INTERNATIONAL TELECOMMUNICATION UNION

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G.723.1
Annex C
(11/96)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA

Digital transmission systems – Terminal equipments – Coding of analogue signals by methods other than PCM

Dual rate speech coder for multimedia communications transmitting at 5.3 and 6.3 kbit/s

Annex C: Scalable channel coding scheme for wireless applications

ITU-T Recommendation G.723.1 – Annex C

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION G.723.1 – Annex C

SCALABLE CHANNEL CODING SCHEME FOR WIRELESS APPLICATIONS

Source

Annex C to ITU-T Recommendation G.723.1, was prepared by ITU-T Study Group 15 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 8th of November 1996.

FOREWORD

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

CONTENTS

Recommendation G.723.1 – Annex C

SCALABLE CHANNEL CODING SCHEME FOR WIRELESS APPLICATIONS

(Geneva, 1996)

C.1 Introduction

C.1.1 Scope

This Annex specifies a channel coding scheme which can be used with the triple rate speech codec G.723.1. The channel codec is scalable in bit-rate and is designed for mobile multimedia applications as a part of the overall H.324 family of standards. With this Annex, G.723.1 can be adapted to any wireline or wireless transmission system. Transmission system dependent functionalities like interleaving or burst formatting are not subject of this Annex.

C.1.2 Bit-rates

A wide range of channel codec bit-rates is supported ranging from 0.7 kbit/s up to 14.3 kbit/s. The channel codec supports all three operational modes of the G.723.1 codec, namely high rate, low rate and discontinuous transmission modes.

The applied channel codec bit-rates depend on the transmission system and the application and are therefore not specified in this Annex.

C.1.3 Delay

No additional delay is introduced by the channel encoder and decoder described in this Annex.

C.1.4 Channel codec description

The channel codec is based on punctured convolutional codes. The possibility to generate multiple rates from a given mother code is the basis for the scalability feature. Based on the subjective importance of each class of information bits, the available channel codec bit-rate is allocated optimally to the bit classes. This allocation is based on an algorithm which has to be known by encoder and decoder. Each time the system control signals either a change in the G.723.1 rate or in the available channel codec bit-rate, this algorithm is executed to adapt the channel codec to the new speech service configuration.

If only a very low channel codec bit-rate is available, the subjectively most sensitive bits are protected first. When increasing the channel codec bit-rate, the additional bits are used first to protect more information bits and second to increase the protection of the already protected classes.

A special configuration of the channel codec enables a robust G.723.1 transmission without the use of convolutional codes but with only an error detection code for the subjectively most sensitive bits. The channel codec bit-rate for this configuration is 667 bits per second.

Prior to the application of the channel encoding functions, the speech parameters are partly modified in a channel adaptation layer to improve their robustness against transmission errors.

Two parameters are sufficient to configure and control the channel codec:

1) G.723.1 configuration bit, signalling the operational mode of the speech encoder;

2) Channel codec configuration bits, signalling the channel codec bit-rate to apply.

C.1.5 Interface to control H.245

The channel codec bit-rate available for the speech service is provided by the control H.245 using one channel codec configuration bits. Both, channel codec configuration bit and G.723.1

configuration bits are protected and transmitted together with the protected information bitstream to the decoder. Prior to the decoding of the information bitstream, the configuration bits are decoded and channel and speech decoder are configured accordingly.

C.2 Channel encoder

C.2.1 Channel encoder adaptation for active speech modes

This clause describes the transformation of the original G.723.1 speech parameters to a modified bitstream with increased robustness to transmission errors.

C.2.1.1 Gain index decompression

The format of the speech parameters is specified in Tables 5 and 6 of Recommendation G.723.1. The 12-bit overall gain index (GAINx_By) of each subframe is a compressed index of two individual gain indices. These indices shall be decompressed as it is described in the speech decoding part (subclauses 2.17 and 2.18 of Recommendation G.723.1). This results in one 8-bit (AGAINx_By) and one 5-bit (FGAINx_By) gain index per subframe, requiring one additional bit compared to the compressed index. The overhead introduced by this decompression operation shall be exploited in the channel decoder for error detection and error concealment purposes.

