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Source: **Nokia**
Title: **TFCI transmission in compressed mode**
Document for: **Decision**

1. Introduction

When in compressed mode, the information normally transmitted during 10 ms frame is compressed in time. This is achieved by either changing the encoding rate or reducing the spreading factor by two. The current 3GPP specification in TS 25.211 and TS 25.212 does not address the details of frame structure, particularly pertaining to the transmission of TFCI, however. This document addresses compressed mode using puncturing in downlink assuming a 15-slot frame based on [1]. The text proposal is based on Nokia contribution [2] presented in the 6th WG1 meeting in Korpilampi. Simulation results showing the effect of puncturing on TFCI symbol error rate are added to the current document.

2. Compressed mode by puncturing method

2.1. Puncturing of TFCI bits

When encoding rate is increased to ½ from 1/3 by puncturing, 3-4 empty time slots can be created into one 10 ms transmission interval. All DPDCH symbols fit into the available 11-12 time slots with some room to spare. In principle, the structure of remaining time slots is similar to that in a normal mode frame. However, all the TFCI bits in a frame must be transmitted also in compressed mode.

Due to the fact that 3-4 slots per frame are cut off during compressed mode also TFCI bits are lost. TFCI information has to be very reliable, so obviously up to 27% puncturing needs to be verified by simulation. The performance loss due to puncturing is shown in Figure 1. The simulation parameters were as follows:

Chip Rate	3.84 Mchips
Slots In Frame	15
CPiCH included, code number	255
CP power / total power	-10 dB
Interferers	20 (SF=256)
Symbols In Frame	300
Spreading Factor	128
Data rate	8 kbps
Information Bits in frame	80
Frames in transport block	2
CRC	16

Tail	8
Coding Rate	0.333
DTX indication bits in one transport block	288
TFCI	2
TPC	2
Pilot	8
DPDCH1	4
DPDCH2	24

Vehicular A channel with 7 taps

No PC

Channel Estimation	From CPiCH channel, an averaging flat FIR over 20 CP symbols (2 slots)

Puncturing of TFCI introduces a loss of nearly 3 dB at residual TFCI symbol error rates (SER) of 10E-2 (and the loss becomes larger at lower SER). This loss is comparable to what Samsung simulations show in [3]. In order to compensate for the TFCI detection loss the transmission power should be roughly doubled in the compressed mode frame.

Another solution to avoid an excessive loss from puncturing TFCI bits with the current biorthogonal format is to halve the maximum number of possible TFCI words, i.e. up to half of the TFCI word can be punctured as redundant. This means that for normal mode the number of TFCI words is reduced from 64 to 32. For extended mode the number of TFCI words would be reduced from 1024 to 256. It is not desirable to reduce the number of TFCI words drastically, so it is seen best to slightly change the frame format during compressed mode transmission in order to transmit all the TFCI symbols.

