TSG-RAN WG1 #20 meeting **TSGR1#20(01)0551**
Busan, Korea
May 21st-25th, 2001

Agenda item:	**HSDPA**
Source:	Nokia
Title:	HSDPA signaling in uplink
Document for:	Discussion

Summary:

Different aspects of HSDPA signaling in uplink are discussed in this contribution. Futher studies are still needed but a set of principles to be applied to the HSDPA signaling in uplink could be defined as follows:

- All HSDPA signaling mapped to DPCCH
- One additional SF of 128 defined for DPCCH
- SAW HARQ feedback sent separately in one slot and other HSDPA signaling (if existing) is mapped to remaining slots
- SF of the DPCCH of UEs that are configured to receive data on HS-DSCH is kept fixed (at 128) in every slot regardless of required HSDPA signaling capacity

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1. INTRODUCTION

High Speed Downlink Packet Access (HSDPA) feasibility study has introduced several technical proposals to improve the packet access of WCDMA system. The most prominent proposed enhancements are Adaptive Modulation and Coding (AMC), Stop-And-Wait HARQ (SAW HARQ) and Fast Cell Selection (FCS) [2]. All of this require various kind of signaling between UE and Node B. In the following, the signaling requirements and possible physical layer solutions in uplink are discussed. As FCS was agreed to be a study item for Rel.-5 (for possible inclusion to Rel.-6) it will not be further discussed in this contribution [1].

2. HSDPA SIGNALING IN UPLINK

2.1 Signaling requirements

2.1.1 AMC

When AMC is employed the modulation order and channel coding should be selected based on the received signal quality. Because network has got more information available than UE to make the selection for a given HSDPA TTI, it is natural that the control of AMC resides e.g. in Node B.

There are many factors that contribute to the selection of the Modulation and Coding Scheme (MCS) of a HSDPA TTI. Yet, from performance point of view it is the signal quality at the reception that should be one of the main decision criteria. Although it is possible for network to indirectly get an idea of the received signal quality at the UE by, for example, monitoring the uplink power control commands, it could be beneficial to signal related information from UE to Node B.

What kind of information to signal from UE to Node B is one important question affecting also the signaling requirements (in terms of number of bits). One possible identified measurement is CPICH RSCP/ISCP which has got direct relationship with received data signal quality. Measurement resolution needs not to be very fine assuming that there is several dB performance difference between the MCSs. Yet, when modulation orders from QPSK up to 64-QAM are supported the dynamics of the measurement need to be quite large (> 20 dB). Thus, it is anticipated that 4-5 bits will be required to represent the CPICH RSCP/ISCP (or other similar measurement) with sufficient resolution.

Another possibility is to signal a MCS request to Node B. Feasibility study results so far have hinted that possibly only 4 different MCSs will be sufficient to guarantee good performance. Thus, only 2 bits per MCS request would need to be signaled. Note that signaling the MCS request can be interpreted as measurement reporting with very coarse resolution.

2.1.2 SAW HARQ

SAW HARQ requires fast feedback in uplink. Each HSDPA TTI can have more than one transport block but in most simple case they all could be acknowledged by a single bit. More bits are needed if partial acknowledgements will be proven beneficial in terms of performance. As so far there has been no evidence on this it is assumed that one bit is needed according to decision by WG1 [3].

2.1.3 Summary of uplink signaling requirements

Table 1 summarizes the anticipated uplink HSDPA signaling needs. Note that the numbers indicate the maximum signaling need per HSDPA TTI. The total signaling load depends also on the signaling rate per parameter. The maximum requirement for HSDPA signaling is then 6 information bits.

Table 1. Summary of HSDPA related signaling in uplink.

Parameter	# of bits per message	Signaling rate	Comments
MCS request	2-5	Up to every HSDPA TTI	MCS request: 2 bits Measurement report: 5 bits
SAW HARQ ACK/NACK	1	Up to every HSDPA TTI	

2.2 Possible physical layer solutions

There are basically two physical channels that could be used for HSDPA uplink signaling: DPDCH and DPCCH. Thus, there are several alternatives for signaling:

- Code multiplex HSDPA signaling with existing DPDCH and DPCCH
- Time multiplex HSDPA signaling with DPDCH
- Time multiplex HSDPA signaling with DPCCH
- Send HSDPA signaling on DPDCH using one (or more) transport channel(s)

Code multiplexing is a straight forward solution. The biggest problem is the increased envelope variations of the transmitted signal resulting in worse PA efficiency. Therefore, this is not the preferred solution.