C.2.1.2 LPC reordering

The 24-bit LPC index (LPC_Bx, x=0,23) consists of three 8 bit sub-vectors as described in 2.6 of Recommendation G.723.1:

$$e_0 = \{LPC\_B7, LPC\_B6, LPC\_B5, LPC\_B4, LPC\_B3, LPC\_B1, LPC\_B0\}$$

$$e_1 = \{LPC\_B15, LPC\_B14, LPC\_B13, LPC\_B12, LPC\_B11, LPC\_B10, LPC\_B9, LPC\_B8\}$$

$$e_2 = \{LPC\_B23, LPC\_B22, LPC\_B21, LPC\_B20, LPC\_B19, LPC\_B18, LPC\_B17, LPC\_B16\}$$

The sub-vectors shall be reordered applying the mapping:

$$e_m^R = \text{ReorderTab}_m[e_m] \quad m = 0,1,2$$

The LPC reordering tables are given in Table C.1a for the first sub-vector, C.1b for the second and C.1c for the third sub-vector. The entry (i,j) to the table is determined by: $e_m = 16 \cdot j + i$. The output obtained is the transmitted index of the sub-vector.

TABLE C.1a/G.723.1

Reordering table for m=0 (ReorderTab$_0$[e_0])

	i=0	i=1	i=2	i=3	i=4	i=5	i=6	i=7	i=8	i=9	i=10	i=11	i=12	i=13	i=14	i=15
j=0	82	91	190	191	189	36	187	32	38	39	185	112	166	175	116	120
j=1	34	35	122	41	40	43	42	56	57	90	168	85	74	170	234	174
j=2	169	172	178	182	184	179	181	180	37	186	44	33	159	183	188	155
j=3	253	252	147	154	246	165	218	139	63	160	157	146	145	144	177	176
j=4	244	131	148	129	128	161	219	135	34	203	200	206	207	204	205	254
j=5	212	222	213	220	221	141	216	88	38	137	136	217	133	132	201	197
j=6	196	76	77	243	192	195	193	119	18	108	121	249	247	245	130	240
j=7	241	235	69	68	210	226	227	224	25	79	211	250	251	255	198	242
j=8	194	127	45	46	117	125	124	2	67	3	101	72	0	13	97	65
j=9	66	98	96	158	248	228	229	93	31	109	100	110	111	75	73	115
j=10	114	23	94	95	6	22	7	230	5	4	99	81	20	21	83	113
j=11	102	14	103	15	12	16	52	17	19	1	29	8	28	30	31	11
j=12	9	126	24	18	26	25	27	86	87	64	71	70	153	152	173	162
j=13	167	164	89	80	238	208	232	233	15	236	239	92	202	209	199	143
j=14	142	140	223	84	78	171	151	156	37	150	149	214	106	107	10	53
j=15	47	54	55	104	105	123	48	58	59	49	50	51	62	60	61	63

TABLE C.1b/G.723.1

Reordering table for m=1 (ReorderTab$_1$[e_1])

	i=0	i=1	i=2	i=3	i=4	i=5	i=6	i=7	i=8	i=9	i=10	i=11	i=12	i=13	i=14	i=15
j=0	122	150	201	213	214	212	246	244	136	135	130	134	140	216	218	146
j=1	209	208	110	153	156	158	152	144	147	145	199	197	193	204	205	249
j=2	248	127	185	172	174	173	179	169	168	181	182	177	183	161	178	167
j=3	163	162	160	165	232	234	235	233	237	236	238	239	78	155	154	75
j=4	74	69	68	71	70	73	72	139	123	114	59	58	113	170	137	141
j=5	186	133	151	132	148	159	196	149	187	189	191	157	198	190	121	126
j=6	125	120	57	112	171	63	45	62	47	46	99	109	98	103	124	102
j=7	107	106	129	128	131	89	118	105	104	95	91	90	94	86	83	82
j=8	138	119	117	88	116	92	37	36	38	32	96	87	81	39	93	49
j=9	48	23	22	21	20	29	8	56	55	44	175	60	61	53	43	143
j=10	115	176	180	142	166	184	188	207	206	231	252	195	194	219	217	221
j=11	223	211	215	210	192	200	164	226	202	203	230	227	229	253	255	224
j=12	225	243	228	220	240	241	242	222	245	251	250	247	254	111	108	77
j=13	76	79	101	100	30	15	97	52	54	41	50	51	40	33	42	35
j=14	34	13	12	14	85	84	25	31	27	80	17	67	66	16	9	28
j=15	24	65	11	10	26	64	19	18	4	1	0	5	7	6	3	2

