Agenda item:	AH24 : High Speed Downlink Packet Data Access
Source:	Lucent Technologies
Title:	MIMO system integration and signalling in HSDPA
Document for:	Discussion

1. INTRODUCTION

The integration of the MIMO scheme within the HSDPA and its integration with functions in L1 and L2 are presented. The MIMO operation within HSDPA is envisioned as an optional transmission mode. The required signalling, modes of operation and the impacts of the proposed schemes to the higher layers and Release 99 are discussed. These results were presented recently to RAN WG2, and their conclusion was that MIMO does not have significant impact on the signalling architecture.

Multiple antenna modes allow considerable enhancement for the performance supportable data rates. 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 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 channel quality information with additional antenna feedback information 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. Thus, the Node-B can schedule MIMO transmission if the channel conditions apply. The integration of MIMO within the HSDPA structure is described in detail in the following sections.

2. DOWNLINK SIGNALLING

The MIMO transmission scheme is anticipated to be optional for the NodeB. That is, a NodeB can employ multiple transmit antennas based, e.g., on a gradual rollout plan or anticipated demand. If a NodeB is capable of MIMO transmission it then must broadcast an appropriate message that should be received by all UEs in the cell-site. It is proposed that the broadcast message be included as a one-bit field within the Common Control Physical Channel (CCPCH) within the Broadcast Channel (BCH). The one-bit field identifies the NodeB as having one of two possible configurations as shown in Table 1.

Once the MIMO capable users in the cell-site acknowledge the MIMO capability of the NodeB, they can request DL MIMO transmission when channel conditions are favourable. This is described in Section 3.

NodeB Configuration	NodeB capabilities
C1	Release 99 compliant (one or two transmit antennas)
C2	MIMO Transmission

Table 1. NodeB configurations

3. UPLINK SIGNALLING

Uplink signalling from every UE to the NodeB is required, to indicate to the NodeB how many antennas the UE employs. This information is necessary to the NodeB in order to schedule multiple antenna transmission for particular users or not. It is necessary that all UEs report their capability once they enter the network. Such functionality will rely within the UE RRC and can be signalled during the call set up within the fields of the RACH-FACH negotiation. Table 2 defines the three possible types of UEs.

UE Type	UE Capabilities
Type I	Single Receive Antenna
Type II	Two Receive Antennas
Type III	Four Receive Antennas

Table 2. Types of UEs

Beyond the declaration of its type, each UE should actively enable or disable the multiple antenna transmission based on the instantaneous channel conditions, thus optimising the use of the HS-DSCH resources. That is, the MIMO scheme should be enabled for the next scheduled transmission depending on the channel quality feedback reported by the UE. If the channel conditions, such as matrix channel correlation, are favourable, then the MIMO transmission is scheduled. Otherwise, the system will fall back to a different mode of transmission. In order to utilise the multiple antennas at the NodeB to the greatest degree, it is proposed that when MIMO transmission is not scheduled, the transmit antennas operate in Selection Transmit Diversity (STD) mode. The STD is a closed loop transmit diversity scheme, it requires two transmit antennas, a single bit feedback per update, and takes advantage of the multi-user diversity exploited by the DL scheduler. The STD delivers superior performance to single antenna transmission under all the considered scheduling algorithms. Additionally, the STD scheme is used when the C/I at the UE is insufficient to allow a MIMO transmission.

The antenna mode signalling should be a component of the UL channel quality feedback field, which was first proposed for the HSDPA in [1] as the Rate and Antenna Indication field (RAI). An efficient way to incorporate the functionality of the antenna mode indication with the channel quality feedback (Channel Quality and Antenna Indicator: CQAI) is to integrate the two into a single feedback message. As an illustration example, Table 3 is shown below assuming a 4-bit field for the integrated channel quality and antenna indication feedback. This example table assumes that the UE makes use of rate feedback through the request for a specific MCS. The interpretation of the 4-bit CQAI field is different for each UE Type. For a Type III UE, the CQAI provides the flexibility to choose a specific MCS along with a matching antenna transmission mode that can be one of the STD, 2x4 MIMO, 4x4 MIMO, or single antenna.

Allowing the channel quality feedback to incorporate the preferred antenna transmission scheme allows for more efficient use of the multiple antennas at the NodeB in the following sense:

- ?? Type I UEs (with a single receive antenna) can take advantage of the multiple transmit antennas in a C2 NodeB by defining additional to MIMO multiple antenna transmit schemes. The Switched Transmit Diversity (STD) scheme is proposed as an option for the DL. The UE may enable the STD scheme for each DL encoder packet transmission based on its current measurement of channel correlation and mobility.
- ?? Type II UEs are given three possible modes of operation: 1) Single antenna DL transmission when the channel correlation or mobility do not favor MIMO transmission, 2) 2x2 DL MIMO transmission, 3) STD transmission when the requested data rate is not supported by MIMO operation.
- ?? Type III UEs are given four possible modes of operation: 1) Single antenna DL transmission when the channel correlation or mobility do not favor MIMO transmission, 2) 4x4 DL MIMO transmission, 3) Fallback 2x4 MIMO DL transmission with two transmit antennas when channel correlation is high, 4) STD transmission when the requested data rate is not supported by MIMO operation.