From PA efficiency point of view, multiplexing with DPDCH could be a better solution. It is possible to set the Tx power of DPDCH+HSDPA signaling to a constant value (neglecting the variations due to fast TPC). This is not the optimum solution as the bit rate difference between the traffic on DPDCH and the HSDPA signaling can be quite large. When that is the case using constant Tx power can result in unnecessary good quality for, e.g., HSDPA signaling part. Another consequence of this solution is that some changes will be needed to uplink rate matching specification. Thus, this option is not the best one either.

HSDPA signaling can also be time multiplexed with DPCCH. In some sense this is very natural solution as e.g. SAW HARQ feedback can be seen as physical layer signaling which suits naturally for DPCCH. Adjusting the Tx power to be constant over a slot is also easier than in the previous case because the bit rate on DPCCH is low. Thus, any extra overhead caused by forcing a constant Tx power will be small. Drawback of this solution is that additional DPCCH slot structure(s) need to be defined.

The last option of using one or more transport channel(s) for HSDPA signaling purposes is attractive in that sense that we could us the existing multiplexing and rate matching solutions. The termination point of those transport channels need to be in MAC HS-DSCH. This is not an optimal solution either as transport channels are normally interleaved over the TTI which is not desirable solution for e.g. SAW HARQ feedback.

In the following two possible compromise solutions are considered.

2.2.1 All HSDPA signaling time multiplexed with DPCCH

One quite natural solution is to send all the HSDPA signaling in uplink using existing DPCCH. It will mean that additional slot formats need to be defined. In order to make room for more bits the SF of the DPCCH needs to be changed. Currently there are 6 different slot formats and the length of the shortest field is 1 bit. Thus, by dividing the SF by N and keeping the number of bits of the existing fields the same we can get (N-1)x10 channel bits for HSDPA signaling per slot. This is illustrated in the Figure 1 for N=2. Note that if Tx power of DPCCH is multiplied by N all the existing fields will have the same energy as for existing slot formats.

HSDPA signaling capacity of DPCCH depends on the length of the HSDPA TTI. If we denote the length of the HSDPA TTI (in slots) my M the available signaling capacity (in channel bits) is then $10M(N-1)$. Table 2 shows the signaling capacity for various combinations of M and N.

Table 2. HSDPA signaling capacity of DPCCH as a function of HSDPA TTI length and SF reduction.

	HSDPA TTI length (slots)		
SF	**1**	**3**	**5**
128 (N=2)	10	30	50
64 (N=4)	30	90	150

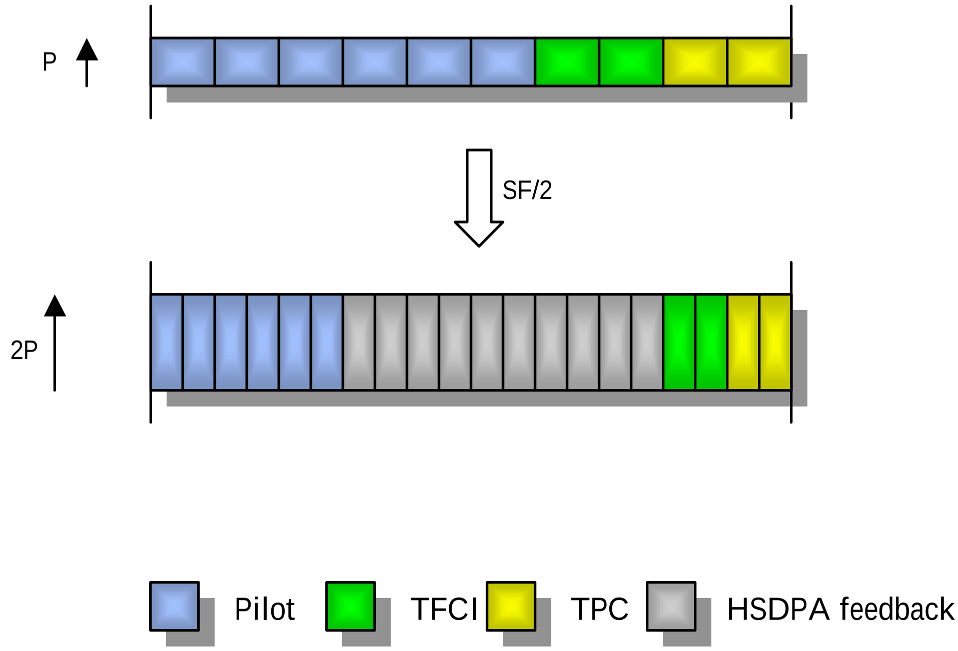

Figure 1. Example uplink DPCCH slot format to accommodate HSDPA signaling bits. Slot format 0 has been assumed.

- By changing the SF and keeping the number of bits of the existing fields constant we can create signaling channel of different transmission capabilities. Figure 2 shows some possible slot structures for different HSDPA signaling needs. In these examples the SF of DPCCH has been set to 128 (note that in the Figure 2 power level has also been doubled in some slots in order to keep the energy of the existing fields unchanged). This leaves 10 channel bits per slot for HSDPA specific signaling. SAW HARQ feedback has been allocated to a different slot in order to allow better control of timing. The remaining slots can be used for other signaling.