TABLE C.1c/G.723.1

Reordering table for m=2 (ReorderTab$_2$[e_2])

	i=0	i=1	i=2	i=3	i=4	i=5	i=6	i=7	i=8	i=9	i=10	I=11	i=12	i=13	i=14	i=15
j=0	243	154	190	170	189	169	140	188	171	168	166	164	165	216	146	132
j=1	242	234	158	144	252	147	148	13	74	75	19	77	76	79	78	70
j=2	71	198	199	72	12	73	220	150	151	131	204	133	205	230	229	225
j=3	200	201	226	227	196	192	197	195	202	203	136	143	142	175	207	206
j=4	137	138	139	174	173	172	240	228	209	224	238	239	128	130	145	250
j=5	236	237	255	248	253	232	153	179	181	180	235	233	152	156	184	178
j=6	185	162	183	182	163	160	161	167	157	159	155	134	186	191	135	187
j=7	141	254	177	251	176	33	244	245	61	60	34	35	32	249	126	41
j=8	62	59	58	63	57	56	42	43	25	29	40	125	120	24	26	127
j=9	123	124	122	48	121	46	47	105	104	109	108	28	116	112	113	247
j=10	246	36	54	149	55	4	52	53	49	37	39	51	50	107	211	215
j=11	20	21	17	3	5	223	222	0	231	129	218	9	217	219	194	221
j=12	193	210	38	2	1	212	14	15	241	44	208	8	45	11	10	110
j=13	68	69	103	100	213	214	16	106	18	111	22	23	6	7	64	65
j=14	27	118	117	102	31	30	97	114	115	96	88	89	90	91	99	94
j=15	80	82	83	119	98	101	92	95	66	67	84	93	85	81	86	87

C.2.1.3 Channel adapted bitstream format

The speech parameter format of the high and low bit-rate modes after gain decompression and LPC reordering is given in Tables C.2a and C.2b (UB means "unused bit").

TABLE C.2a/G.723.1

Format of decompressed high rate codec speech parameters

Channel Encoder Octets	PARx_By
1	R_LPC_B5...R_LPC_B0, VAD, RATE
2	R_LPC_B13...R_LPC_B6
3	R_LPC_B21...R_LPC_B14
4	ACL0_B5...ACL0_B0, R_LPC_B23, R_LPC_B22
5	ACL2_B4...ACL2_B0, ACL1_B1, ACL1_B0, ACL0_B6
6	AGAIN0_B3...AGAIN0_B0, ACL3_B1, ACL3_B0, ACL2_B6, ACL2_B5
7	AGAIN1_B3...AGAIN1_B0, AGAIN0_B7...AGAIN0_B4
8	AGAIN2_B3...AGAIN2_B0, AGAIN1_B7...AGAIN1_B4
9	AGAIN3_B3...AGAIN3_B0, AGAIN2_B7...AGAIN2_B4
10	FGAIN0_B3...FGAIN0_B0, AGAIN3_B7...AGAIN3_B4
11	FGAIN2_B1, FGAIN2_B0, FGAIN1_B4...FGAIN1_B0, FGAIN0_B4
12	FGAIN3_B4...FGAIN3_B0, FGAIN2_B4...FGAIN2_B2
13	MSBPOS_B3...MSBPOS_B0, GRID3_B0, GRID2_B0, GRID1_B0, GRID0_B0
14	MSBPOS_B11...MSBPOS_B4
15	POS0_B6...POS0_B0, MSBPOS_B12
16	POS0_B14...POS0_B7
17	POS1_B6...POS1_B0, POS0_B15
18	POS2_B0, POS1_B13...POS1_B7
19	POS2_B8...POS2_B1
20	POS3_B0, POS2_B15...POS2_B9
21	POS3_B8...POS3_B1
22	PSIG0_B2...PSIG0_B0, POS3_B13...POS3_B9
23	PSIG1_B4...PSIG1_B0, PSIG0_B5...PSIG0_B3
24	PSIG3_B1, PSIG3_B0, PSIG2_B5...PSIG2_B0
25	UB,UB,UB,UB,UB,PSIG3_B4...PSIG3_B2

