TSG-RAN Working Group 1
Stockholm, Sweden
November 21-24

TSGR1#17(00)1384

Agenda item: AH24: HSDPA

Source: Lucent Technologies

Title: Text Proposal for the HSDPA Technical Report

Document for: Discussion and decision

1 Introduction

In **3GPP TSG RAN WG1#1**, Lucent Technologies has proposed enhancements that can be applied to UTRA in order to provide very high speed downlink packet access [1]-[3]. In this paper, text proposals for the HSDPA Technical Report are presented.

2 Text Proposal

---------------------------------------Begin text proposal for TR Section 5 and Section 6--

5 Overview of Technologies considered to support UTRA High Speed Downlink Packet Access

5.1 Adaptive Modulation and Coding

In support of rate adaptation via AMC, the UE feedbacks link quality information to the node-B. Explicit feedback from the UE is preferred over sending Signal to Interference Ratio (SIR) measurements to the Node-B for the following reason.

The UE can read the available power fraction and current and near-term shared channel activity on all active legs, as well as the path losses and finger information from each of these active legs. It can use this information in estimating the total expected interference accurately. This permits a more accurate determination of the rate that is important for the performance and fair scheduling of cell edge mobiles that are dominated by interferers

5.2 Hybrid ARQ (H-ARQ)

The HARQ or IR operation in stop-and-wait mode minimizes the block addressing overhead i.e., no need for sequence numbers. The operation in stop-and-wait mode also minimizes the memory requirements in the UE i.e., only one block is outstanding at a given time per stop-and-wait instance that the UE needs to store.

With asynchronous operation, no synchronized timing relationship is needed between different transmissions (re-transmissions) from the same user. The transmitter waits for a minimum of round-trip time called between different transmissions (re-transmissions) to the same user. The sender can always schedule other users' transmissions for any number of slots before more information/redundancy is sent to the same user. This allows to fully exploit the multi-user diversity gains. The asynchronous property also allows flexible multiplexing of transmissions of different lengths to multiple receivers at different rates and different round trip delays. The asynchronous property of the scheme also permits operation as a pure link adaptation scheme (without stop and wait) where the transmitter can send more redundancy without waiting for the ACK/NACK feedback from the receiver. This mode can be used, for example, in cases where data needs to be sent to a single user and it is desired to minimize the total transmission time, and maximize channel occupancy.

5.3 Fast Cell Selection (FCS)

To support fast cell site selection, the UE selects the best cell for its downlink transmission every TTI. Selecting the best cell based purely on signal strength measurement when the UE is unaware of the loading in the surrounding cells can result in selecting a cell that is heavily loaded. By defining a downlink broadcast channel that transmits both the available Node-B transmitter power fraction and its channelization code space, the UE can read the available resources on all active legs. This allows for a better selection of the best cell by the UE. In addition, a channelization code cover based approach for signalling the preferred cell site is worth considering to avoid explicit field for cell ID.

6 Proposed Physical Layer Structure of High Speed Downlink Packet Access

6.1 Basic Physical Structure

6.1.1 HSDPA physical layer structure in the code domain

The number of codes of fixed SF (e.g. 32) that are available for HS-DSCH would vary depending on the codes being used by the dedicated channel users. These values can be broadcast on a newly defined broadcast channel enabling the UE to make a better estimate of the supportable rate.

6.1.2 HSDPA physical layer structure in the time domain

An HS-DSCH TTI that equals 1 slot interval, TTI =1 x T_{SLOT} is proposed. The slot duration is T_{SLOT} = 0.667ms. Such a fine granularity of HS-DSCH TTI provides the following advantages:

?? Better source adaptation due to the formation of smaller size packets. This is essential for the higher rates of the HS-DSCH and leads to higher frame-fill efficiency. Note that Internet packet sizes vary from 60 bytes-1500 bytes, which encourages a choice of smaller TTI.

?? Better adaptation to the channel conditions that can be further combined with efficient and fast scheduling for multiple users. By using smaller TTIs in the uplink (3 time slots), changes in the channel can be fed back and applied faster on the downlink as well.

