

Service Adaptable 3G Turbo Decoder for Indoor/Low Range Outdoor Environment

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Abstract

For the well-known 3G mobile communications standard UMTS, four different service classes have been specified. Considering two turbo decoding algorithms, like SOVA and log-MAP, it would be desirable to use an efficient turbo decoder. In this paper this decoder is shown to adapt dynamically to different service scenarios, considering parameters like performance and complexity for indoor/low range outdoor operating environment. The scenarios show that for streaming service class real-time class applications the proposed decoding algorithm depends on data rate; for the majority of scenarios SOVA is proposed, whereas log-MAP is optimal for increased data rates and medium-sized frames. On the other hand, conversational service class real-time applications cannot be established. For the majority of non real-time applications (interactive and background service classes) either algorithm can be used, while log-MAP is proposed for medium data rates and frame lengths.

Keywords: Reconfigurable Systems, Turbo Decoder, UMTS, Flat Rayleigh Fading, Indoor/Low Range Outdoor Operating Environment

1. Introduction and UMTS Data Flow

Channel coding is a critical signal processing element in modern mobile communications systems. Turbo codes [1] represent a powerful channel coding technique. Universal Mobile Telecommunications System (UMTS) belongs to the third generation (3G) of mobile communication systems. Turbo codes have been incorporated as a channel coding scheme in UMTS for data rates higher or equal to 28.8 kbps [2]. They also provide high coding gains in flat fading channels with the use of outer block interleaving [3,4]. Soft-input/soft-output (SISO) decoder is part of a turbo decoder and two candidate algorithms to be used in a SISO decoder are soft output Viterbi algorithm (SOVA) and log maximum a-posteriori (log-MAP) algorithm [2,5-7].

A reconfigurable turbo decoder can be derived according to the common operations of the two algorithms, optimal in terms of performance and latency [8,9,10]. We consider just SOVA and log-MAP and not other turbo decoding algorithms like max-log-MAP or MAP, because SOVA is better in terms of delay, while log-MAP is better in terms of performance [3,5].

SOVA and log-MAP algorithms share common opera-

tions which have been addressed in [8-10]. These common operations form a turbo decoder which can be reconfigured and choose the suitable turbo decoding algorithm for different applications (reconfigurable SOVA/log-MAP turbo decoder). In [8] and [10] is also shown that in a reconfigurable SOVA/log-MAP turbo decoder scaling of the extrinsic information is possible with a common scaling factor, which is constant and independent of signal-to-noise ratio for additive white Gaussian noise (AWGN) channels. In [9] it is shown that in the case of a flat Rayleigh fading channel for a reconfigurable SOVA/log-MAP decoder a common scaling factor with value 0.7 is the optimal choice.

Nowadays, UMTS represents the dominant 3G system in the mobile communications market. According to UMTS specifications, a transport channel transfers data over radio interface from Medium Access Control sub-layer of layer 2 to physical layer and is characterized by its transport format set, which consists of different transport formats. They must have the same type of channel coding and time transmission interval (TTI), while the transport block set or data frame size can vary. The transport block set determines the number of input bits to the channel encoder and can be transmitted every

TTI, with possible values for TTI of 10, 20, 40 and 80 msec [2,11]. After channel coding, outer block interleaving is performed, and since the frame duration in UMTS is 10 msec, the number of columns of the outer block interleaver can be 1, 2, 4 or 8, depending on TTI value. Therefore, the TTI values and the number of columns of the outer block interleaver are interrelated. Furthermore, every transport channel is assigned a radio access bearer with a particular data rate, which provides the transfer of the service through the radio network. A mobile terminal may use several parallel transport channels simultaneously, each having its own characteristics (transport format set).

UMTS radio interface transfers multiple applications. Parameters like bit error rate (BER) performance and delay are assigned to these applications. Four different service traffic classes are defined: conversational, streaming, interactive and background. For real-time conversational and streaming classes BER has to be less than 10^{-3} , while for non-real time interactive and background classes BER has to be less than 10^{-5} . The maximum acceptable delay for conversational class is 80 msec, for streaming it is 250 msec, for interactive it is 1 sec, while for background it is higher than 10 sec [2,11].

2. Simulation Parameters

The discrete representation of flat Rayleigh fading channel is given by the following equation:

$$y_k = \alpha_k \cdot x_k + n_k \quad (1)$$

where k is an integer symbol index, x_k is a binary phase shift keying (BPSK) symbol amplitude (± 1), n_k is a Gaussian random variable and y_k is a noisy received symbol. The fading amplitude α_k is a sample from a correlated Gaussian random process with zero mean and is generated using the Sum of Sines or Jakes-model, which is described in [12]. This model is based on summing 9 sinusoids whose frequencies are chosen as

samples of the Doppler spectrum. The properties of Jakes model are further analysed in [13].