TABLE C.2b/G.723.1

Format of decompressed low rate codec speech parameters

Channel Encoder Octets	PARx_By
1	R_LPC_B5...R_LPC_B0, VAD, RATE
2	R_LPC_B13...R_LPC_B6
3	R_LPC_B21...R_LPC_B14
4	ACL0_B5...ACL0_B0, R_LPC_B23, R_LPC_B22
5	ACL2_B4...ACL2_B0, ACL1_B1, ACL1_B0, ACL0_B6
6	AGAIN0_B3...AGAIN0_B0, ACL3_B1, ACL3_B0, ACL2_B6, ACL2_B5
7	AGAIN1_B3...AGAIN1_B0 , AGAIN0_B7...AGAIN0_B4
8	AGAIN2_B3...AGAIN2_B0 , AGAIN1_B7...AGAIN1_B4
9	AGAIN3_B3...AGAIN3_B0 , AGAIN2_B7...AGAIN2_B4
10	FGAIN0_B3...FGAIN0_B0 , AGAIN3_B7...AGAIN3_B4
11	FGAIN2_B1 , FGAIN2_B0 , FGAIN1_B4...FGAIN1_B0 , FGAIN0_B4
12	FGAIN3_B4...FGAIN3_B0 , FGAIN2_B4...FGAIN2_B2
13	POS0_B3...POS0_B0 , GRID3_B0, GRID2_B0, GRID1_B0, GRID0_B0
14	POS0_B11...POS0_B8 , POS0_B7...POS0_B4
15	POS1_B7...POS1_B4 , POS1_B3...POS1_B0,
16	POS2_B3...POS2_B0 , POS1_B11...POS1_B8
17	POS2_B11...POS2_B8 , POS2_B7...POS2_B4
18	POS3_B7...POS3_B4 , POS3_B3...POS3_B0
19	PSIG0_B3...PSIG0_B0 , POS3_B11...POS3_B8
20	PSIG2_B3...PSIG2_B0 , PSIG1_B3...PSIG1_B0
21	UB . UB , UB , UB , PSIG3_B3...PSIG3_B0

C.2.2 Bit sensitivity classes for active speech modes

The bits of the decompressed speech parameters specified in Tables C.2a and C.2b are rearranged according to Table C.3a for the high bit-rate mode and Table C.3b for the low bit-rate mode.

The numbers indicate the position of the corresponding information bit in the ordered bitstream. The subjectively most sensitive bit is copied to position "0" of the ordered bitstream.

The ordered bitstream is denoted with:

$$i(0), i(0), \ldots i(92)$$

for the high rate codec, and:

$$i(0), i(1), ...i(162)$$

for the low rate codec.

TABLE C.3a/G.723.1

High rate codec bit ordering table

Octet	Bit position in ordered bitstream							
1	175	180	189	190	191	192	VAD	RATE
2	98	73	107	154	167	168	169	170
3	30	17	16	31	48	55	49	71
4	6	4	0	2	11	26	10	14
5	5	1	3	12	27	24	60	8
6	44	66	62	82	25	61	9	7
7	45	67	63	83	78	36	50	40
8	46	68	64	84	79	37	51	41
9	47	69	65	85	80	38	52	42
10	56	99	159	185	81	39	53	43
11	161	187	20	57	100	160	186	19
12	22	59	102	162	188	21	58	101
13	35	54	70	72	179	178	177	176
14	13	15	23	28	29	32	33	34
15	128	132	146	155	163	171	181	18
16	76	86	90	94	103	108	112	116
17	129	133	147	156	164	172	182	74
18	183	87	91	95	104	109	113	117
19	114	118	130	134	148	157	165	173
20	184	75	77	88	92	96	105	110
21	115	119	131	135	149	158	166	174
22	136	124	120	89	93	97	106	111
23	151	141	137	125	121	144	150	140
24	127	123	145	152	142	138	126	122
25	UB	UB	UB	UB	UB	153	143	139

TABLE C.3b/G.723.1

Low rate codec bit ordering table

Octet	Bit position in ordered bitstream							
1	152	153	158	159	160	161	VAD	RATE
2	69	64	70	91	145	140	147	146
3	24	15	14	25	46	50	47	63
4	4	6	0	2	11	18	10	13
5	7	1	3	12	19	16	48	8
6	42	59	55	65	17	49	9	5
7	43	60	56	66	26	30	34	38
8	44	61	57	67	27	31	35	39
9	45	62	58	68	28	32	36	40
10	51	87	141	154	29	33	37	41
11	143	156	21	52	88	142	155	20
12	23	54	90	144	157	22	53	89
13	100	128	96	104	151	150	149	148
14	132	112	116	136	108	120	124	92
15	109	121	125	93	101	129	97	105
16	102	130	98	106	133	113	117	137
17	134	114	118	138	110	122	126	94
18	111	123	127	95	103	131	99	107
19	83	79	75	71	135	115	119	139
20	85	81	77	73	84	80	76	72
21	UB	UB	UB	UB	86	82	78	74