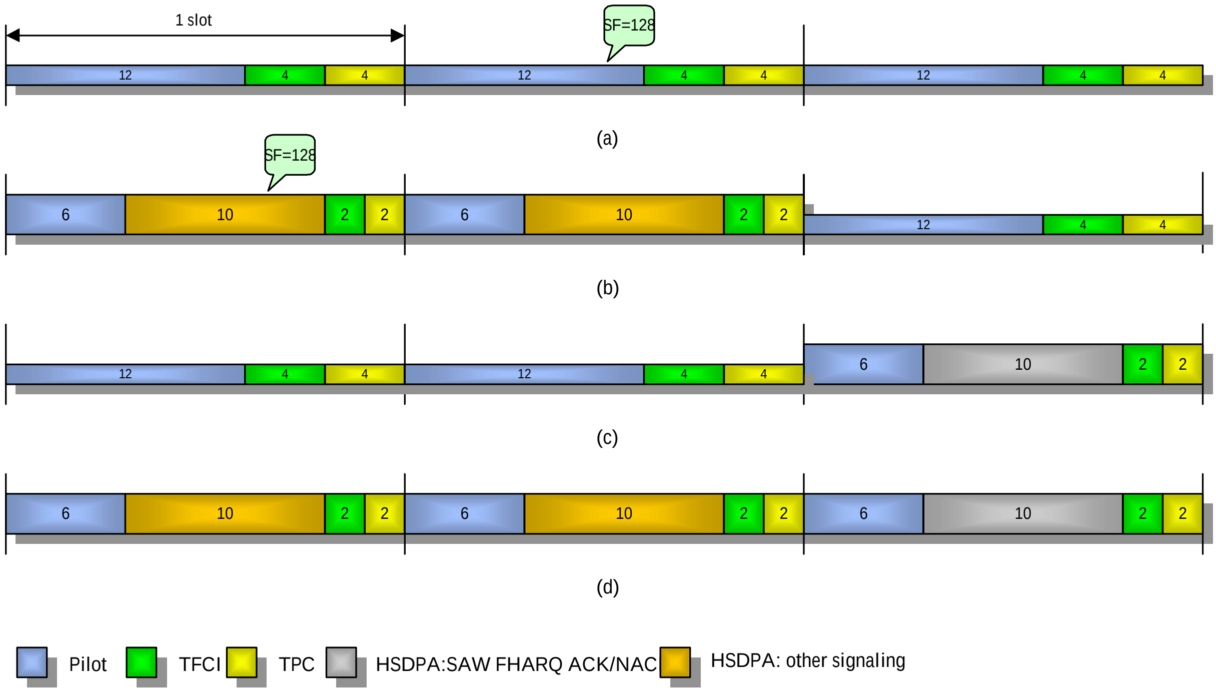

Figure 2. Example DPCCH slot structures for different uplink signaling cases: a) no HSDPA signaling, b) HSDPA signaling excluding SAW HARQ feedback, c) Only SAW HARQ feedback, d) all HSDPA signaling present. . Existing slot format 0, HSDPA slot length of 3 and SF=128 for all the cases have been assumed.

2.2.2 Hybrid signaling solution

In a hybrid solution some part of the signaling could be sent on DPCCH and other part on DPDCH. As pointed out earlier if DPDCH is used then the signaling information should be sent using one or more transport channels. In order to keep the changes to minimum the channel interleaving should be done over the whole TTI. Therefore, this suits best for signaling needs where sub-TTI allocation of bits is not required.

In order to maximize available processing time both at UE and Node B the timing of the SAW HARQ feedback should be carefully designed. This can be more easily done if DPCCH is used to transmit SAW HARQ acknowledgements. Thus, as in the examples of Figure 2, SAW HARQ feedback could be sent during the last slot of a HSDPA TTI. Other signaling could be sent either on DPCCH or DPDCH.

In the most flexible solution all the HSDPA signaling except SAW HARQ feedback could be sent on DPDCH. In this way it would be easy to change the signaling rate as desired by defining a variable rate transport channel. One change to the existing transport channel concept is needed, though. In order to support the maximum signaling rate as defined in the Table 1, same TTI length must be possible on DPDCH as for HSDPA.

2.3 Channel encoding solutions for HSDPA signaling

One important design criteria of HSDPA is to avoid unnecessary changes and use existing solutions to the extent possible. In case of channel encoding we should then first consider the use of already specified convolutional code (r=1/2 and 1/3), Turbo code (r=1/3), second order Reed Muller code (r=10/32) and first order Reed Muller code (r=5/16).