6.1.3 HSDPA in the power domain

A broadcast channel can be defined that transmits the available node-B power fraction to the UEs on every HSDPA TTI. When the HSDPA TTI is equal to T_{SLOT}, the HS-DSCH rate adaptation speed is matched to the dedicated user channels’ power control speed. This allows for: a) better utilisation of the power bin and b) reduced lag between power control and rate adaptation loops thus reducing the error in power allocated to the DSCH. This implies more relaxed overload control margins and hence improved capacity/ throughput.

6.2 Adaptive Modulation and Coding (AMC)

6.3 Hybrid ARQ (H-ARQ)

A NEW/CONTINUE flag is used to indicate whether a transmitted sub-block is the beginning of a new code block or the continuation (redundant information) for a previous code sub-block. This helps the receiver to determine code block boundaries in case an ACK/NACK is misinterpreted. The NEW code block indication also helps the receiver IR engine get in synchronization with the transmitter if a NEW/CONTINUE flag error occurs. Under error conditions, a receiver may miss a transmission or detect a NEW/CONTINUE flag in error. In either case, the receiver will try to decode the code block by combining wrong (or out-of-order) encoded sub-blocks thus making it difficult or impossible to recover the correct code block. Recovery occurs on the receipt of the next NEW code block indication, when the receiver will discard any previously stored coded sub-blocks and will start to decode

6.4 Fast Cell Selection (FCS)

Fast cell site selection can be based on using channelization code covers for the RAI field. This can be done by spreading the UE link quality feedback field in the UL DPCCH using a SF=128 channelization code that identifies the cell from which downlink transmission is desired. When a soft handoff leg is added, the UTRAN notifies the UE which channelization code of SF=128 the UE should use when the added cell is selected.

6.5 MIMO Processing

6.6 Fast Scheduling

6.7 Associated signalling needed for operation of HSDPA

6.7.1 Associated Uplink Signalling

Uplink Slot Duration and Feedback Rate

From a frame-fill efficiency perspective, it is best to retain a single-slot (0.667ms) granularity for the HS-DSCH downlink physical frame. However, for the uplink, the constraint may be relaxed. Here, our goal is to keep the feedback rate (bps) required to support HS-DSCH adequately low. The higher the feedback rate, the greater the noise-rise and consequently, greater the reduction in uplink capacity for dedicated channels. A three-slot (2ms) granularity for feedback of measured downlink quality information achieves the best trade-off between link quality tracking and feedback overhead. Three slots (2ms) are also a sub-multiple of radio frame of 10ms.

Uplink DPCCH Frame Format

The uplink DPCCH spreading factor is lowered from 256 to 128. This allows for 20 coded bits per slot and HS-DSCH related control information is readily accommodated with the conventional UL DPDCH related control information. As before, each slot has 2560 chips. Two new fields are defined: Rate and Antenna Information field (RAI) and an acknowledgement (ACK)/negative acknowledgement (NACK) field. Other fields that already exist in current DPCCH are retained: Pilot, TFCI, FBI and TPC. Pilot bits (5 per slot) will be used for coherent demodulation, TFCI bits (2 per slot) indicate the frame format of the associated UL DPDCH, FBI bits (2 per slot) indicate antenna weights and/or the site chosen for the downlink DPDCH (if any), and the TPC bits (1 per slot) are used for downlink power control on all the dedicated downlink channels (not the DSCH). The RAI and ACK field are now described.

Link Quality Feedback using RAI Field

Explicit signalling of Rate and Antenna Information (RAI) from the UE may be preferred as compared to signalling the SIR estimate for reasons cited in Section 5.1. Towards this end we define a 5-bit Rate and Antenna Information (RAI) field. This will comprise of a 4 bit Rate Information (RI) part that allows the UE to select from one of sixteen possible AMC (Adaptive Modulation and Coding) states as a function of the available resources (power fraction and code space) and a 1-bit antenna indication (AI) field.

The role of the AI field can be made dependent on the RI bits to allow the various antenna configurations to be supported. For example, the allowed rates could be partitioned into two (or more if needed) disjoint sets, high and low (say). If the RI field indicates a rate from the high set then the AI field could signal MIMO or non-MIMO reception, whereas if the RI field indicates a rate from the low set, then the AI field could be purely antenna selection. The UE determines the RAI field based on downlink quality estimates, available HS-DSCH power (i.e. the power fraction), available DL channelization code space and predicted neighbour cell loading. A rate 1/3 block code could then be used to map the 5 RAI bits to 15 coded bits. These 15 coded bits are carried over three time slots, as shown in Figure 1.