C.2.3 Bit sensitivity classes for SID frames

The format of the SID frame type is specified in Annex A of Recommendation G.723.1. The bits of this frame are rearranged according to Table C.3c. For SID frames neither a gain decompression nor a LPC reordering is performed. The numbers indicate the position of the corresponding information bit in the ordered bitstream. The subjectively most sensitive bit is copied to position "0" of the ordered bitstream.

The ordered bitstream is denoted with:

$$i(0), i(1), ...i(29)$$

TABLE C.3c/G.723.1

Bit ordering table for SID frames

Octet	Bit position in ordered bitstream							
1	21	22	23	24	25	26	VAD	RATE
2	13	14	15	16	17	18	20	19
3	5	6	7	8	9	10	11	12
4	0	1	2	29	28	27	3	4

C.2.4 CRC encoder

The subjectively most sensitive bits are protected by five parity bits used for error detection in the channel decoder.

The first CRC_{WIN} bits of the ordered bitstream are within the CRC window:

Low rate codec: $CRC_{WIN} = 34$

High rate codec: $CRC_{WIN} = 44$

SID frames: $CRC_{WIN} = 30$

The following generator polynomial for the cyclic code shall be applied:

$$g(D) = D^5 + D^2 + 1.$$

The five parity bits p(0) - p(4) are copied right after the CRC_{WIN} ordered information bits.

The bitstream after CRC encoding shall therefore have the following format:

Low rate codec: bs(n) = i(0),i(1), ...i(33),p(0),p(1),p(2),p(3),p(4),i(34),i(35), ... i(161); n=0 ... 166

High rate codec: bs(n) = i(0),i(1), ...i(43),p(0),p(1),p(2),p(3),p(4),i(44),i(45), ... i(192); n=0 ... 197

SID frame: bs(n) = i(0),i(1), ...i(29),p(0),p(1),p(2)p(3),p(4); n=0 ... 34

C.2.5 Convolutional encoder

The information bits bs(n) shall be encoded with punctured convolutional codes defined by the mother polynomials:

$$g_{CC}^0 = D^4 + D + 1$$
$$g_{CC}^1 = D^4 + D^3 + D^2 + 1$$
$$g_{CC}^2 = D^4 + D^2 + D + 1$$

Puncturing of the mother code with a puncturing period of 12 generates 24 intermediate rates:

$$\frac{12}{36} \le r \le \frac{12}{13}$$

The puncturing matrices are given in Table C.4.

TABLE C.4/G.723.1

Puncturing tables (all values in hexadecimal representation)

Rate r	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24
$P_r(0)$	D6F	D7F	D7F	D7F	DFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF
$P_r(1)$	690	690	691	695	695	695	69D	6DD	6DF	7DF	7FF	FFF
$P_r(2)$	000	000	000	000	000	000	000	000	000	000	000	000

Rate r	12/25	12/26	12/27	12/28	12/29	12/30	12/31	12/32	12/33	12/34	12/35	12/36
$P_r(0)$	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF
$P_r(1)$	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF	FFF
$P_r(2)$	001	009	109	309	329	729	72D	72F	7AF	7BF	7FF	FFF

C.2.5.1 Allocation of channel codec bit-rate

In this clause the resource allocation algorithm is described which shall be applied for determining the degree of protection for each information bit. This algorithm has to be executed in the channel encoder and channel decoder each time at least one of the following events occur:

- Reset.
- Change of the channel codec bit-rate allocated for G.723.1.
- Change of the G.723.1 source codec bit-rate.