For the simulation model a carrier frequency $f_c = 2$ GHz is considered. It is also assumed that 1000000 bits are transmitted and grouped into frames whose length k_f must be ≥ 40 and ≤ 5114 , according to UMTS specifications [2,14]. For a particular transport channel, every TTI the data with the characteristics specified in a transport format of the transport channel (k_f bits), is turbo encoded (constraint length $K = 4$ and rate $r_c = 1/3$) at the transmitter. Furthermore, each time instant it is assumed that the two recursive systematic convolutional encoders of the turbo encoder start encoding from all-zero state. After turbo coding and block interleaving using the UMTS parameters, the bits are BPSK modulated and transmitted through the mobile channel. At the receiver, outer block deinterleaving and turbo decoding is performed. The received values are not quantized which means that floating point arithmetic is used. The receiver is also assumed to have exact estimates of the fading amplitudes (perfect channel estimation without side information), while eight iterations are used in the turbo decoder.

Table 1 illustrates eight different UMTS dedicated transport channels with different transport format sets, which represent different implementation scenarios of the reconfigurable turbo decoder. The transport format set for each transport channel consists of different example transport formats and also of dynamic and semi-static parts. The semi-static part (turbo encoder parameters, TTI) is the same for all transport formats of the transport format set, while the dynamic part (frame size) differs [2, 11,15]. Moreover, as published simulation results have shown in [3,4] for flat Rayleigh fading channels, data rate, outer block interleaving (thus TTI) and signal-to-noise ratio (SNR) greatly affect BER performance: for each scenario of Table 1 these three parameters differ considering also the examples presented in [15].

Table 1. Implementation scenarios.

Transport channel type	Transport format set				Data rate R_b (kbps)	SNR (dB)	Scenario	
	Dynamic part		Semi-static part					
	Transport block set or frame sizes (bits)	Turbo encoder parameters		TTI (msec)				
		K	Code rate					
Dedicated channel	576, 1152		4	1/3	40	28.8	32	1
	576, 1152, 1728, 2304		4	1/3	40	57.6	30	2
	336, 672, 1008, 1344		4	1/3	20	64	30	3
	336, 672, 1344, 2688		4	1/3	20	128	30	4
	336, 672, 1344, 2688, 3024		4	1/3	20	144	28	5
	168, 336, 672, 1344, 2016, 2688, 3360, 4032		4	1/3	20	384	28	6
	2560		4	1/3	40	64	30	7
	336, 1344, 2688, 4032, 4704		4	1/3	40	2000	40	8

Table 2. Quality of service and proposed decoding algorithm for scenarios 1, 2 and 3 of Table 1.

		Frame size (bits)	t_d using SOVA (msec)	t_d using log-MAP (msec)	Max latency (msec)	Log-MAP BER	SOVA BER	BER range	Proposed decoding algorithm	
Scenario 1	Conv. class	576	240	528	80	0.000472	0.000523	$<10^{-3}$	Cannot be applied	
		1152	400	976	80	0	0	$<10^{-3}$		
	Streaming class	576	240	528	250	0.000472	0.000523	$<10^{-3}$		SOVA
		1152	400	976	250	0	0	$<10^{-3}$		Cannot be applied
	Non-real time classes	576	240	528	Up to 1 sec interactive, >10 sec background	0.000472	0.000523	$<10^{-5}$		Cannot be applied
		1152	400	976		0	0	$<10^{-5}$		Log-MAP or SOVA
Scenario 2	Conv. class	576	160	304	80	0.001836	0.002096	$<10^{-3}$	Cannot be applied	
		1152	240	528	80	0.000988	0.001036	$<10^{-3}$		
		1728	320	752	80	0.000582	0.000634	$<10^{-3}$		
		2304	400	976	80	0	0	$<10^{-3}$		
	Streaming class	576	160	304	250	0.001836	0.002096	$<10^{-3}$		
		1152	240	528	250	0.000988	0.001036	$<10^{-3}$		
		1728	320	752	250	0.000582	0.000634	$<10^{-3}$		
		2304	400	976	250	0	0	$<10^{-3}$		
	Non-real time classes	576	160	304	Up to 1 sec interactive, >10 sec background	0.001836	0.002096	$<10^{-5}$		Cannot be applied
		1152	240	528		0.000988	0.001036	$<10^{-5}$		
		1728	320	752		0.000582	0.000634	$<10^{-5}$		
		2304	400	976		0	0	$<10^{-5}$		
Scenario 3	Conv. class	336	82	157.6	80	0.003485	0.003888	$<10^{-3}$	Cannot be applied	
		672	124	275.2	80	0.00146	0.00183	$<10^{-3}$		
		1008	166	392.8	80	0.000779	0.000984	$<10^{-3}$		
		1344	208	510.4	80	0.000519	0.000538	$<10^{-3}$		
	Streaming class	336	82	157.6	250	0.003485	0.003888	$<10^{-3}$		
		672	124	275.2	250	0.00146	0.00183	$<10^{-3}$		
		1008	166	392.8	250	0.000779	0.000984	$<10^{-3}$		SOVA
		1344	208	510.4	250	0.000519	0.000538	$<10^{-3}$		SOVA
	Non-real time classes	336	82	157.6	Up to 1 sec interactive, >10 sec background	0.003485	0.003888	$<10^{-5}$		Cannot be applied
		672	124	275.2		0.00146	0.00183	$<10^{-5}$		
		1008	166	392.8		0.000779	0.000984	$<10^{-5}$		
		1344	208	510.4		0.000519	0.000538	$<10^{-5}$		

Table 3. Quality of service and proposed decoding algorithm for scenarios 4 and 5 of Table 1.