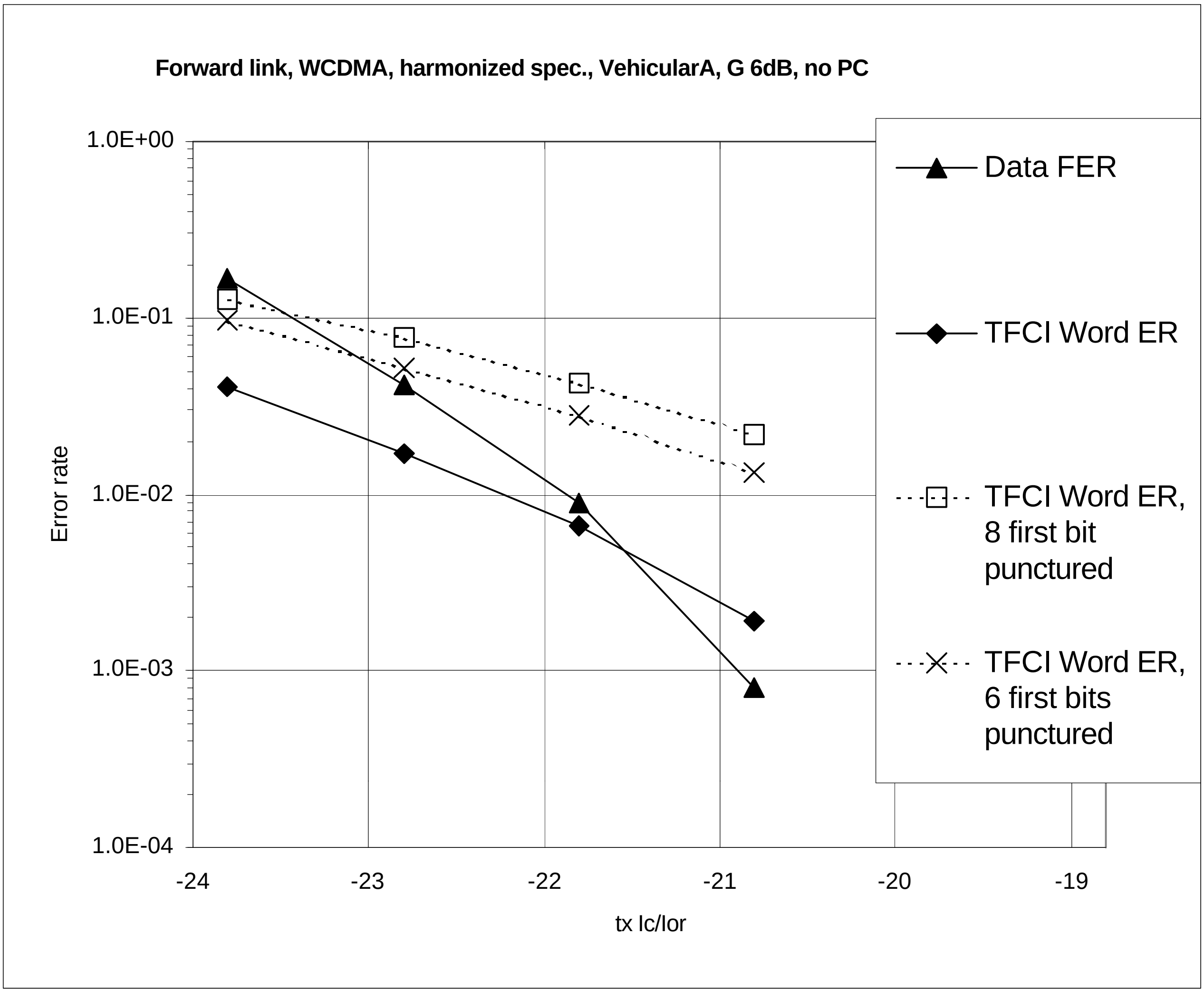


Figure 1. Effect of puncturing on the performance of TFCI detection

2.2. Insertion of TFCI bits

Because of the high loss due to puncturing, the TFCI bits must be included somewhere else in the frame. For spreading factors of SF=128 and higher, 2 TFCI bits are included in each slot. Compressed mode thus removes 6 – 8 TFCI bits. For spreading factors of SF=64 and smaller, 8 TFCI bits are included in each slot; this corresponds to 24 – 32 removed bits. Since it is always know beforehand when compressed mode is employed there could be a unique frame structure with some extra tweaks for this purpose. There are a few options for finding room for these bits in the remaining slots of a compressed frame.

- Puncture TFCI into TPC field
- Puncture TFCI into pilot field
- Insert TFCI into DPDCH field

Puncturing of TPC field does not sound like such a good idea. In the worst case scenario of SF=64,32 there are only 4 TPC bits per slot compared with 8 TFCI bits. Thus the existing 11 slots of a compressed frame (assuming maximum 4-slot compression) would contain

11*4=44 TPC bits. However, the four compressed slots would displace 8*4 = 32 bits. There would be hardly any TPC information left!

Puncturing of pilot field would also pose problems. For example, for SF = 64 there are a minimum of 11x8 = 88 pilot symbols in the remaining slots. Using up to 4*8 = 32 of these for TFCI would be deleting 36% of the remaining pilot energy. Moreover, the receiver would have to adapt to a different amount of pilot symbols during a compressed mode frame compared to normal mode frame (in fact the length of consecutive pilot symbols within the frame would differ, too).