The following rate allocation procedure shall be executed:

- The ordered bitstream shall be divided in five-bit classes c[i], i=0...4, where c[0] contains the most sensitive and c[4] the least sensitive bits.
- A weighting factor w[i], i=0...4 shall be assigned to each class, controlling the rate allocation algorithm.
- Class 0 contains c[0]-5 information bits and the five parity check code bits which are copied to the end of that class.
- If no channel bits ($B = 0$) are available the channel bitstream shall contain the decompressed G.723.1 bitstream and the five parity check bits.
- The maximum number of channel codec bits per frame is achieved, when all classes have the protection rate r = 1/3

$$B_{\max} = 2 \cdot \left(\sum_{i=0}^{i=4} c[i] \right) + 4$$

- If:

$$B \le c[0] + 8$$

channel codec bits are available per frame these shall be equally distributed over the bits of class 0, applying the formula:

$$r[0] = \frac{12}{\mathrm{INT}\left(12 * \left(1 + \frac{B}{c[0] + 4}\right)\right)}$$

INT Next lower integer value

- If $B > c[0] + 8$ channel codec bits per frame are available, in a first pass the intermediate rates r'[i], i=0...4 of the bit classes shall be determined with the following formula:

$$r'[i] = \frac{12}{\mathrm{MIN}\left[36, \mathrm{NINT}\left(12 * \left(1 + \frac{B * w[i]}{c[i]}\right)\right)\right]}$$

The final rate is determined by applying the constraint:

$$r[i] = \begin{cases} 1 & if \;\; r'[i] > \frac{12}{18} \\ r'[i] & \text{otherwise} \end{cases}$$

- If the above algorithm allocates less bits than available, in the second pass bits from the first unprotected class shall be shifted to the last protected class until all available bits are allocated.
- If more bits than available have been allocated, in the second pass bits from the last protected class shall be shifted to the first unprotected class until the maximum allowed channel codec bit-rate is achieved.
- In the original configuration class 3 contains the tail bits. If this class receives no protection applying the above formula, the tail bits shall be attached to the last protected class.

C.2.5.1.1 Control parameter settings for active speech modes

The following settings of c[i] and w[i] shall be chosen (Table C.5a):

TABLE C.5a/G.723.1

Settings of control parameters for rate allocation (active speech frames)

	G.723.1 – 6.3 kbit/s					G.723.1 – 5.3 kbit/s				
i	0	1	2	3	4	0	1	2	3	4
c[i]	44+5crc	44	46	47+4tail	12	34+5crc	40	40	40+4tail	8
w[i]	0.26	0.29	0.24	0.21	0.00	0.24	0.31	0.24	0.21	0.00

C.2.5.1.2 Control parameter settings for SID frames

The following settings of c[i] and w[i] shall be chosen (Table C.5b):

TABLE C.5b/G.723.1

Settings of control parameters for rate allocation (SID frames)

	G.723.1 – SID				
i	0	1	2	3	4
c[i]	30+5crc+4tail	0	0	0	0
w[i]	1.0	0.00	0.00	0.00	0.00

C.2.5.2 End of trellis adaptation

To take the lower error probability of the last protected bits into account, the bits

$$\mathrm{bs}(Nlast\text{-}n); \quad n = 0 \ldots 9;$$

shall be exchanged with the bits:

$$\mathrm{bs}(Nlast\text{-}19+n); \quad n = 0 \ldots 9.$$

Nlast is the last protected information bit in the bitstream.

This operation shall only be performed if more than 19 information bits are protected in the classes 1 to 3.

C.2.5.3 Encoding of the information bitstream

Each bit bs(*j*) which receives protection ($r[i] < 1$) shall be encoded applying the following steps:

- Encoding of information bit bs(*j*) of class *i* with the three generator polynomials g_{CC}^{n}. This results in three intermediate channel bits u'(*n*) at the output (*n*=0,1,2).
- Puncturing of u'(*n*) with $P_{r[i]}$ (*n*) in the following way:

  If bit *p* of $P_{r[i]}$ (*n*) equals 0 then u'(*n*) is discarded otherwise it is inserted in the channel bitstream u(*m*) and *m* is incremented. *p* is a modulo 12 counter which is incremented with the information bit counter *j*.

After encoding of the protected bits the channel bitstream is contained in array u(*m*), $m = 0 \, .. \, M_p - 1$.

The unprotected bits shall be copied to the end of the protected channel bitstream, starting at location $m = M_p$ and ending at location $m = M_{All} - 1$.

C.2.5.4 Encoding of configuration bits

Three channel codec configuration bits shall be added to the two source codec configuration bits as shown in Table C.6. With this it is possible to add to each of the G.723.1 source codec modes (high rate, low rate, SID) one of 8 different channel codec bit-rates. The choice of the channel codec bit-rates depends on the transmission system and is therefore not subject of this Annex.

