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Title: Variable TTI proposal for HSDPA

Document for: Discussion and decision

1 Introduction

The notion of using a variable length transmission time interval (TTI) for the HS-DSCH was introduced in [1]. The benefits of this approach are elaborated upon here along with some simulation results.

2 Motivation

Previous approaches ([2] and [3]) have used fixed length TTIs for transmission of HSDPA frames. In [2], a TTI duration of 3.33ms (5 slots) has been used, while in [3] the TTI duration was fixed at 0.667 ms (1 slot). Keeping the TTI fixed results in difficulties on the following points.

a) Frame Fill Efficiency: When the bit-rate assigned to a user is high, a large TTI could result in there being insufficient data to transmit over the duration of one TTI. This results in "frame-fill" inefficiency. As an example if the user is assigned a bit-rate of 10.8 Mbps and the TTI is 3.33ms, the HSDPA frame size is 4496 bytes. For typical Internet traffic and packet sizes, this could result in considerable inefficiency.

b) Minimum Bit Rate Allowed: With a small TTI and a reasonable value for the minimum code block size, the minimum assignable bit-rate may be too high. As an example, consider a minimum code block size of 320 bits (as used in [3]) and a TTI of 0.667 ms. The resultant minimum assignable bit-rate is 480 Kbps. Furthermore, small code block sizes would result in lower Turbo decoding gains and consequently, require higher energy-per-bit for same error rate.

c) MCS Level for Retransmissions: The use of fixed TTI makes it necessary to use the same MCS level for retransmission (if soft combining is to be done) as the one used for the first transmission of a frame. The channel conditions, available power and/or code space at the time of retransmission (within the same cell or selected cell) may not permit the use of the same MCS level as the original transmission. By making the TTI variable, incremental redundancy (IR) operation can be made adaptive wherein retransmissions can be at a different MCS level from the original transmission (see [4] and [5]).

d) Signalling Overhead: The user identification overhead with fixed and small TTI is higher in the low to medium data rates range as compared to a variable TTI. This is due to the fact that in a scheme with fixed TTI, lower rate implies smaller code block sizes. Consequently the user identification and other HARQ control overhead per information bit is high. The variable TTI approach allows the sub-block transmission over a larger number of slots for low data rates. This reduces the user identification and other HARQ control overhead per sub-block transmission.

e) Flexibility: The code block size is coupled to the data rate with fixed TTI. With variable TTI, different rates can be achieved for the same code block size by varying the TTI. The variable TTI proposal also allows for different code block sizes at the same MCS level. This will make sure that the appropriate code block size is chosen for a given data rate and a given user buffer size. This achieves a good tradeoff between signalling overhead and padding. For example, suppose the supportable rate is 960Kbps and there are 1280 bits (4 transport blocks of size 320 bits each) in the user buffer. With a single slot fixed TTI these bits will be transmitted as two code blocks over two slots. Therefore, overheads (e.g. CRC) will be associated with each of the two transmissions. With a fixed TTI of five slots, a total of 3200 bits will have to be transmitted resulting in a padding of 1780 bits. With the variable TTI approach as proposed here, 1280 bits can be transmitted as a single code block over 2 slots. This results in only one set of overheads with no padding and thus provides more efficient transport as compared to either of the fixed TTI options.

In this contribution we illustrate how the use of a variable length TTI with the granularity of 0.667 ms (1 slot) coupled with fixed length code blocks overcomes some of the difficulties with the other approaches and allows for more efficient operation of the HS-DSCH. The concept is elaborated upon in Section 2. Section 3 contains simulation results followed by concluding remarks in Section 4. A text proposal based on the variable length TTI concept is outlined in Section 5.

3 Dynamically varying TTI

In a scheme with fixed TTI, the code block size is determined uniquely by the MCS level and therefore, the number of information bits in the TTI changes with the data rate. With the variable TTI approach, the duration of the transmission is varied while the code block size in bits is kept fixed.

The data rates for the variable TTI scheme are given in Table 1 [5]. Note that for a given data rate, up to four different code block sizes can be chosen depending upon the data backlog in the user buffer. The flexibility of using different code block sizes for the same data rate avoids huge performance loss due to frame-fill inefficiency and would also limit signalling overhead as discussed in Section 1.

Table 1. Data Rates [assumes 20 channelization codes at SF=32]

MCS	Data Rate [Kb/s]	Modulation	Effective coding rate [actual coding + repetition]	Transmission Time Interval (TTI) [number of slots]			
				16 Transport blocks per TTI [code block = 5120 bits]	8 Transport blocks per TTI [code block = 2560 bits]	4 Transport blocks per TTI [code block = 1280 bits]	2 Transport blocks per TTI [code block = 640 bits]
1	60	QPSK	0.0125				16
2	120	QPSK	0.0250			16	8
3	240	QPSK	0.0500		16	8	4
4	480	QPSK	0.1000	16	8	4	2
5	960	QPSK	0.2000	8	4	2	1
6	1920	QPSK	0.4000	4	2	1	
7	3840	QPSK	0.8000	2	1		
8	7680	16-QAM	0.8000	1			

4 Simulation Results

With a single slot fixed TTI, the minimum code block size will have to be small to keep the minimum supported data rate reasonable. However, if the TTI is allowed to be variable, the minimum code block size can be picked to be larger, while keeping the minimum supported data rate reasonable. The result will be improved Turbo coding performance at the expense of multi-slot transmission at the lower rates. Simulation results were conducted to compare the frame error rate as a function of block size while keeping the data rate fixed.

The simulation parameters are given in Table 2.