The tables below show that for all spreading factors smaller that 512 there is indeed space in the DPDCH field to insert these TFCI bits. Only for SF=512 it is impossible to substitute DPDCH field for TFCI bits. If SF=512 is employed it would be better to enter compressed mode by using SF/2 method instead.

Table 1. DPDCH/DPCCH fields for compressed mode with 4 slots per frame

Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame			Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Extra bits in DPDCH
			DPDCH	DPCCH	TOT		N_{Data1}	N_{Data2}	N_{TFCI}	N_{TPC}	N_{Pilot}	
16	8	512	40	66	110	10	2	2	0	2	4	4
16	8	512	20	96	110	10	0	2	2[1]	2	4	-6
32	16	256	100	110	220	20	2	8	0	2	8	10
32	16	256	80	140	220	20	0	8	2[1]	2	8	0
64	32	128	300	110	440	40	6	24	0	2	8	30
64	32	128	280	140	440	40	4	24	2[1]	2	8	20
128	64	64	600	252	880	80	4	56	8*[1]	4	8	28
256	128	32	1400	252	1760	160	20	120	8*[1]	4	8	108
512	256	16	2880	384	3520	320	48	240	8*[1]	8	16	256
1024	512	8	6080	384	7040	640	112	496	8*[1]	8	16	576
2048	1024	4	12480	384	14080	1280	240	1008	8*[1]	8	16	1216

1) *This figure does not take into account the extra TFCI bits from deleted slots*

Table 2. DPDCH/DPCCH fields for compressed mode with 3 slots per frame

Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame			Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Extra bits in DPDCH
			DPDCH	DPCCH	TOT		N_{Data1}	N_{Data2}	N_{TFCI}	N_{TPC}	N_{Pilot}	
16	8	512	40	72	120	10	2	2	0	2	4	8
16	8	512	20	102	120	10	0	2	2[1]	2	4	-2
32	16	256	100	120	240	20	2	8	0	2	8	20
32	16	256	80	150	240	20	0	8	2[1]	2	8	10
64	32	128	300	120	480	40	6	24	0	2	8	60
64	32	128	280	150	480	40	4	24	2[1]	2	8	50
128	64	64	600	264	960	80	4	56	8*[1]	4	8	96
256	128	32	1400	264	19200	160	20	120	8*[1]	4	8	256
512	256	16	2880	408	3840	320	48	240	8*[1]	8	16	552
1024	512	8	6080	408	7680	640	112	496	8*[1]	8	16	1192
2048	1024	4	12480	408	15360	1280	240	1008	8*[1]	8	16	2472

1) This figure does not take into account the extra TFCI bits from deleted slots

2.3. Frame structure

The frame structure for a punctured compressed mode frame is similar to normal mode frame apart from the extra DTX needed for unused DPDCH and TFCI bits embedded into the DPDCH field. When 4 slots are deleted, 8 TFCI bits are to be inserted into 11 slots. In the case of 3 slots being deleted, 6 TFCI bits are to be inserted into 12 slots. It is easiest to append the additional TFCI bits to the existing TFCI field in a slot. In order to achieve best interleaving gain all the extra TFCI bits should not be appended into only one slot, however. For example, they can be inserted into the first 8 (or 6) slots after the transmission gap. Or they can be spread evenly over all the remaining slots (e.g. into every other time slot when 6 TFCI bits are allocated within 12 slots.

Figures 2 and 3 give examples on how TFCI bits of a (30,6) code word can be mapped into remaining slots in a compressed frame. Each TFCI bit is appended to the existing TFCI field in the slot. Mapping of two (15,5) code words takes place in an analogous fashion.