TABLE C.6/G.723.1

G.723.1 and channel codec configuration bits

Octet	Configuration Bits							
1	UB	UB	UB	UB	UB	ccc	VAD	RATE

A (13,5) block code with the generator polynomial:

$$g_{ch}(D) = D^{10} + D^8 + D^5 + D^2 + D + 1$$

shall be applied for error protection of the configuration bits.

The 13 encoded configuration bits (ucb[n], n=0 ... 12) shall be transmitted prior to the encoded information bits.

Table C.7 shows the format of the packed channel bitstream (depending on the value of M_{All}, there may be unused bits "UB" in the last octet).

TABLE C.7/G.723.1

Channel bitstream packing

Transmitted Octet	Channel Bit							
1	ucb[7]	ucb[6]	ucb[5]	ucb[4]	ucb[3]	ucb[2]	ucb[1]	ucb[0]
2	u[2]	u[1]	u[0]	ucb[12]	ucb[11]	ucb[10]	ucb[9]	ucb[8]
3	u[10]	u[9]	u[8]	u[7]	u[6]	u[5]	u[4]	u[3]
M_p/8+2	...	...	u[M_p]	u[M_p-1]	u[M_p-2]	...	...	...
...	...	...	...	...	...	...	...	...
M_{All}/8+2	UB	UB	UB	u[M_{All}-1]	u[M_{All}-2]	u[M_{All}-3]	u[M_{All}-4]	u[M_{All}-5]

The bit-rate of the protected bitstream is $\left(M_{All} + 13\right) \bullet \frac{1000}{30}$ bits per second.

C.3 Channel decoder

C.3.1 Decoding of configuration bits

The first 13 bits shall be decoded to obtain the speech and channel codec configurations. The rate allocation algorithm described in C.2.5.1 is executed after reset or after a change in one of the configuration bits.

C.3.2 Speech decoder adaptation for active speech modes

The speech parameter format of the channel codec shall be adapted to the speech parameter format of G.723.1.

C.3.2.1 Gain index compression

If the speech decoder operates either in high or low bit-rate mode the gain compression operation as described in 2.17 and 2.18 of Recommendation G.723.1 shall be performed to generate the bitstream format required by the speech decoder. One 8-bit (AGAINx_By) and one 5-bit (FGAINx_By) gain index per subframe are compressed to form one 12-bit compressed gain index. If forbidden indices occur either in the decoded adaptive codebook gain index or in the decoded fixed excitation gain index the *forbidden index, indication* flag (FII) shall be set and the indices shall be replaced by suitable valid values. The FII flag shall also be set, if a forbidden lag index is decoded (subclause 2.18 of Recommendation G.723.1). The decoded lag shall then be replaced by a suitable valid value.

C.3.2.2 LPC ordering

The three LPC sub-vectors shall be ordered applying the inverse tables of C.2.1.2.

$$e_m = \text{ReorderTab}_m^{inv}\left[e_m^R\right] \qquad m = 0,1,2$$

C.3.3 Error analysis

Two flags indicating the reliability of the received G.723.1 speech parameters shall be generated in the channel decoder:

1) Bad Frame Indication (BFI) which signals uncorrected errors within the bits of the CRC window (CRC_{WIN}).

2) Erroneous Frame Indication (EFI) which signals uncorrected errors outside the bits covered by the CRC code. This flag shall only be evaluated if information bits outside the CRC window are protected.

These flags shall be made available to the speech decoder together with the speech parameters and the FII flag. In the case of received SID frames, only the BFI flag shall be determined.

C.3.4 Speech parameter format

The speech parameters shall be transmitted from the channel decoder to the speech decoder in the format specified in Tables 5 and 6 of Recommendation G.723.1 with the error flags appended to the end. This format is shown in Table C.8a for the high bit-rate mode, Table C.8b for the low bit-rate mode and in Table C.8c for SID frames.