		Frame size (bits)	t_d using SOVA (msec)	t_d using log-MAP (msec)	Max latency (msec)	Log-MAP BER	SOVA BER	BER range	Proposed decoding algorithm	
Scenario 4	Conv. class	336	61	98.8	80	0.003465	0.004047	$<10^{-3}$	Cannot be applied	
		672	82	157.6	80	0.001584	0.001713	$<10^{-3}$		
		1344	124	275.2	80	0.000796	0.000934	$<10^{-3}$		
		2688	208	510.4	80	0	0	$<10^{-3}$		
	Streaming class	336	61	98.8	250	0.003465	0.004047	$<10^{-3}$		
		672	82	157.6	250	0.001584	0.001713	$<10^{-3}$		
		1344	124	275.2	250	0.000796	0.000934	$<10^{-3}$		SOVA
		2688	208	510.4	250	0	0	$<10^{-3}$		SOVA
	Non-real time classes	336	61	98.8	Up to 1 sec interactive, >10 sec background	0.003465	0.004047	$<10^{-5}$		Cannot be applied
		672	82	157.6		0.001584	0.001713	$<10^{-5}$		
		1344	124	275.2		0.000796	0.000934	$<10^{-5}$		

Scenario 5	Conv. class	2688	208	510.4		0	0	<10 ⁻⁵	Log-MAP or SOVA
		336	58.6	92.26	80	0.005771	0.006268	<10 ⁻³	
		672	77.3	144.5	80	0.003005	0.003287	<10 ⁻³	
		1344	114.6	249.06	80	0.000704	0.0010007	<10 ⁻³	Cannot be applied
		2688	189.3	458.13	80	0	3.091e-05	<10 ⁻³	
	Streaming class	3024	208	510.4	80	0	0	<10 ⁻³	
		336	58.6	92.26	250	0.005771	0.006268	<10 ⁻³	Cannot be applied
		672	77.3	144.5	250	0.003005	0.003287	<10 ⁻³	
		1344	114.6	249.06	250	0.000704	0.0010007	<10 ⁻³	Log-MAP
		2688	189.3	458.13	250	0	3.091e-05	<10 ⁻³	SOVA
	Non-real time classes	3024	208	510.4	250	0	0	<10 ⁻³	SOVA
		336	58.6	92.26		0.005771	0.006268	<10 ⁻⁵	
		672	77.3	144.5	Up to 1 sec interactive, >10 sec background	0.003005	0.003287	<10 ⁻⁵	Cannot be applied
		1344	114.6	249.06		0.000704	0.0010007	<10 ⁻⁵	
		2688	189.3	458.13		0	3.091e-05	<10 ⁻⁵	Log-MAP
		3024	208	510.4		0	<10 ⁻⁵	Log-MAP or SOVA	

Table 4. Quality of service and proposed decoding algorithm for scenarios 6 and 7 of Table 1.

		Frame size (bits)	t _d using SOVA (msec)	t _d using log-MAP (msec)	Max latency (msec)	Log-MAP BER	SOVA BER	BER range	Proposed decoding algorithm
Scenario 6	Conv. class	168	43.5	49.8	80	0.0073	0.008	<10 ⁻³	
		336	47	59.6	80	0.0065	0.007	<10 ⁻³	
		672	54	79.2	80	0.0051	0.0062	<10 ⁻³	
		1344	68	118.4	80	0.0022	0.0028	<10 ⁻³	
		2016	82	157.6	80	0.000654	0.001307	<10 ⁻³	Cannot be applied
		2688	96	196.8	80	0	0	<10 ⁻³	
		3360	110	236	80	0	0	<10 ⁻³	
		4032	124	275.2	80	0	0	<10 ⁻³	
	Streaming class	168	43.5	49.8	250	0.0073	0.008	<10 ⁻³	
		336	47	59.6	250	0.0065	0.007	<10 ⁻³	Cannot be applied
		672	54	79.2	250	0.0051	0.0062	<10 ⁻³	
		1344	68	118.4	250	0.0022	0.0028	<10 ⁻³	
		2016	82	157.6	250	0.000654	0.001307	<10 ⁻³	Log-MAP
		2688	96	196.8	250	0	0	<10 ⁻³	Log-MAP or SOVA
		3360	110	236	250	0	0	<10 ⁻³	Log-MAP or SOVA
		4032	124	275.2	250	0	0	<10 ⁻³	SOVA
	Non-real time classes	168	43.5	49.8		0.0073	0.008	<10 ⁻⁵	
		336	47	59.6		0.0065	0.007	<10 ⁻⁵	
		672	54	79.2	Up to 1 sec interactive, >10 sec background	0.0051	0.0062	<10 ⁻⁵	Cannot be applied
		1344	68	118.4		0.0022	0.0028	<10 ⁻⁵	
		2016	82	157.6		0.000654	0.001307	<10 ⁻⁵	
2688		96	196.8		0	0	<10 ⁻⁵	Log-MAP or SOVA	
3360		110	236		0	0	<10 ⁻⁵	Log-MAP or SOVA	
4032		124	275.2		0	0	<10 ⁻⁵	Log-MAP or SOVA	
Scenario 7	Conv. class	2560	400	976	80	0	0	<10 ⁻³	Cannot be applied
	Streaming class	2560	400	976	250	0	0	<10 ⁻³	Cannot be applied
	Non-real time classes	2560	400	976	Up to 1 sec interactive, >10 sec background	0	0	<10 ⁻⁵	Log-MAP or SOVA