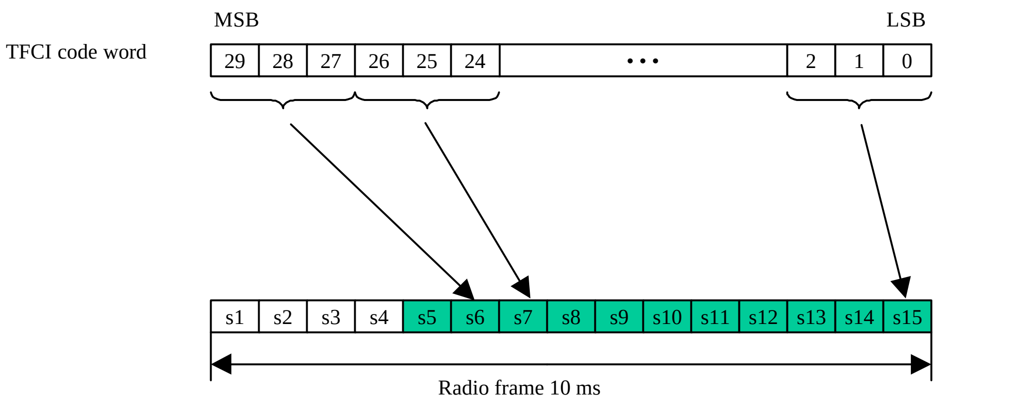


Figure 2. Mapping of TFCI bits for compressed mode frame with 11 slots

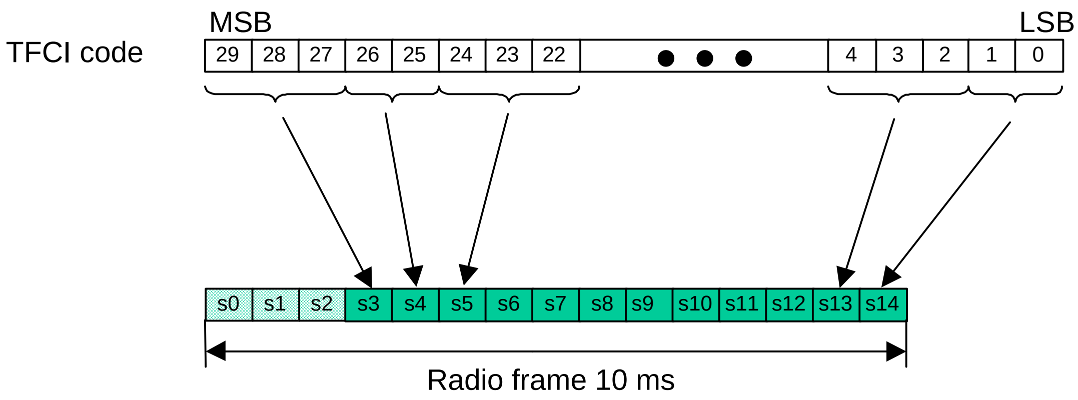


Figure 3. Mapping of TFCI bits for compressed mode frame with 12 slots

2.4. DTX in compressed frame

When encoding rate is increased from 1/3 to 1/2, there are extra DPDCH symbols available in the radio frame. TFCI bits puncture a few of these extra DPDCH symbols. The rest are not needed and can be assigned for DTX. The best location for DTX within the data field is probably to split it evenly across remaining slots. This study makes no assumptions on whether DTX is already present due to rate matching by L2. In this case, it would naturally add to the extra DPDCH symbols in the frame but does not change how TFCI bits are inserted.

3. Text proposal for TS 25.212

4.3.3. Interleaving of TFCI words

4.3.3.1. Interleaving of default TFCI word

As only one code word for TFCI of maximum length of 6 bits is needed no channel interleaving for the encoded bits are done. Instead, the bits of the code word are directly mapped to the slots of the radio frame as depicted in the Figure 4-12. Within a slot the more significant bit is transmitted before the less significant bit.

In compressed mode all the TFCI bits are reallocated into the remaining slots. However, the same principle of transmitting the most significant bit first is valid.