TABLE C.8a/G.723.1

Decoder bitstream packing for high rate mode

Speech Decoder Octets	PARx_By, ...
1	LPC_B5...LPC_B0, VAD, RATE
2	LPC_B13...LPC_B6
3	LPC_B21...LPC_B14
4	ACL0_B5...ACL0_B0, LPC_B23, LPC_B22
5	ACL2_B4...ACL2_B0, ACL1_B1, ACL1_B0, ACL0_B6
6	GAIN0_B3...GAIN0_B0, ACL3_B1, ACL3_B0, ACL2_B6, ACL2_B5
7	GAIN0_B11...GAIN0_B4
8	GAIN1_B7...GAIN1_B0
9	GAIN2_B3...GAIN2_B0, GAIN1_B11...GAIN1_B8
10	GAIN2_B11...GAIN2_B4
11	GAIN3_B7...GAIN3_B0
12	GRID3_B0, GRID2_B0, GRID1_B0, GRID0_B0, GAIN3_B11...GAIN3_B8
13	MSBPOS_B6...MSBPOS_B0, UB
14	POS0_B1, POS0_B0, MSBPOS_B12...MSBPOS_B7
15	POS0_B9...POS0_B2
16	POS1_B2, POS1_B0, POS0_B15...POS0_B10
17	POS1_B10...POS1_B3
18	POS2_B3...POS2_B0, POS1_B13...POS1_B11
19	POS2_B11...POS2_B4
20	POS3_B3...POS3_B0, POS2_B15...POS2_B12
21	POS3_B11...POS3_B4
22	PSIG0_B5...PSIG0_B0, POS3_B13, POS3_B12
23	PSIG2_B2..PSIG2_B0, PSIG1_B4...PSIG1_B0
24	PSIG3_B4...PSIG3_B0, PSIG2_B5...PSIG2_B3
25	UB , UB , UB , UB , UB , FII , EFI , BFI

TABLE C.8b/G.723.1

Decoder bitstream packing for low rate mode

Speech Decoder Octets	PARx_By, ...
1	LPC_B5...LPC_B0, VAD, RATE
2	LPC_B13...LPC_B6
3	LPC_B21...LPC_B14
4	ACL0_B5...ACL0_B0, LPC_B23, LPC_B22
5	ACL2_B4...ACL2_B0, ACL1_B1, ACL1_B0, ACL0_B6
6	GAIN0_B3...GAIN0_B0, ACL3_B1, ACL3_B0, ACL2_B6, ACL2_B5
7	GAIN0_B11...GAIN0_B4
8	GAIN1_B7...GAIN1_B0
9	GAIN2_B3...GAIN2_B0, GAIN1_B11...GAIN1_B8
10	GAIN2_B11...GAIN2_B4
11	GAIN3_B7...GAIN3_B0
12	GRID3_B0, GRID2_B0, GRID1_B0, GRID0_B0, GAIN3_B11...GAIN3_B8
13	POS0_B7...POS0_B0
14	POS1_B3...POS1_B0, POS0_B11...POS0_B8
15	POS1_B11...POS1_B4
16	POS2_B7...POS2_B0
17	POS3_B3...POS3_B0, POS2_B11...POS2_B8
18	POS3_B11...POS3_B4
19	PSIG1_B3...PSIG1_B0, PSIG0_B3...PSIG0_B0
20	PSIG3_B3...PSIG3_B0, PSIG2_B3...PSIG2_B0
21	UB , UB , UB , UB , UB , FII , EFI , BFI

TABLE C.8c/G.723.1

Decoder bitstream packing for SID frames

Speech Decoder Octets	PARx_By, ...
1	LPC_B5...LPC_B0, VAD, RATE
2	LPC_B13...LPC_B6
3	LPC_B21...LPC_B14
4	GAIN_B5 ... GAIN_B0, LPC_B23, LPC_B22
5	UB , UB , UB , UB , UB , UB , UB , BFI

C.3.5 Error concealment

The flags produced by the channel decoder and by the gain compression operation shall be used in the speech decoder for error concealment purposes.

C.3.6 Performance of error analysis flags

This clause specifies the minimum required error analysis performance in terms of bad frame detection probability (PD_{BFI}) and erroneous frame detection probability (PD_{EFI}). The requirements contained in Table C.9 shall apply to all transmission channels.

TABLE C.9/G.723.1

Detection performance of BFI and EFI flags

	G.723.1 – 6.3 kbit/s	G.723.1 – 5.3 kbit/s	G.723.1 – SID
PD_{BFI}	0.99	0.99	0.99
PD_{EFI}	0.65	0.65	---

C.4 Fixed point C source code

All details of the channel encoder algorithm are described in the form of a fixed point ANSI-C source code. In the case of any discrepancy between the above description and the C source code, the latter has to be adopted as reference. This C source code is a part of the code distributed by the ITU-T as Recommendation G.723.1.

Test vectors are included to check the bit-exactness of an implementation compared to the C source code.

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