Table 5. Quality of service and proposed decoding algorithm for scenario 8 of Table 1.

		Frame size (bits)	t_d using SOVA (msec)	t_d using log-MAP (msec)	Max latency (msec)	Log-MAP BER	SOVA BER	BER range	Proposed decoding algorithm
Scenario 8	Conv. class	336	81.34	83.76	80	0.001815	0.0019574	$<10^{-3}$	
		1344	85.37	95.05	80	0.001414	0.0016548	$<10^{-3}$	
		2688	90.75	110.1	80	9.97e-07	9.97e-07	$<10^{-3}$	Cannot be applied
		4032	96.12	125.1	80	0	0	$<10^{-3}$	
		4704	98.81	132.68	80	0	0	$<10^{-3}$	
	Streaming class	336	81.34	83.76	250	0.001815	0.0019574	$<10^{-3}$	
		1344	85.37	95.05	250	0.001414	0.0016548	$<10^{-3}$	Cannot be applied
		2688	90.75	110.1	250	9.97e-07	9.97e-07	$<10^{-3}$	Log-MAP or SOVA
		4032	96.12	125.1	250	0	0	$<10^{-3}$	Log-MAP or SOVA
		4704	98.81	132.68	250	0	0	$<10^{-3}$	Log-MAP or SOVA
	Non-real time classes	336	81.34	83.76		0.001815	0.0019574	$<10^{-5}$	
		1344	85.37	95.05		0.001414	0.0016548	$<10^{-5}$	Cannot be applied
		2688	90.75	110.1	Up to 1 sec interactive, >10 sec background	9.97e-07	9.97e-07	$<10^{-5}$	Log-MAP or SOVA
		4032	96.12	125.1		0	0	$<10^{-5}$	Log-MAP or SOVA
		4704	98.81	132.68		0	0	$<10^{-5}$	Log-MAP or SOVA

According to [2] and [11], three different operating environments have been specified for UMTS:

- Rural outdoor operating environment with maximum supported mobile terminal speed 500 km/h and maximum data rate of 144 kbps. Here, it has to be mentioned that a speed of 500 km/h corresponds to high speed vehicles (e.g. trains). More typical value for this environment is 300 km/h.
- Urban or suburban outdoor operating environment with maximum supported mobile speed 120 km/h and maximum data rate of 384 kbps.
- Indoor or low range outdoor operating environment with maximum supported mobile speed 10 km/h and maximum data rate of 2 Mbps.

In [9] the approach is similar, but we considered the first two operating environments: a terminal speed of 300 km/h for a rural outdoor environment and a terminal speed of 100 km/h for an urban/suburban outdoor environment. In this paper we focus on the last operating environment and we choose a low terminal speed of 4 km/h. This means that the maximum data rate of 2 Mbps can be considered. A terminal speed of 4 km/h is a typical common value and it is important to be explored: represents walking human speed. In other words, each implementation scenario of the reconfigurable decoder of Table 1 is applied to indoor or low range outdoor operating environment. Moreover, similarly to [8,9,10], for the calculation of total maximum delay per frame for SOVA and log-MAP we use the following equations assuming a pipeline turbo decoder architecture and a processor that runs at the same rate for both SOVA and log-MAP:

Total max delay using SOVA:

$$t_d = 2 \times TTI + \left(\frac{k_f}{R_b} \times N \right) \quad (2)$$

Total max delay using log-MAP:

$$t_d = 2 \times TTI + \left(\frac{k_f}{R_b} \times N \times 2.8 \right) \quad (3)$$

where t_d is the total delay, k_f is the frame size, R_b is the data rate of the radio bearer assigned to the transport channel and N is the number of turbo decoder iterations. In these equations the higher complexity of log-MAP compared to SOVA (2.8 times) is also considered.

3. Simulation Results

The suitable decoding algorithm for each scenario is chosen according to performance and delay. Therefore, for each scenario of Table 1 all four service classes are applied to determine the quality of service profile parameters for different applications. Delay is calculated for each algorithm using Equations (2) and (3), while the simulated BER for each scenario is given in the following subsections together with a brief analysis of the results. Particularly, Table 2 shows quality of service for the different frame lengths of scenarios 1, 2, 3, while Tables 3 and 4 present quality of service for scenarios 4, 5 and 6, 7, respectively. Finally, Table 5 presents quality of service for scenario 8.