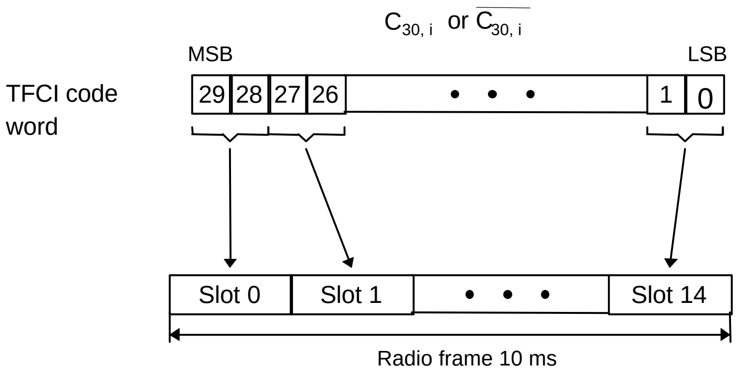


Figure 4-12. Time multiplexing of code words of (30~~2~~, 6) code to the slots of the radio frame.

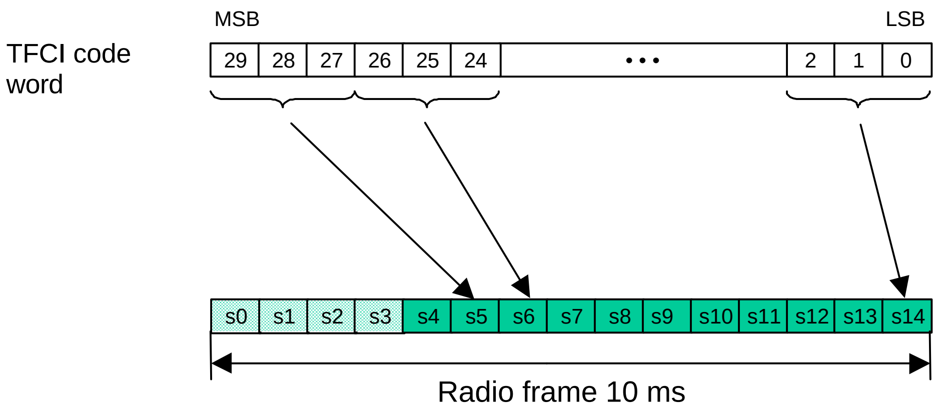


Figure 4-13. Time multiplexing of code words of (30,6) code to the slots of a compressed radio frame of 11 slots.

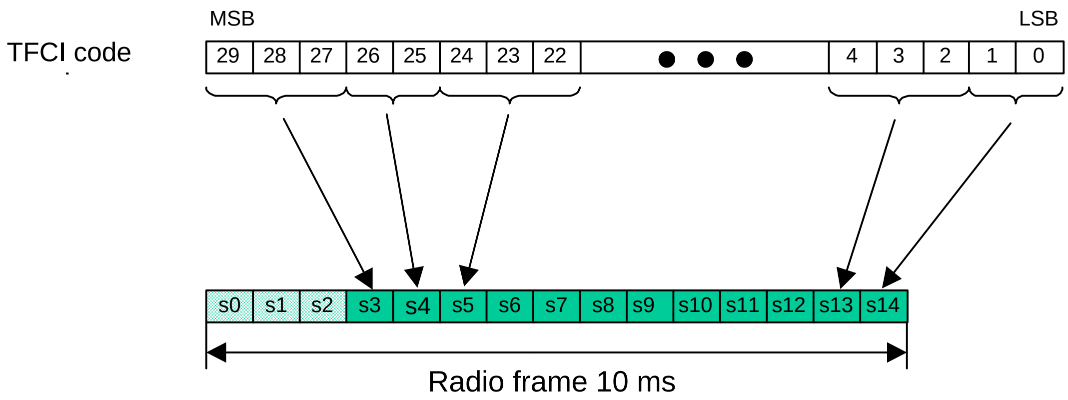


Figure 4-14. Time multiplexing of code words of (30,6) code to the slots of a compressed radio frame of 12 slots.

4.3.3.2. Interleaving of extended TFCI word

After channel encoding of the two 5 bit TFCI words there are two code words of length 15~~6~~ bits. They are interleaved and mapped to DPCCH as shown in the Figure 4-. Note that $b_{1,i}$ and $b_{2,i}$ denote the bit i of code word 1 and code word 2, respectively.