Table 2. Simulation parameters

Parameter	Value
No of iterations for Turbo Codes	8
Metric for Turbo Code	Max
Turbo Code Rates	0.2-0.8
Input to Turbo Decoder	Soft
Turbo Interleaver	As per 3GPP (modified to handle large code blocks)

The Frame Error Rate (FER) as a function of the received $\hat{I}_{or}/I_{oc}$ is shown in Figure 1. The results are given for five different code block sizes i.e., 320, 640, 1280, 2560 and 5120 bits and two different modulation and coding schemes i.e., MCS 4 (480Kb/s) and MCS5 (960 Kb/s). For MCS4 at 1% FER, 320 bits code block needs 1.6dB higher E_b/N_o compared to 5120 bits code block size.

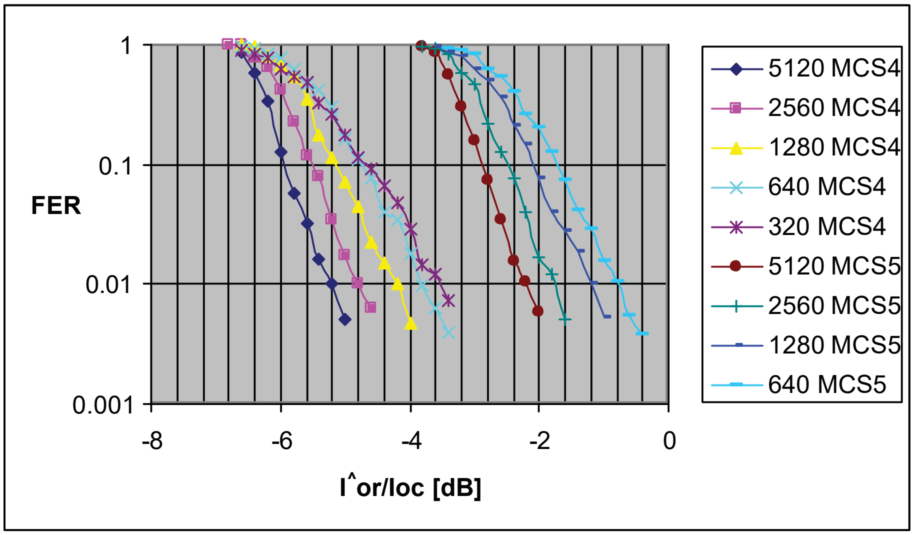

Figure 1. FER for different code block sizes.

5 Concluding Remarks

We have presented a variable TTI concept where the code block size in bits is fixed and the transmission duration is varied in order to achieve different data rates. The variable TTI concept allows using larger code block sizes even for lower data rates in order to get maximum Turbo coding gains. For higher data rates, the transmission time is kept to minimum to fully exploit the scheduling gains, while still achieving high Turbo interleaving gains. Another aspect of our design is that retransmitted blocks can be at a different MCS level as compared to the original transmission. The variable TTI scheme also presents minimum user identification overhead (particularly at lower data rates) because the large number of information bits (code block) can be transmitted over larger number of slots. Note that the user identification overhead is per code block and is higher for smaller code blocks.

6 Text Proposal for TR

Based on the arguments and results presented in this document, variable TTI offers some advantages over a fixed TTI approach. As such it should be considered as part of the feasibility study. Therefore, the following text is recommended to be included in Section 6.1.2, "HSDPA Physical Layer Structure in the Time Domain" of 3G TR25.848.

Variable TTI schemes wherein the code block size stays fixed but the duration of transmission to the user is changed based on the chosen rate, afford several benefits.

?? *The minimum code block size can be large without the minimum assignable bit-rate being too large. Reasonable code block sizes help in fully exploiting Turbo interleaving gains.*

?? *With a minimum TTI of one slot, better frame-fill efficiency is obtained for bursty traffic at high data rates.*

?? *The MCS level for retransmission of a frame can be different from the MCS level for the original transmission. This is very useful in cases when the channel conditions, available power and code space at the time of retransmission are different from that of the original transmission. This is also true with fast cell site selection (FCSS) when the selected cell does not have the same available resources for the HS-DSCH as the original cell.*

?? *By allowing for multiple code block sizes for a given MCS level, the chosen code block size for a given MCS level (and thereby the transmission duration) can be better matched to the data backlog in the user buffer.*

?? *Signalling overheads, such as those required for user identification and Hybrid ARQ operation are per code block. Since the minimum code block size can be designed to be large, the overhead-to-payload ratio can be lower with the variable TTI approach.*

Variable TTI schemes with single-slot granularity should be compared to schemes that use fixed TTIs in terms of performance, flexibility and complexity.

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7 References:

[1] Lucent Technologies, "Downlink and Uplink Channel Structures for HSDPA," TSGR1#17(00) 1381, Stockholm, Sweden, November 2000.

[2] Motorola, "HSDPA System Performance Based on Simulations (II)", TSGR1#17(00) 1397, Stockholm, Sweden, November 2000.

[3] Ericsson, "Performance Comparison of Chase Combining and Incremental Redundancy for HSDPA," TSGR1#17(00) 1428, Stockholm, Sweden, November 2000.

[4] "Asynchronous and Adaptive Incremental Redundancy (A^2IR)", Lucent Technologies, TSGR1#17(00) 1382, Stockholm, Sweden, November 2000.

[5] "A^2IR – An asynchronous and adaptive HARQ scheme for HSDPA", Lucent Technologies, TSGR1#18(01) 0080, Boston, USA, January, 2001.