyond n=3 or 4, because this does not contribute to an appreciate decrease in C_m and also gives an increase in the delay values.

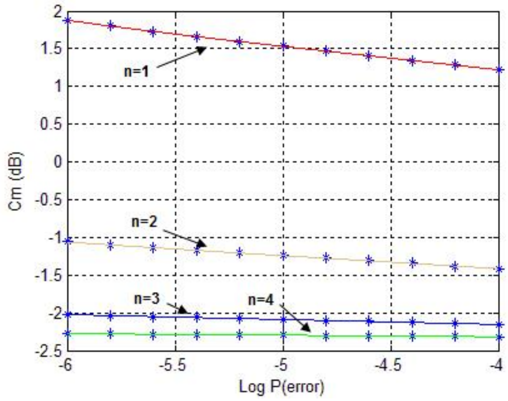

Figure 1 - C_m x *Log P(error)* values for *n=1, 2, 3 and 4*

Another situation of interest is the minimization of the maximum x_n value for a given process, instead of C_m. In this case, for this calculation it is necessary only to change the step 8 of the algorithm of section 4 of Reference [1] to:

8. *Select the least of the maximum x_n values for each P(error) in a given process, obtained from all the above interactions.*

The Tables 4 and 5 present the results for this situation.

P(error) (dB)	x_1 (dB)	x_2 (dB)	C_m (dB)	*Delay* (sec)
-4.0	0.5000	0.5016	0.5434	1.0100
-4.2	0.5000	0.5894	0.5443	1.0100
-4.4	0.5000	0.6717	0.5451	1.0100
-4.6	0.6000	0.6601	0.6260	1.0059
-4.8	0.6000	0.7385	0.6265	1.0059
-5.0	0.7000	0.7206	0.7146	1.0034
-5.2	0.7000	0.7961	0.7149	1.0034
-5.4	0.7000	0.8683	0.7151	1.0034
-5.6	0.8000	0.8456	0.8080	1.0018
-5.8	0.8000	0.9159	0.8082	1.0018
-6.0	0.8000	0.9841	0.8083	1.0018

Table 4 - *N=600* and *n=2* case. Minimization of x_n

P(error) (dB)	x_1 (dB)	x_2 (dB)	x_3 (dB)	C_m (dB)	Delay (sec)
-4.0	0.0000	0.2000	0.2129	0.3563	1.0762
-4.2	0.1000	0.2000	0.2487	0.3577	1.0557
-4.4	0.2000	0.2000	0.2750	0.3784	1.0391
-4.6	0.1000	0.3000	0.3724	0.3550	1.0551
-4.8	0.3000	0.3000	0.3054	0.4167	1.0260
-5.0	0.3000	0.3000	0.4092	0.4168	1.0260
-5.2	0.3000	0.4000	0.4134	0.4164	1.0257
-5.4	0.4000	0.4000	0.4177	0.4736	1.0166
-5.6	0.3000	0.5000	0.5032	0.4169	1.0256
-5.8	0.4000	0.5000	0.5070	0.4739	1.0165
-6.0	0.5000	0.5000	0.5025	0.5447	1.0101

Table 5 - *N=600* and *n=3* case. Minimization of x_n

The Figure 2 shows the variations of $C_m(dB)$ x *Log P(error)* for the situations of Tables 4 and 5 and the case of *n=1* for comparison purposes.

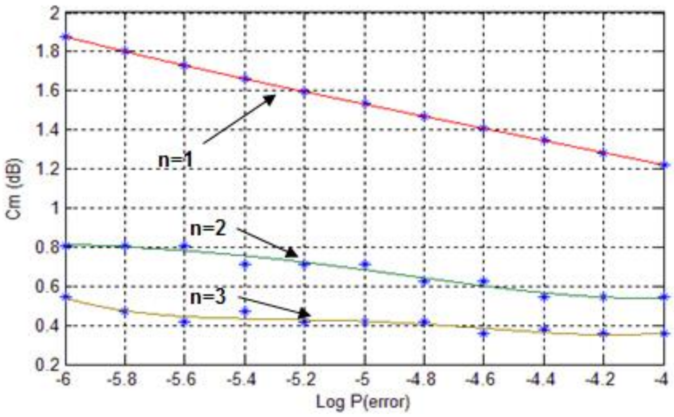

Figure 2 - C_m x *Log P(error)* values for *n=1, 2, and 3.* Minimization of x_n

Comparing the results presented by Figures 1 and 2 gives the conclusion that, as expected, the corresponding C_m values for the case of "Minimization of x_n" are superior than those obtained for the previous situation of "C_m Minimization", but the maximum x_n values are lower than the corresponding ones for the "C_m Minimization" case, as can be seen by comparison of the previous Tables. Also, the "Minimization of x_n" case gives lower mean delay values, as stated by the last column of the corresponding Tables.

III. Conclusions

The ARQ process is a powerful technique used in UMTS systems, with the main objective to provide the information transfer with a certain degree of error rate. In the case of UMTS systems, it is a task to transfer the information packets in the air interface using the minimum possible amount of power, while maintaining the QoS of the service. This is particularly important in the uplink direction of transmission, because the saving of power transmission represents more economy of cellular batteries and reduced interference levels in the Node B station. This last effect is important for decreasing de *noise rise* levels, thus allowing more active users per cell.

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