Implicitly, the definition of the RAI provisions for the use of additional multiple transmit antenna schemes, besides MIMO. These additional schemes, such as Selection Transmit Diversity (STD), could provide improved DL performance in scenarios when a UE does not support MIMO reception or when the channel conditions are not favourable.

Acknowledgement (ACK) Field

A single bit ACK/NACK field is defined in support of Incremental Redundancy (IR) and it indicates whether the previously received packet was in error or not. The rate of ACK/NACK signalling is once per slot i.e. once every 0.667 ms as opposed to the RAI field which is defined over three slots i.e. 3*0.667=2ms. The ACK bit is repeated five times to form five coded bits and transmitted over a 0.667 ms duration. When the UE does not have a transmission to acknowledge, the ACK/NACK field is ignored by the Node-B or could be gated OFF.

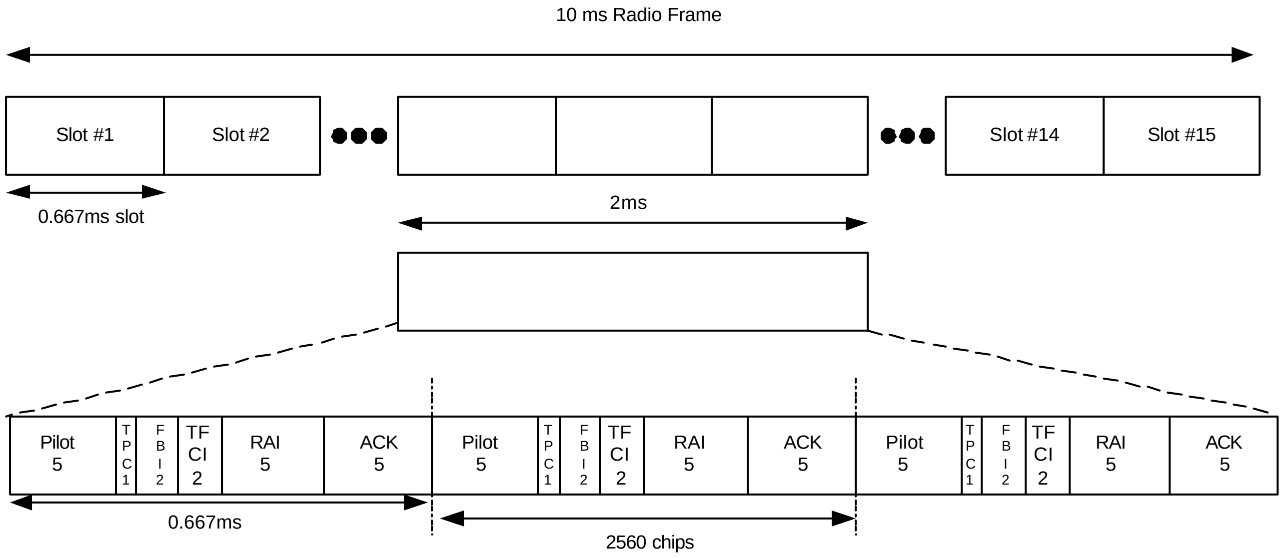

Figure 1: UL DPCCH frame structure that supports DSCH operation.

6.7.2 Associated Downlink Signalling

HS-DSCH Associated Control Channel (DACCH)

The new DACCH downlink channel carries the TPC bits that implement uplink power control. In addition, the Pilot bits are time-multiplexed in this channel as well. For each UE, their DACCH are code multiplexed with a channelization code of SF 512, resulting in code space conservation in the downlink. Furthermore, since this is a dedicated channel, it is power controlled from the TPC bits sent in the UL DPCCH. Power saving can be expected because of the additional bits provisioned for the Pilot.

If the UE has already been assigned a dedicated channel for circuit switched application, the DACCH is thus not required and will be turned off, thus saving a channelization code. In such cases, the Pilots and the TPC bits are already being sent in the DPCCH.

