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Document for: Discussion and decision

1 Introduction

Downlink and uplink channel structures and frame formats in support of the High Speed Downlink Shared Channel (HS-DSCH) are proposed. The downlink structure is motivated by the need for a more efficient use of the Node-B transmit power and of the channelization (OVSF) code space. Additionally, the new structure accommodates advanced physical and MAC layer techniques, such as incremental redundancy (IR), fast adaptation to channel conditions, and multiple input multiple output (MIMO) antenna configurations. The uplink channel and frame structures are designed to keep the signalling overhead for HSDPA as low as necessary. Based on this discussion, some initial text for the HSDPA Technical Report is proposed in [5].

The key aspects of the proposal that allow for efficient use of the HS-DSCH are outlined here, while the details can be found in accompanying contributions [3],[4]. The channel and frame structures necessary to support the concepts (listed below) are provided in sections that follow.

1. **Explicit Rate Information from the UE**
   Explicit feedback of the supportable rate from the UE is preferred over sending Signal to Interference Ratio (SIR) measurements to the Node B. It is preferable that the UE compute the supportable rate for the following reasons:
   - The UE can read the available resources (power fraction and channelization code space) left over from satisfying dedicated channel user load on all active legs. This information can be used in determining the supportable rate as well as the best serving cell by the UE during fast cell selection. Broadcast of power fraction and code space at a cell is provided for in a new broadcast channel defined in Section 3.
   - 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. In Section 3, we describe how such activity indication can be broadcast to UEs.
   - The UE can measure the matrix channel quality and can use this information to map directly to a rate that can be supported when multiple antenna transmission (MIMO) is employed.

2. **Preamble Based User Identification on the HS-DSCH**
   The use of a user-specific preamble that is time multiplexed prior to user-data transmission on the downlink shared channel (HS-DSCH) is a more efficient approach to identifying a user as compared to methods that use dedicated channels for notification. Since the preamble uses codes from the same set as that used for HS-DSCH data transmission, this approach is more efficient in terms of downlink channelization code usage. Furthermore, the delay between notification and data transmission is minimized with the preamble based approach.

3. **Asymmetric Downlink TTI and Uplink Feedback Rate**
   From a frame-fill efficiency perspective, it is preferable to have one slot (0.667ms) as the granularity for an HS-DSCH frame. That is, the minimum duration for which the shared channel is assigned to a user is 1 slot. This is because at data rates in excess of 10Mbps and with typical Internet packet sizes, frame sizes greater than one

slot could lead to considerable inefficiency. However, the link quality (or rate information) feedback from the UE doesn't have to be at the rate of once per slot. The typical rate at which channel quality changes is slower than one slot. Besides, the overhead associated with per slot feedback of the link quality (or rate) would be excessive. Therefore, in our design, the feedback information is sent over 3 slots, or every 2 ms.
With this design, we can better adapt to the channel conditions that can be further combined with efficient and fast scheduling to realize multi-user diversity gain [8].

4. **Fast Cell-site 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. In Section 3, a downlink broadcast channel is defined, among other functions, to support the UE fast cell site selection. In this downlink broadcast channel, both the Node-B transmitter power fraction and its available channelization code space are sent. In addition, a channelization code cover based approach for signalling the preferred cell site is proposed. Thus, fields defined in the UL DPCCH [2] for cell ID can be avoided.

5. **Dynamic Power and Code Sharing**
The shared channel is defined based on the use of fixed spreading factor codes [1] e.g. SF=32. The number of codes of SF=32 that are available for HS-DSCH would vary depending on the codes being used by the dedicated channel users. The same is true of the Node-B transmitter power available for the shared channel. These values are broadcast on a newly defined channel (see Section 3) enabling the UE to make a better estimate of the supportable rate. By matching the HS-DSCH rate control speed to the dedicated user channels' power control speed we obtain: a) better utilisation of the power bin and b) reduced lag between power control and rate control loops thus reducing the error in power allocated to the DSCH. This implies more relaxed overload control margins and hence improved capacity/ throughput.

6. **Multiple Input Multiple Output (MIMO)**
Multiple antenna modes allow considerable enhancement of the supportable data rates [6]. The HSDPA users are anticipated to cover a wide range of requirements in terms of the DL desired data rates, mobility, and UE capabilities. The MIMO architecture [7] allows the accommodation of high data rates with higher spectral efficiency than high-order modulation schemes. It also delivers higher peak data rates without additional transmit power requirements. The use of MIMO depends on the per user channel conditions and mobility. In order to optimise the instantaneous DL seen by each UE, a flexible transmit configuration should be considered. The integration of the rate feedback information with additional antenna feedback information (see Section 2) offers this capability, while keeping the feedback required at a minimum. Consequently, the UE feedback will control the activation of MIMO transmission and will make the use of MIMO transparent to the other, non-MIMO users, within the HSDPA.