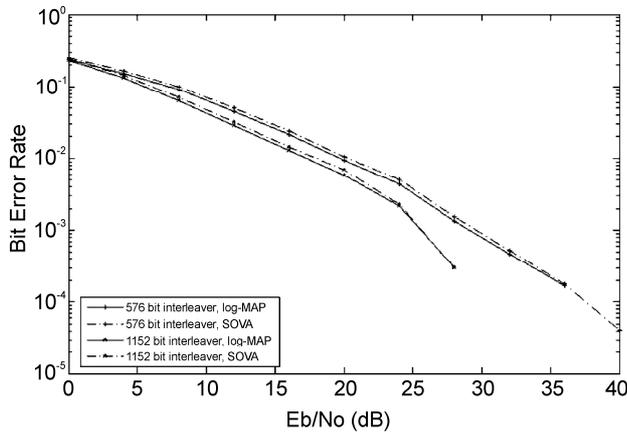


Figure 1. BER vs Eb/No for scenario 1.

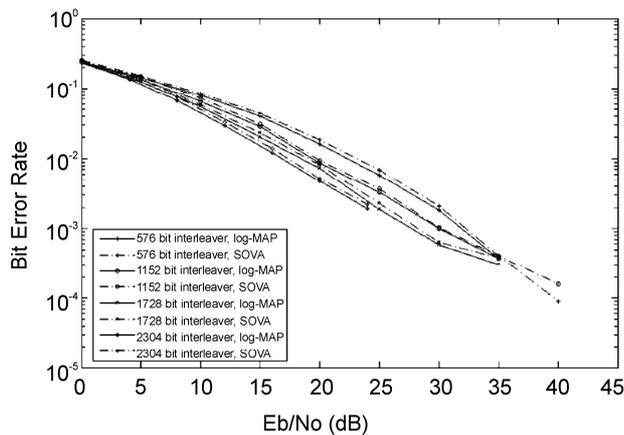


Figure 2. BER vs Eb/No for scenario 2.

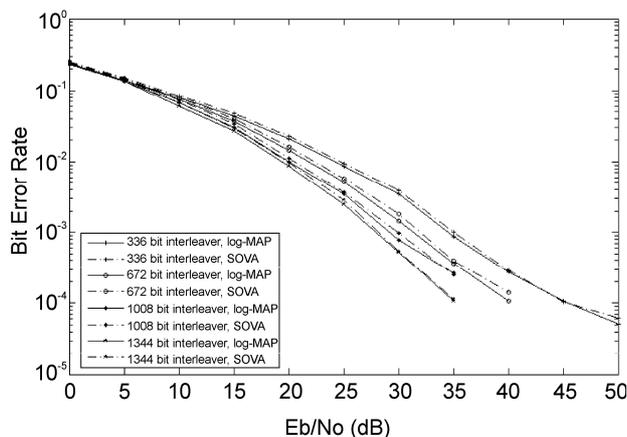


Figure 3. BER vs Eb/No for scenario 3.

3.1. Scenario 1

The simulated BER for this scenario is shown in Figure 1 assuming a symbol rate R_s of 86.4 Kbaud, normalised

fade rate $f_d T_s = 0.000085$ with Doppler frequency $f_d = 7.407$ Hz. Two frame lengths are considered in this scenario: 576 and 1152 bits, as Table 2 illustrates.

3.1.1. Conversational Service Class

At a SNR of 32 dB, the conversational class cannot be considered for this scenario because even though the BER criterion is satisfied, latency is too high for all frame lengths for either SOVA or log-MAP.

3.1.2. Streaming Service Class

For this class only a frame length of 576 bits can be applied. In this case SOVA satisfies both requirements, while log-MAP exceeds the maximum acceptable delay limit. For a frame of 1152 bits for SOVA and log-MAP is too high to achieve the limit for this class.

3.1.3. Interactive/Background Service Classes

For a frame length of 576 bits neither algorithm can be used because of the low BER criterion, while both requirements are achieved from both algorithms for a frame length of 1152 bits. Thus, a 576 bit frame service can not be applied, whereas in an 1152 bit frame service either SOVA or log-MAP can be used.

3.2. Scenario 2

The simulated BER results for this scenario are shown in Figure 2 assuming a symbol rate R_s of 172.8 Kbaud, normalised fade rate $f_d T_s = 0.000042$ and a SNR of 30 dB.

3.2.1. Conversational Service Class

According to Table 2, for this class the four different frame lengths cannot be applied because of the tight delay limit (80 msec).

3.2.2. Streaming Service Class

Similarly, as illustrated in Table 2, the four frame lengths are not applicable. Particularly, for frame lengths of 576 and 1152 bits SOVA satisfies the delay criterion, but does not satisfy BER criterion. On the other hand, the use of log-MAP gives unacceptable delay. For frame lengths of 1728 and 2304 bits although BER is satisfied from both algorithms, maximum acceptable delay is exceeded.