The DACCH fields are shown in Table 1.

Channel	SF	Total Bits/Slot	Pilot (Bits/ Slot)	TPC (Bits/ Slot)
DACCH	512	10	8	2

Table 1. DACCH Fields

High Speed Downlink Shared Channel (HS-DSCH)

The High Speed Downlink Shared Channel (HS-DSCH) is defined in this section. The HS-DSCH uses multi-code transmission using the available channelization code space. In this channel, traffic data and a preamble, per TTI, are time multiplexed within the DSCH frame. As described in Section 6.1.2, a shorter TTI that is equal to 1 slot is proposed. The preamble field duration per TTI is not fixed and is determined by the RAI field in the UL DPCCH. The preamble contains fields that declare:

?? MAC user ID to which the TTI is assigned to.
?? Adaptive Asynchronous Incremental Redundancy (A^2IR) control fields.

The use of preamble within the HS-DSCH TTIs alleviates the use of additional code-multiplexed channels that will have to carry the various control fields. The preamble solution preserves the channelization code space, and reduces decoding latencies. The variable length preamble is equivalent to power controlled of a dedicated downlink channel that performs user identification. The UE is then aware of the preamble length.

Preamble (bits)	Data (bits)
Variable length containing A2IR control fields.	Variable length dependent on UL DPCCH RAI field decoding.

Table 2: HS-DSCH Fields

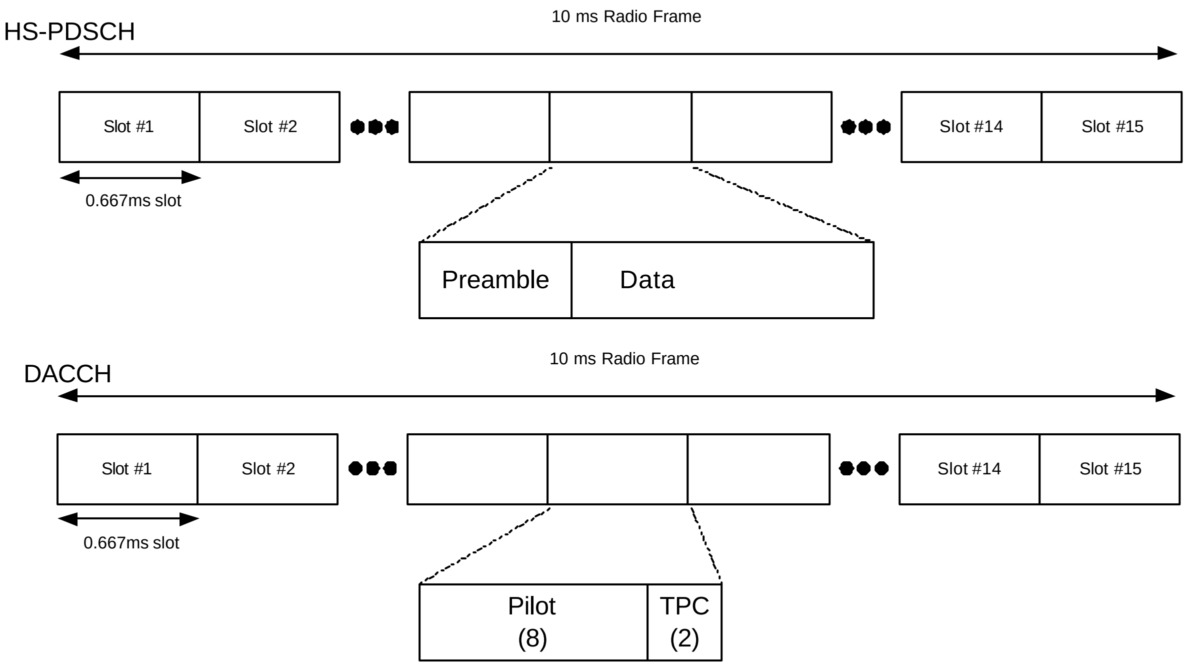

Figure 2: Frame Structure of HS-DSCH and DACCH channels

Power and Code Broadcast Channel (PCBCH)

A new Power and Code Broadcast Channel (PCBCH) is defined with fields as shown in Table 3. The coexistence of HS-DSCH with dedicated downlink channels requires that the downlink power available to the HS-DSCH users, as well as the subset of the channelization code space available for multicode transmission be broadcasted to all HS-DSCH users.