The MIMO transmission will require alternate and new MCS schemes to be defined (MCS9-MCS14). It is thus implicit that the MCS tables available to a Type II/III UE will be different than the MCS table for a Type I UE. The Type II/III UE MCS table will include higher data rates, lower-order modulation schemes, and the ability to switch among the different antenna transmission schemes for different data rate ranges in the table.

Note that the NodeB antennas that may be in use are indexed as A_i, i=1,2,3,4. Note also that for configuration C2 and a Type I UE the AI bit indicates the preferred transmit antenna and the STD scheme is used by default. However, the UE can disable the STD scheme and revert to a single transmit antenna transmission by maintaining the same feedback message.

4. INTEROPERABILITY ISSUES

The introduction of the multiple antenna schemes in the HSDPA does not affect the operation of the standard, single antenna, UEs. Specifically, the following arguments apply:

- ?? A Type I UE can operate normally in both C1 and C2 NodeB configurations.
- ?? Mixtures of Type I and II/III UEs can coexist and operate in the same cell site. MIMO transmissions are transparent to non-MIMO UEs.
- ?? The new Type I/II/III UEs are compatible with R99 NodeBs and UTRAN.
- ?? R99 UEs will be compatible with the new NodeB and UTRAN.

5. L2 REQUIRED FUNCTIONALITY

The DL and UL signalling messages that declare the NodeB configuration and the UE type will originate in the RRC functions and then mapped to L2. The rest of the MIMO and STD operation within a cell site is transparent to the higher layers.

Channel Quality & Antenna Feedback Label	Type I UE (1 ant.) MCS; Rate (kbps); Tx ant			Type II UE (2 ants.) MCS; Rate (kbps); Tx ant			Type III UE (4 ants.) MCS; Rate (kbps); Tx ant		
1	MCS1	60	A1	MCS2	120	A1	MCS3	240	A1
2	MCS1	60	A4	MCS2	120	A4	MCS3	240	A4
3	MCS2	120	A1	MCS3	240	A1	MCS4	480	A1
4	MCS2	120	A4	MCS3	240	A4	MCS4	480	A4
5	MCS3	240	A1	MCS4	480	A1	MCS5	960	A1
6	MCS3	240	A4	MCS4	480	A4	MCS5	960	A4
7	MCS4	480	A1	MCS5	960	A1	MCS6	1920	A1
8	MCS4	480	A4	MCS5	960	A4	MCS6	1920	A4
9	MCS5	960	A1	MCS6	1920	A1	MCS7	3840	A1
10	MCS5	960	A4	MCS6	1920	A4	MCS7	3840	A4
11	MCS6	1920	A1	MCS7	3840	A1	MCS9	7680	A1,A4
12	MCS6	1920	A4	MCS7	3840	A4	MCS10	11520	A1,A4
13	MCS7	3840	A1	MCS8	7680	A1	MCS11	15360	A1,A4
14	MCS7	3840	A4	MCS8	7680	A4	MCS12	11520	A1,A2, A3,A4
15	MCS8	7680	A1	MCS9	7680	A1,A4	MCS13	15360	A1,A2, A3,A4
16	MCS8	7680	A4	MCS11	15360	A1,A4	MCS14	23040	A1,A2, A3,A4

Table 3. Channel Quality and Antenna Indication tables for the three UE Types

6. IMPACT TO R99

The proposed transmission schemes of MIMO and STD impact the existing structure of the RAN R99 on the following issues:

1. The use of MIMO requires the definition of new MCS schemes that attain higher information data rates. Also, alternative MCS schemes must be defined for the substitution of an existing high order modulation (64QAM) MCS with an equivalent data rate MCS with lower order modulation

2. DL Transmit path modifications are required for the demultiplexing of the encoder packet across the transmit antennas, as described in [2].

3. Additional L2 signalling must be defined, as described in Section 4.

Note that an active CPICH is required for each additional NodeB transmit antenna for accurate channel estimation at the UE receiver. This requirement complies with R99.

All the above modifications to R99 will not impact the backward compatibility of the R99 UEs.

7. RFERENCES

[1] Lucent Technologies. Throughput simulations for MIMO and transmit diversity enhancements to HSDPA, TSG-RAN #17(00)1387, 21-24th, November 2000, Stockholm, Sweden.

[2] Lucent. Further link level results for HSDPA using multiple antennas. TSG_R WG1 document TSGR1#17(00)1386, 21-24th, November 2000, Stockholm, Sweden.