3.2.3. Interactive/Background Service Classes

For these service classes it is well-known that BER must be low and latency limits are not very strict. Thus, the first three frame lengths cannot be applied due to not acceptable BER. For a frame length of 2304 bits the two criteria are achieved by both decoding algorithms: either SOVA or log-MAP can be used.

3.3. Scenario 3

Figure 3 presents the simulation results for this scenario using the following parameters: $R_s = 192$ Kbaud, $f_d T_s = 0.000038$ and a SNR of 30 dB.

3.3.1. Conversational Service Class

According to the analysis of Table 2, the four frame lengths give too high delay. Thus, their application is not possible for SOVA or log-MAP.

3.3.2. Streaming Service Class

The analysis of Table 2 clearly shows that for all frame lengths SOVA satisfies the delay limit of 250 msec at 30 dB. On the other hand the BER limit is not achieved for the small frames of 336 and 672 bits. Thus, SOVA can be used for frames of 1008 and 1344 bits. For log-MAP and frames of 672, 1008, 1344 bits the delay limit cannot be achieved. For a small frame of 336 bits the delay limit is achieved, but the BER limit is not achieved.

3.3.3. Interactive/Background Service Classes

For these non-real time service classes and for all four frames the achieved BER is lower than the acceptable limit. Therefore, although the delay limit is achieved the four frames can not be applied.

3.4. Scenario 4

Figure 4 presents the simulated BER for this scenario using the following parameters: $R_s = 384$ Kbaud, $f_d T_s = 0.000019$ with $f_d = 185.1$ Hz and a SNR of 30 dB.

3.4.1. Conversational Service Class

Again, for this class the four frames cannot be applied

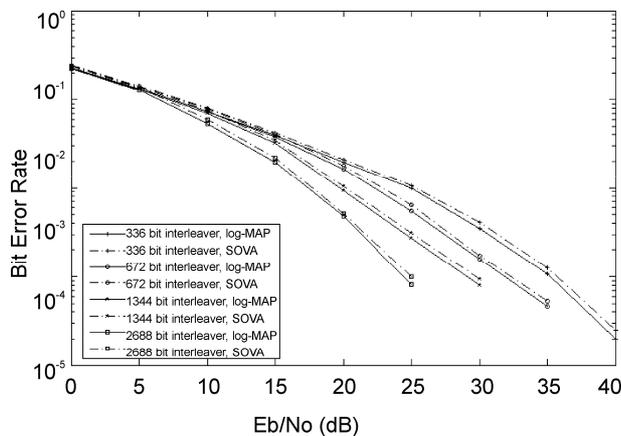


Figure 4. BER vs Eb/No for scenario 4.

because of high delay. For a frame of 336 bits although delay is acceptable for SOVA, BER criterion is not satisfied. According to Table 3 it is obvious that this service scenario is not possible to be implemented.

3.4.2. Streaming Service Class

The analysis of Table 3 clearly shows that for all frame lengths SOVA satisfies the delay limit of 250 msec at 30 dB. On the other hand the BER limit is not achieved for the small frames of 336 and 672 bits. Thus, SOVA is the proposed turbo decoding algorithm for frames of 1344 and 2688 bits. For log-MAP and frames of 1344, 2688 bits the delay limit cannot be achieved. For small frames of 336 and 672 bits the delay limit is achieved, but the BER limit is not achieved.

3.4.3. Interactive/Background Service Classes

According to Table 3, for these classes and for the first three frames the achieved BER is lower than the acceptable limit. Therefore, although the delay limit is achieved these frames can not be applied. On the other hand, for a frame of 2688 bits the two parameters (BER, delay) are satisfied by both algorithms.

3.5. Scenario 5

For Figure 5 the following parameters are assumed: $R_s = 432$ Kbaud, $f_d T_s = 0.000017$ and a SNR of 28 dB. Figure 5 shows BER performance for the five different frame lengths specified in Table 1 for this scenario.

3.5.1. Conversational Service Class

For this class (Table 3) for all five frames the delay criterion is too low to be achieved from both algorithms. There is an exception for the small frames of 336 and 672 bits, where the delay criterion is achieved for SOVA but BER criterion is not. It is obvious that the constraints

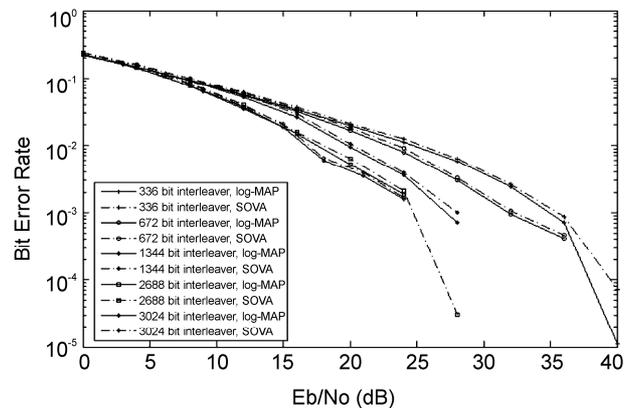


Figure 5. BER vs Eb/No for scenario 5.

of the two parameters cannot be achieved by both algorithms.