- ?? The power fraction (PF) available for the HS-DSCH is updated every TTI (1 slot). This update rate is required in order to follow the power control rate of the dedicated channels.
- ?? The Downlink Activity Indicator (DAI) available for HS-DSCH is updated every TTI (1 slot). This field indicates the upcoming data activity on the HS-DSCH.
- ?? The available channelization code space (CCS) for the HS-DSCH is updated once every 10ms frame.

Channel	SF	Total Bits/Slot	Power Fraction (Bits/Slot)	DAI (Bits/Slot)	CCS (Bits/Slot)
PCBCH	256	20	10	4	6

Table 3. PCBCH Channel Field Structure

6.8 Downlink Transport Channel Multiplexing Structure for HSDPA

This contribution provides an approach for time division multiplexing of transport channel in the HSDPA downlink. The considerations made in this design are

1. Simplicity: Since the shared channel is intended for packet data services, the design here tries to simplify many of the elements of the Release 99 Transport Channel Multiplexing Structure for Downlink (TS25.212 V3.4.0, Figure 2). In particular, the proposed design uses time division multiplexing of transport channels to achieve significant simplification of the rate matching procedures compared to Release 99. Here rate matching (coding, repetition, puncturing) is handled per transport channel.

2. Efficiency: The proposed structure is optimised for transport channels with requirements that are suitably multiplexed into a HS-PDSCH rather than a dedicated channel. The single-slot granularity ensures high frame-fill efficiency compared to frames that span many slots. This eliminates the need for multiplexing of multiple transport channels within a single frame. Instead, different transport channels each having separate delay-throughput requirements are multiplexed using time division multiplexing. In addition to simple rate matching, scheduling flexibility is used to achieve QoS requirements. This approach maximizes system throughput while meeting transport channel QoS requirements.

3. Low Overheads: Since the frame granularity could be as small as a slot, the overhead in carrying TFCI information on the downlink or acknowledgement (ACK) information for multiple transport channels on the uplink would be excessive. The time division multiplexing of transport channels, outlined here limits the overhead due to TFCI (downlink) as well as that from ACK information (uplink).

The design is particularly well suited for efficient transport of high-speed packet data on the HS-DSCH. The positioning of the proposed multiplex structure with respect to the current specified structure in TS25.212 V3.4.0 is shown in Figure 3.

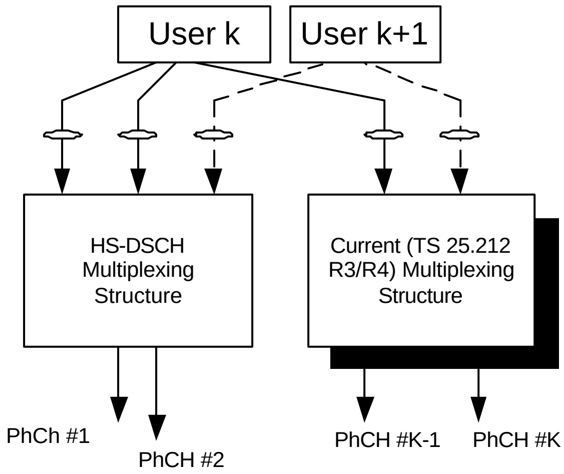

Figure 3: Positioning of HS -DSCH multiplexing structure

The two structures exist and can operate in parallel. The HS-DSCH structure accepts information from a number of transport channels, one or more of which belong to different users, time multiplexes/schedules those into a single Coded Shared (or Scheduled) Transport Channel (CSTrCH). The CSTrCH is then mapped into a number of Physical Channels each corresponding to an channelization code. All HS-PDSCH codes have the same spreading factor and are known to the UE via the mechanism that allows dynamic code-sharing as outlined in [2]

The RRC layer determines the user ids (denoted by k and h) and/or TrCH ids (denoted by l and i in the subsequent discussion) that are multiplexed via the HS-DSCH structure and those that will be multiplexed in the currently specified UMTS R3/R4 structure. The RRC layer would make this determination based on the required QoS.