The MIMO operation does not conflict with the operation of the dedicated channels or the other non-MIMO data UEs. A Node-B that employs multiple antennas for MIMO operation should notify its capability to all UEs through signaling. All data UEs should notify the Node-B of their MIMO capability upon the call set-up. This way the Node-B can schedule MIMO transmission if the channel conditions apply.

7. **Incremental Redundancy**
The accompanying contribution [4] describes an asynchronous and adaptive incremental redundancy (A^2IR) approach that provides for greater scheduling flexibility, improved link adaptation, and reduced packet addressing overhead. The necessary fields in support of A^2IR are provided in the downlink frame structure for the HS-DSCH as outlined in Section 3.3.

8. **Code Block and Encoded Sub-block Concept**
Code block segments of sufficiently large size (number of bits) at the input of the encoder are proposed [3], [4] for all DSCH rates that use turbo coding to permit reasonable turbo interleaving efficiency. Encoded sub-blocks are formed at the output of the channel encoder for allowing incremental redundancy. The actual transmission time allocated per encoded sub-block dynamically varies in integer multiples of the slot as a function of the rate.

9. **Transport Channel Multiplexing**

The use of a minimal set of allowed code block segment sizes for the HS-DSCH coupled with *time division multiplexing* of multiple transport channels to a UE simplifies operation of incremental redundancy and allows for the use of a "compressed" TFCI. This results in limiting the overhead in the downlink direction. The accompanying contribution [3], [4] describes these ideas in further detail.

Uplink and downlink channel and frame structures in support of the above concepts are now described. It is worth pointing out that channelization code space and power were considered constraining on the downlink, and the overhead data rate was assumed to be constraining on the uplink. In Section 2, the uplink signalling channel is described, followed by the downlink channel structures in Section 3.

2 Uplink DPCCH Channel Structure

Aspects of our proposed structure for the uplink control channel are listed below.

2.1 Uplink Slot Duration and Feedback Rate

As discussed in the previous section, 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 as recommended in [1].

2.2 Uplink DPCCH Frame Format

The uplink DPCCH spreading factor is lowered from 256 to 128, as proposed in [2]. 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) for the user. The RAI and ACK fields are described below.

2.2.1 Link Quality Feedback using RAI Field

Explicit signalling of Rate and Antenna Information (RAI) from the UE is preferred as compared to signalling the SIR estimate for reasons cited in Section 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.

2.2.2 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.

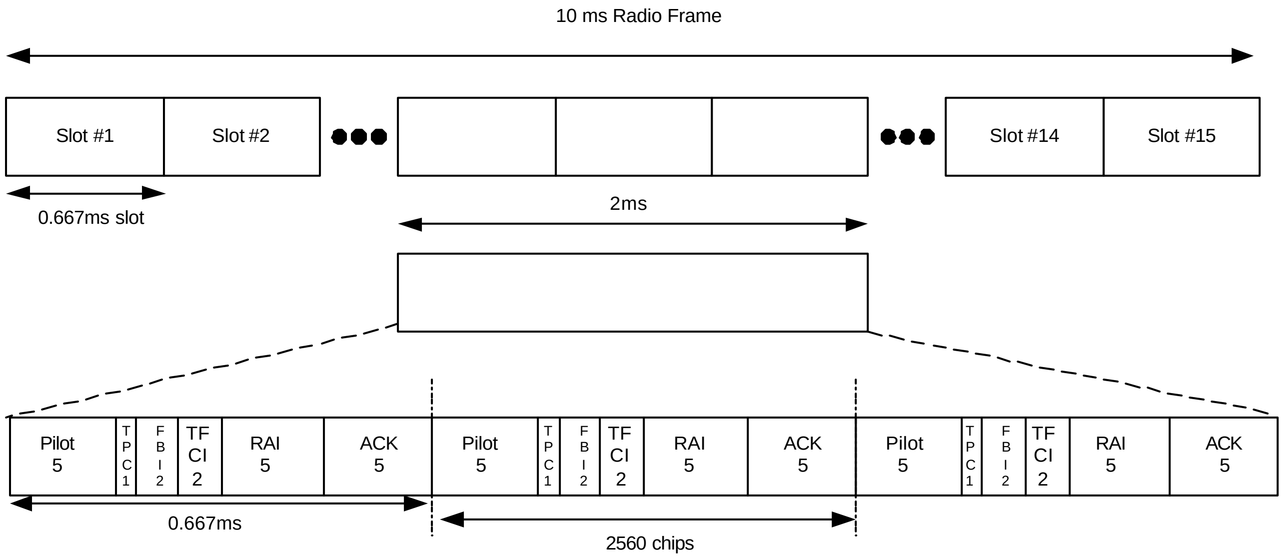

Figure 1: UL DPCCH frame structure that supports DSCH operation.