3.5.2. Streaming Service Class

The analysis of Table 3 identifies three cases:

- Small frames of 336 and 672 bits. Here, the delay limit is achieved, but the BER limit is not for SOVA and log-MAP. This means that these frames cannot be implemented.
- Medium frame of 1152 bits. Here, the delay limit is achieved by both algorithms. Log-MAP is the proposed choice because it can achieve the BER limit as well. SOVA cannot achieve the BER limit. Thus, log-MAP represents the proposed algorithm.
- Large frames of 2688 and 3024 bits. Here, SOVA is the algorithm that can be implemented. The reason is the following: BER limit is achievable by both algorithms, whereas delay limit is achieved only by SOVA.

3.5.3. Interactive/Background Service Classes

According to Table 3, the delay limit is achieved by both SOVA and log-MAP for all frames. Furthermore, for the first three frames the BER limit is not achieved, but for 2688 bits frame it is achieved only by log-MAP. In this case log-MAP is proposed. For a frame of 3024 bits the limits of the two parameters are achieved by both algorithms.

3.6. Scenario 6

Figure 6 illustrates the simulated BER of the different frame lengths for this scenario using the following parameters: $R_s = 1152$ Kbaud, $f_d T_s = 0.0000064$ and a SNR of 28 dB.

3.6.1. Conversational Service Class

For this class (Table 4) for the first three frames although delay criterion is satisfied, BER criterion is not satisfied.

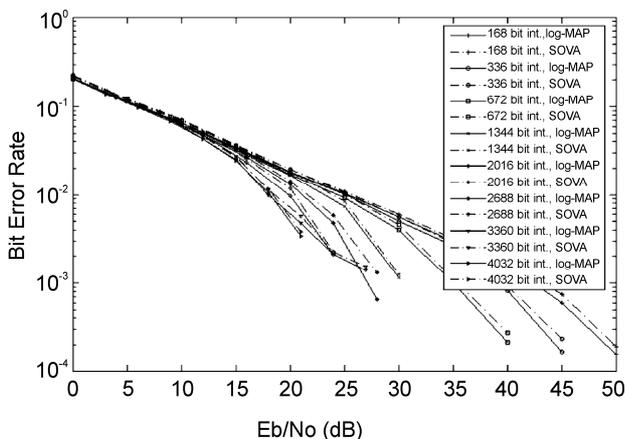


Figure 6. BER vs Eb/No for scenario 6.

For the next four frames either BER, or delay limits are not achieved for SOVA and log-MAP. Thus, this service class is not possible to be implemented for all frames.

3.6.2. Streaming Service Class

The analysis of Table 4 identifies four cases:

- Frames of 168, 336, 672 and 1344 bits. Here, the delay limit is achieved, but the BER limit is not achieved for SOVA and log-MAP. This means that these frames cannot be implemented.
- Frame of 2016 bits. Here, the delay limit is achieved by both algorithms. Log-MAP is the proposed choice because it can achieve the BER limit as well, while SOVA cannot achieve the BER limit. Thus, log-MAP represents the proposed algorithm.
- Frames of 2688 and 3360 bits. Here, SOVA and log-MAP achieve both limits. Therefore, both algorithms can be used.
- Frame of 4032 bits. Here, SOVA is the algorithm that can be implemented. The reason is the following: BER limit is achievable by both algorithms, whereas log-MAP gives unacceptable delay.

3.6.3. Interactive/Background Service Classes

According to Table 4, the delay limit is achieved by both SOVA and log-MAP for all frames. Furthermore, for the first five frames the BER limit is not achieved. Thus, they cannot be implemented. For frames of 2688, 3360 and 4032 bits the limits of the two parameters are achieved by both algorithms.

3.7. Scenario 7

In Figure 7 BER performance for the different frame lengths for this scenario can be seen using the following parameters: $R_s = 192$ Kbaud, $f_d T_s = 0.000038$ and a SNR of 30 dB.

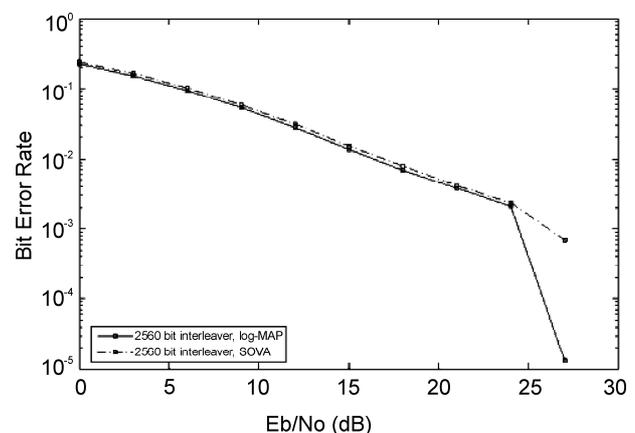


Figure 7. BER vs Eb/No for scenario 7.