The signal flow diagram of the proposed HS-DSCH structure is shown in Figure 4.

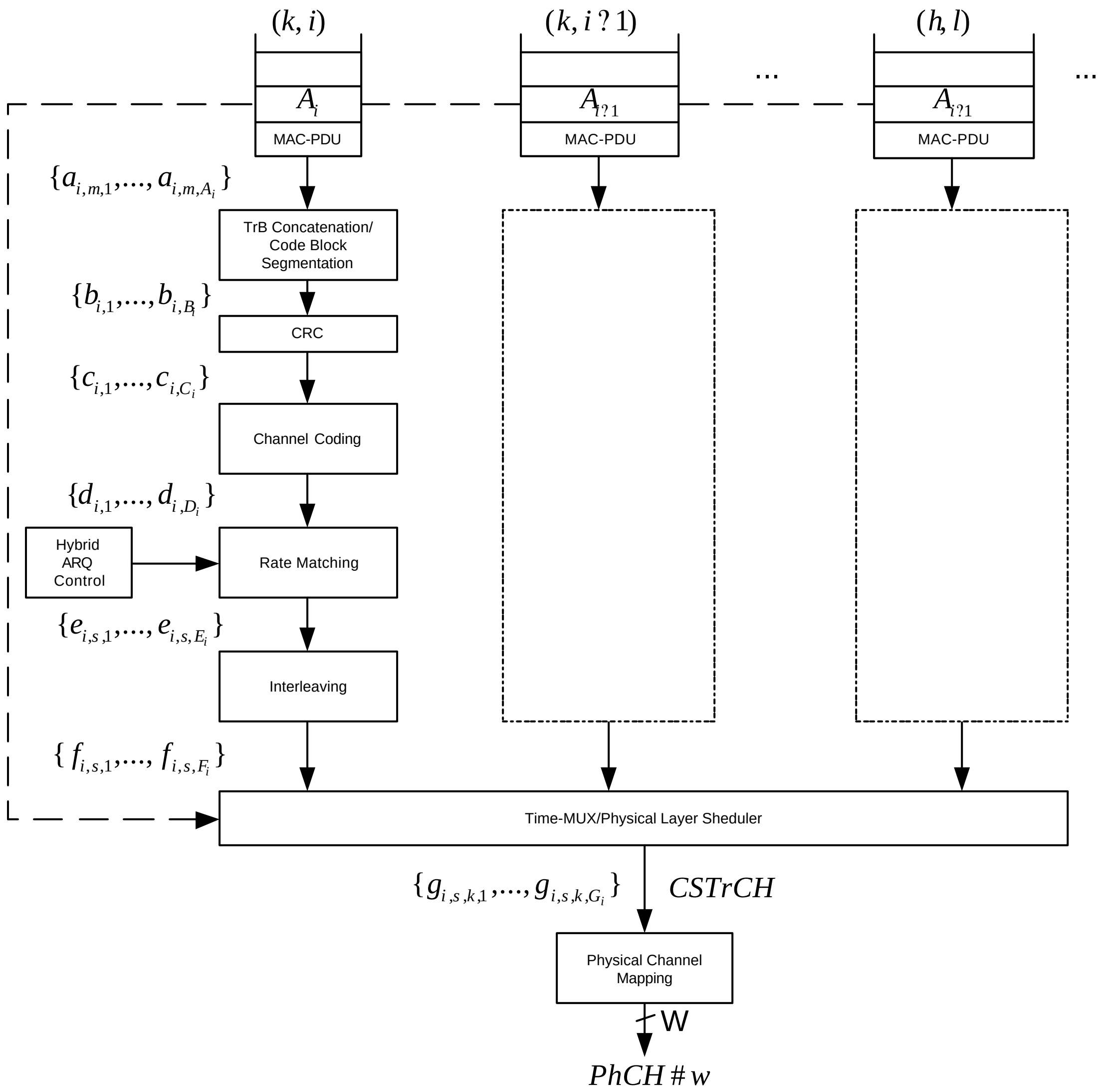

Figure 4: Proposed HSDPA Multiplex Structure (k, h are user ids, i, l are TrCH ids)

The Transport Channel i injects into the HSDPA physical layer multiplex structure, information formatted in MAC-PDU units. Each MAC PDU consists of $A(i)$ bits and is represented as $\{a_{i,m,1},\ldots,a_{i,m,A_i}\}$. The index m, identifies one of the M MAC-PDUs that are injected into the physical layer to be transmitted within a Transmission Time Interval (TTI) that is given by,

$$TTI \; ? \; n ? T_{slot}$$

where n depends on HSDPA scheduling, hybrid ARQ state and rate information provided by the mobile (see accompanying contribution [2].