2.3 Fast Cell Site Selection

Fast cell site selection can be based on using channelization code covers for the RAI field. This can be done by spreading the RAI 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.

3 Downlink Channels Structure

3.1 HS-DSCH TTI

In [1], shorter HSDPA Transmission Time Interval (TTI) has been recommended. Finer granularity 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.

Therefore, it is proposed that the HS-DSCH makes the following two basic definitions:

- ?? An HS-DSCH TTI that equals 1 slot interval, TTI =1 x T_{SLOT}. The slot duration is T_{SLOT} = 0.667ms.
- ?? This new TTI is the minimum time interval for which the HS-DSCH resource is allocated to a UE.
- ?? The actual time of transmission of a coded sub-block can be multiples of the TTI depending on the rate signalled by the UE [3]. The total transmission time to successfully decode an encoded block is a function of the Incremental Redundancy (IR) performance.

3.2 HS-DSCH Associated Control Channel (DACCH)

The new DACCH downlink channel carries the TPC bits that imp lement uplink power control. In addition, the Pilot bits are time-multiplexed in this channel as well. For each UE, their DACCH is 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, the DACCH is 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 definition of this new channel replaces the dedicated pointer channel (DPTRCH) as introduced in [2]. Similarly, new functionality is defined for the DSCH in the next section. 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

3.3 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 3.1, 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 assigned to
- ?? A^2IR control fields [3].

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 control of a dedicated downlink channel that performs user identification. The UE is then aware of the preamble length since it is based on RAI information.

Preamble (bits)	**Data (bits)**
Variable length containing A^2IR control fields.	Variable length dependent on UL DPCCH RAI field decoding.

Table 2: HS -DSCH Fields

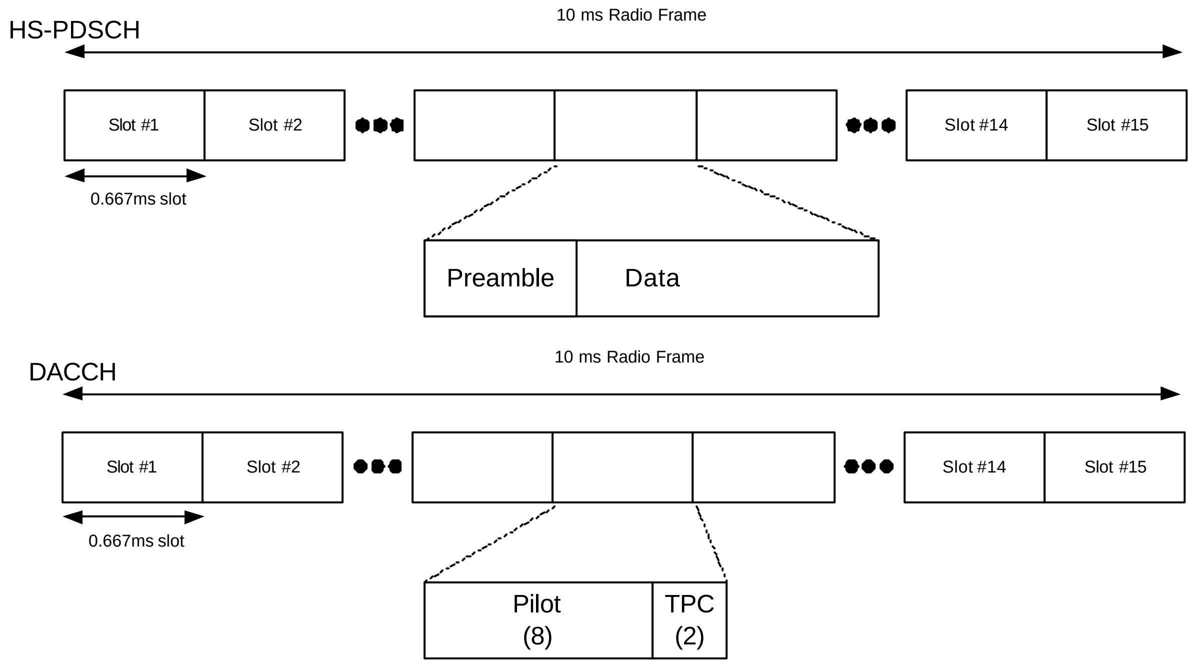

Figure 2: Frame Structure of HS -DSCH and DACCH channels

3.4 Power and Code Broadcast Channel (PCBCH)

A new Power and Code Broadcast Channel (PCBCH) is defined with fields 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. This information is updated at the following rate:

?? 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

References

[1] “Physical layer aspects of HSDPA and text proposals for HSDPA Technical Reports” TSGR1#16(00)1193, Ericsson.

[2] “Control Channel Structure for High Speed DSCH (HS-DSCH)”, TSG-RAN #16(00)1242, Motorola.

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[8] 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.