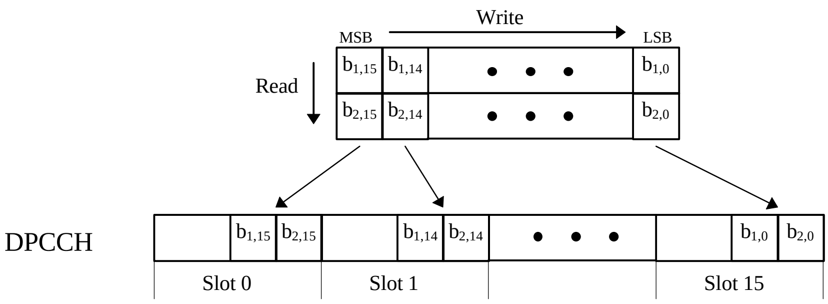


Figure 4-15. Interleaving of TFCI code words.

In compressed mode the mapping of TFCI bits takes place in a similar fashion as for (30,6) word in section 4.3.3.1. The order of bits is $b_{1,15}, b_{2,15}, b_{1,14}, b_{2,14}, \ldots b_{1,0}, b_{2,0}$.

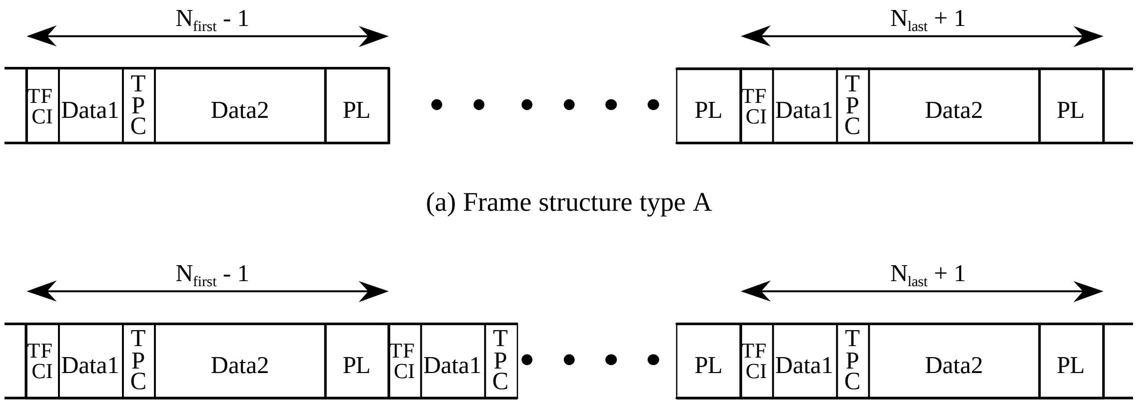
4.4 Coding of compressed mode

4.4.1 Frame structure types in downlink

There are two different types of frame structures defined for downlink compressed transmission. Type A is the basic case, which maximises the transmission gap length. Type B, which is more optimised for power control, can be used if the requirement of the transmission gap length allows that. Slot structure for uplink compressed mode is for further study.

- With frame structure of type A, BTS transmission is off from the beginning of TFCI field in slot Nfirst, until the end of Data2 field in slot Nlast (Figure 3-2(a)).

- With frame structure of type B, BTS transmission is off from the beginning of Data2 field in slot Nfirst, until the end of Data2 field in slot Nlast (Figure 3-2(b)) Dummy bits are transmitted in the TFCI and Data1 fields of slot Nfirst, and BTS and MS do not use the dummy bits. Thus BTS and MS utilize only the TPC field of Nfirst.



(a) Frame structure type A

(b) Frame structure type B

Figure 3-2. Frame structure types in downlink compressed transmission

4.4.2 Transmission Time Reduction Method

When in compressed mode, the information normally transmitted during a 10 ms frame is compressed in time. The mechanism provided for achieving this is either changing the code rate, which means puncturing in practice, or the reduction of the spreading factor by a factor of two.-The maximum idle length is defined to be 5 ms per one 10 ms frame.