In the current multiplexing structure, the presence of multiple transport channels into the physical layer and the multitude of configuration possibilities, mandate exp licit Transport Format Combination Indication signalling to the UE.

In HSDPA though, it is the UE that sends via the proposed UL DPCCH channel's RAI field [2], the required Rate Information (RI) to the Node-B. In this respect, the TFCI signalling can be significantly reduced by mapping the RI and the TrCH id (index i) scheduled by the Physical Layer Scheduler (PLS) entity, into the number of PDUs that are transmitted to the UE i.e.

$$M \; ? \; ?(RI, i).$$

where the function $?(.)$ is known to both the Node-B and the UE. The only information that is required by the UE to allow HS-DSCH demultiplexing, is the TrCH id, as in general more than one TrCH are time multiplexed by the PLS. At any instant in time only one TrCH will be transmitted to one of the UEs.

The UE upon decoding the TrCH id, can determine the number M of PDUs and can de-multiplex the HS-DSCH channel. Inefficiencies may arise in the following scenario: when the channel conditions are favourable, the UE indicates a Rate Information that corresponds to an $M ?? M_{actual}$ where M_{actual} is the number of PDUs that are actually waiting in the Node-B buffer. Consequently, another option would be the explicit signalling to the UE of $M ? \{M_{\min},\ldots,M_{\max}\}$ in order to avoid excessive padding. The set of allowed values for M are communicated to the UE via higher layer signalling.

<u>After</u> the concatenation of the M PDUs and Code Block segmentation, a CRC code is appended to each Code Block Segment CBS of $B(i)$ bits resulting in a block of

$$C(i) ? B(i) ? CRC(i)$$

bits that is encoded by a Turbo encoder with nominal code rate r. The resulting $D(i)$ bits are punctured to a code rate $r^*(i, RI) ? r$ that is a deterministic function of the decoded Rate Information (RI) received in the UL-DPCCH. A coded sub-block (denoted by the index s) is defined as a rate-matched block of size $E(RI,i)$ bits that is submitted to the block interleaver with memory $E(RI,i)$ and finally via the Time-Multiplexer/Physical Layer Scheduler (PLS) entity forms a Coded Shared Transport Channel (CSTrCH). The mapping from CSTrCH to a number of physical channels is performed using the number of W-ary OVSF codes (W is a system constant) that are available at the point of time of the actual transmission.

---------------------------------------End Text Proposal for TR Section 5 and Section 6------------------------------------

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References

[6] "Downlink and Uplink Channel Structures for HSDPA Technical Report," TSGR1#17(00)1381, Lucent Technologies.

[7] "Asynchronous and Adaptive Incremental Redundancy (A^2IR) Proposal for HSDPA," TSGR1#17(00)1382, Lucent Technologies

[8] "Downlink Transport Channel Multiplexing Structure for HSDPA," TSGR1#17(00)1383, Lucent Technologies.

[9] David N. C. Tse, and Stephen Hanly, ``Multiaccess Fading Channels -Part I: Polyumatroid Structure, Optimal Resource Allocation and Throughput Capacities," IEEE Transactions on Information Theory, Vol. 44, No. 7, November 1998.

---End Text Proposal for TR Section 10-- ---

References

[1] "Downlink and Uplink Channel Structures for HSDPA Technical Reports," TSGR1#17(00)1381, Lucent Technologies.

[2] "Incremental Redundancy (IR) Proposal for HSDPA," TSGR1#17(00)1382, Lucent Technologies

[3] "Downlink Transport Channel Multiplexing Structure for HSDPA," TSGR1#17(00)1383, Lucent Technologies.