One characteristic of HSDPA signaling is that there are only few bits per encoding block. From encoding efficiency point of view situation is very similar to TFCI encoding.

2.3.1 All HSDPA signaling on DPCCH

Based on Tables 1 and 2 we can determine available code rates for different cases. By assuming that SAW-HARQ feedback will be sent separately we have up to 5 bits of other HSDPA signaling information to be sent. If all that is encoded together we get the code rates as shown in the Table 3.

Table 3. Available code rates for different combinations of SF and HSDPA TTIs. It is assumed that one slot has been allocated for SAW-HARQ feedback and number of other signaling bits per HSDPA TTI is up to 5 .

	HSDPA TTI length (slots)	
SF	**3**	**5**
128 (N=2)	1/4	1/8
64 (N=4)	1/12	1/24

Out of the existing encoding solutions Turbo coding is not suitable for HSDPA uplink signaling due to very short block length. Convolutional code or first/second order Reed-Muller code could be used. Convolutional code has got the advantage in that its code rate can be more easily adjusted by using repetition/puncturing than that of Reed-Muller code.

In case of Reed-Muller code it would be beneficial to match the numerology of the existing code directly with the available transmission capacity. That seems to be possible if we adopt SF=64 for DPCCH as then each slot contains 30 bits for HSDPA signaling. In that case we could easily map both first and second order Reed-Muller encoded code words to the slots of the HSDPA TTI using repetitions when ever needed.

Other than already specified channel codes could also be used provided that they yield better performance with acceptable complexity increase.

2.3.2 Hybrid signaling solution

If HSDPA signaling (excluding SAW-HARQ feedback) will be sent on DPDCH existing channel encoding solutions should be used. One reason for this is the rate matching solution which preferably should be kept the same. From performance point of view this solution may not be as efficient as the use of Reed-Muller code due to short encoding block length. Thus, using only DPCCH for HSDPA signaling could be more efficient.

2.4 Other aspects of UL HSDPA signaling

When deciding the details of HSDPA uplink signaling there are some additional factors that need to be considered including:

- Variability/flexibility of the signaling
- Variability of slot structures per HSDPA TTI

- Increased signal envelope variations

Variability/flexibility refers to the fact that not all of the signaling information need to be sent with same rate. Rate for MCS request/measurements reports could be defined independently by the network. In addition, SAW HARQ feedback and other HSDPA signaling can have different rates. This implies varying signaling capacity needs.

Keeping the slot structure constant within the HSDPA TTI could be beneficial from implementation point of view. As pointed out earlier separating the SAW HARQ feedback from other signaling makes keeping that principle a little bit difficult. You could always map the existing HSDPA signaling to all of the available slots reserved for it. So in case SAW HARQ feedback were missing (like in Figure 2b), other encoded HSDPA signaling could be mapped also to the slot reserved for HARQ feedback. Yet, this would anyway change the encoding/decoding process so easier solution could be to allow some variability of the slot structures within the HSDPA TTI.

Another aspect is the variability of the SF. Demodulation of the DPCCH symbols require fast processing which in practice may require ASIC implementation whereas DSP implementation lends itself more naturally to processing of the demodulated bits. Given that, it could be beneficial to keep the SF of DPCCH constant regardless of the required signaling capacity. Thus, UEs that have been configured to receive data from HS-DSCH could always use same SF on DPCCH. This assumption was used in the examples depicted in the Figure 2. Note that in Figure 2a an existing slot format of 0 is used with SF=128 (number of bits per field are doubled).

Time multiplexing of HSDPA signaling with other L1 signaling will not as such increase the envelope variations of the uplink DPCH. Some variations could occur as HSDPA signaling may not be present in every HSDPA TTI. How big Tx power increase will be needed due to HSDPA signaling depends on signaling data rate and quality requirements. It is anticipated that the power increase will be at most few dBs which should not much increase the envelope variations. Note that if the slot structure within the HSDPA TTI is not constant there could be some regular Tx power fluctuations at the rate of inverse of the length of the HSDPA TTI.

3. CONCLUSIONS

Details of the uplink HSDPA signaling solution require still some further studies. One possible detailed solution could be summarized as follows (see Figure 2):

- All HSDPA signaling mapped to DPCCH
- One additional SF of 128 defined for DPCCH
- SAW HARQ feedback sent separately in one slot and other HSDPA signaling (if existing) is mapped to remaining slots
- SF of the DPCCH of UEs that are configured to receive data on HS-DSCH is kept fixed (at 128) in every slot regardless of required HSDPA signaling capacity

The detailed channel encoding solution needs some further analysis/simulations. As mentioned earlier we should first consider the already defined channel codes. Out of those either convolutional or Reed-Muller code seems feasible.

REFERENCES

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