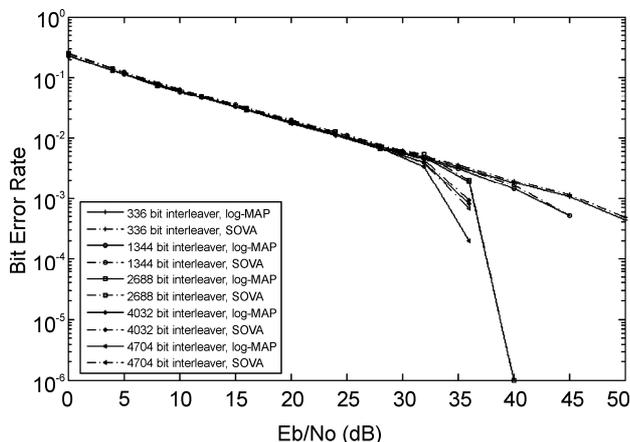


Figure 8. BER vs E_b/N_0 for scenario 8.

3.7.1. Conversational/Streaming Service Classes

The analysis of Table 4 clearly shows that the frame of 2560 bits gives unacceptable delay for both real time classes and both decoding algorithms. Therefore, they cannot be implemented.

3.7.2. Interactive/Background Service Classes

For non-real time classes both limits are achieved by both algorithms, which mean that they are both suitable for this application.

3.8. Scenario 8

Figure 8 presents BER performance of the different frame lengths for this scenario using the following parameters: $R_s = 6000$ Kbaud, $f_d T_s = 0.0000012$ and a SNR of 40 dB.

3.8.1. Conversational Service Class

For all five frames the calculated delay, according to Table 5, is too high. Thus, this scenario cannot be implemented for this service class.

3.8.2. Streaming Service Class

Here, delay criterion is achieved by both algorithms and for all frames. Furthermore, for frames of 336 and 1344 bits the BER limit is not achievable by the two algorithms. This means that these two frames cannot be implemented. On the other hand, for frames of 2688, 4032 and 4704 bits the two criteria are satisfied by both algorithms: they are equally suitable.

3.8.3. Interactive/Background Service Classes

From Table 5 it can be seen that the analysis is similar to the previous section: the first two frames cannot be established, whereas for the last three frames either SOVA or log-MAP can be used.

4. Conclusions

In this paper we have presented possible reconfiguration scenarios applied to an important receiver technique, namely, channel decoding. It has been shown that reconfigurability is a desirable feature towards the implementation of energy efficient receivers without performance sacrifices.

For a UMTS turbo decoder SOVA and log-MAP correspond to the main decoding algorithms. Considering performance and complexity or delay, SOVA is the best choice in terms of complexity, while log-MAP is the best choice in terms of performance. The similarities in the data-flow of the two algorithms support the idea of a reconfigurable SOVA/log-MAP turbo decoder [8,9,10]. Moreover, according to [3] at low terminal speeds BER is worse than at higher terminal speeds. For UMTS some applications require the lowest possible delay, while for others the lowest possible performance is sufficient. Having in mind the results of [9] it is observed that at rural and urban/suburban outdoor operating environments more frames can be established compared to indoor/low range outdoor environment. Thus, for indoor/low range outdoor environment there are many applications which cannot be established.

Our results for indoor/low range outdoor environment show that for all implementation scenarios real time conversational class cannot be established. The reason is the low terminal speed which gives high BER. Comparing with urban/suburban environment in [9], this class can be applied to medium sized frames and high data rates, whereas in rural outdoor operating environment this class can be applied to small frames and low or medium data rates.

For real time streaming class the proposed algorithm choice depends on data rate. For low data rates all frames cannot be applied, except for small frames where SOVA is optimal. For medium data rates (64 kbps, 128 kbps) small frames cannot be applied, while for medium-sized frames SOVA is proposed. For 144 kbps again SOVA is proposed for larger frames, while for medium-sized frames log-MAP is optimal. For high data rates (384 kbps) small frames cannot be considered, for medium frames log-MAP is proposed, while for large frames SOVA is proposed. For the other frame lengths either algorithm is proposed. For very high data rates (2 Mbps) small frames cannot be established: for the other frames either SOVA or log-MAP can be used. On the other hand, in [9] for streaming class applications urban/suburban and rural outdoor operating environments SOVA is optimal for the scenarios that can be established. It is remarkable that, similarly to [9], as data rate increases more and larger frames can be applied.

For non-real time applications performance is the priority and delay requirements are looser. We observe that

for all scenarios small frames cannot be applied due to tight BER. For larger frames both algorithms are equally suitable. Furthermore, for medium data rates and medium frames log-MAP is the proposed algorithm choice. For urban/suburban outdoor environment the conclusions are similar in [9], whereas for rural outdoor environment log-MAP is optimum for the small frames and the two algorithms are equally suitable for larger frames.

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