4.4.2.1 Method A1: by Puncturing, basic case

During compressed mode, rate matching (puncturing) is applied for making short transmission gap length in one frame. Algorithm of rate matching (puncturing) described in 4.2.5 is used. The maximum transmission gap length allowed to be achieved with this method is the case where the code rate is increased from 1/3 to 1/2 by puncturing, which corresponds to 2 - ~~5~~4 time slots per 10 ms frame, depending on the rate matching conditions that would be used in the non-compressed frame case. The explanation of the rate matching conditions are given below:

Example 1: If rate matching conditions in the non-compressed frame case would be such that maximum puncturing =0.2 would be used, then during compressed mode further puncturing of 1-(2/(3*(1-0.2))) =0.17 is allowed which corresponds to 0.17*15~~6~~=2.55~~7~~ => 2 time slots.

Example 2: If rate matching conditions in the non-compressed frame case would be such that no puncturing would be used, then during compressed mode puncturing of 1-(2/3)=0.33 is allowed which corresponds to 0.33*15~~6~~=4.95~~5.3~~ => 4~~5~~ time slots.

DPDCH and DPCCH fields for compressed mode when puncturing 4 slots and 3 slots, respectively, are shown in Tables 4-7 and 4-8. Because of higher encoding rate, some DPDCH symbols remain unused and shall be indicated as DTX.

Table 4-7: DPDCH and DPCCH fields in compressed mode when puncturing 4 slots

Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame			Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Extra DPDCH symbols for DTX
			DPDCH	DPCCH	TOT		N_{Data1}	N_{Data2}	N_{TFCI}	N_{TPC}	N_{Pilot}	
16	8	512	40	66	110	10	2	2	0	2	4	4
32	16	256	100	110	220	20	2	8	0	2	8	10
32	16	256	80	140	220	20	0	8[1]	2[1]	2	8	0
64	32	128	300	110	440	40	6[1]	24	0	2	8	30
64	32	128	280	140	440	40	4[1]	24	2[1]	2	8	20
128	64	64	600	252	880	80	4[1]	56	8[1,2]	4	8	28
256	128	32	1400	252	1760	160	20[1]	120	8[1,2]	4	8	108
512	256	16	2880	384	3520	320	48[1]	240	8[1,2]	8	16	256
1024	512	8	6080	384	7040	640	112[1]	496	8[1,2]	8	16	576
2048	1024	4	12480	384	14080	1280	240[1]	1008	8[1,2]	8	16	1216

1) This figure does not take into account the extra TFCI bits from deleted slots

2) If no TFCI then the TFCI field is blank

Note: Compressed mode with puncturing cannot be used for SF=512 with TFCI

Table 4-8: DPDCH and DPCCH fields in compressed mode frame when puncturing 3 slots

Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame			Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Extra DPDCH symbols for DTX
			DPDCH	DPCCH	TOT		N_{Data1}	N_{Data2}	N_{TFCI}	N_{TPC}	N_{Pilot}	
16	8	512	40	72	120	10	2	2	0	2	4	8
32	16	256	100	120	240	20	2	8	0	2	8	20
32	16	256	80	150	240	20	0	8[1]	2[1]	2	8	10
64	32	128	300	120	480	40	6	24	0	2	8	60
64	32	128	280	150	480	40	4[1]	24	2[1]	2	8	50
128	64	64	600	264	960	80	4[1]	56	8[1,2]	4	8	96
256	128	32	1400	264	1920	160	20[1]	120	8[1,2]	4	8	256
512	256	16	2880	408	3840	320	48[1]	240	8[1,2]	8	16	552
1024	512	8	6080	408	7680	640	112[1]	496	8[1,2]	8	16	1192
2048	1024	4	12480	408	15360	1280	240[1]	1008	8[1,2]	8	16	2472

1) This figure does not take into account the extra TFCI bits from deleted slots

2) If no TFCI then the TFCI field is blank

Note: Compressed mode with puncturing cannot be used for SF=512 with TFCI

4. Conclusions

This document describes the frame structure and TFCI transmission for compressed mode when puncturing is used.

5. References

[1] "Impacts of the OHG harmonization recommendation on UTRA/FDD and UTRA/TDD", Tdoc TSG WG1#5(99)677

[2] Nokia, " Compressed mode by puncturing method – TFCI transmission", Tdoc TSG WG1#6(99)808

[3] Samsung, "New Optimal Coding for extended TFCI with almost no Complexity increase (rev 2)", Tdoc TSG WG1#6(99)b60