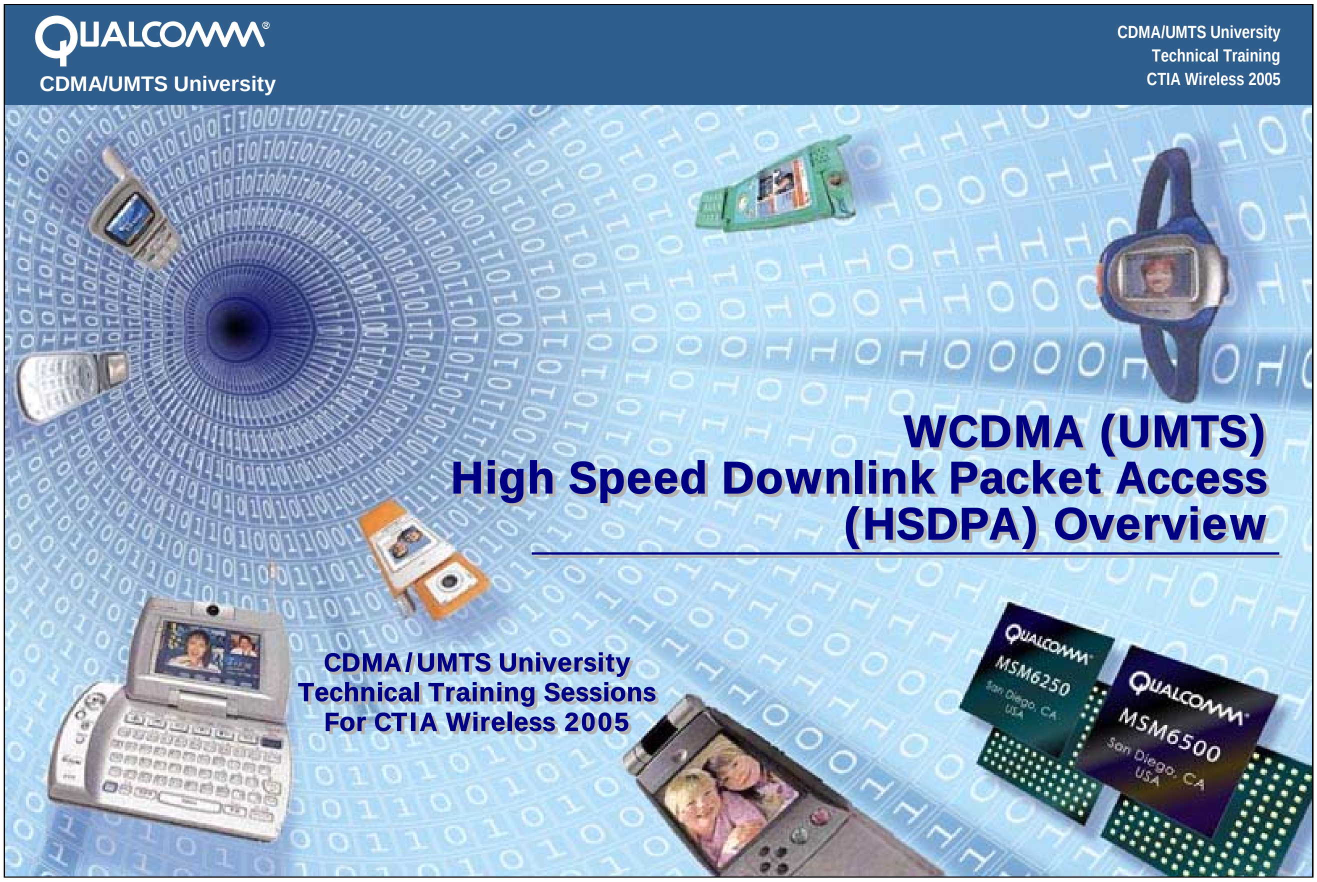

CDMA/UMTS University

Technical Training Sessions

For CTIA Wireless 2005

80-W0329-1 Rev A

Material Use Restrictions

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Technical Training
CTIA Wireless 2005

The material in this seminar is a brief sampler excerpted from technical training developed by QUALCOMM's CDMA/UMTS University.

To learn more about this seminar topic, sign up for the following courses:

- ***WCDMA (UMTS) HSDPA: A Standards and Performance Overview*** (2 days)
  - ***Module 1: WCMDA (UMTS) HSDPA Protocols and Physical Layer***
  - ***Module 2: WCDMA (UMTS) HSDPA Performance and Deployment***

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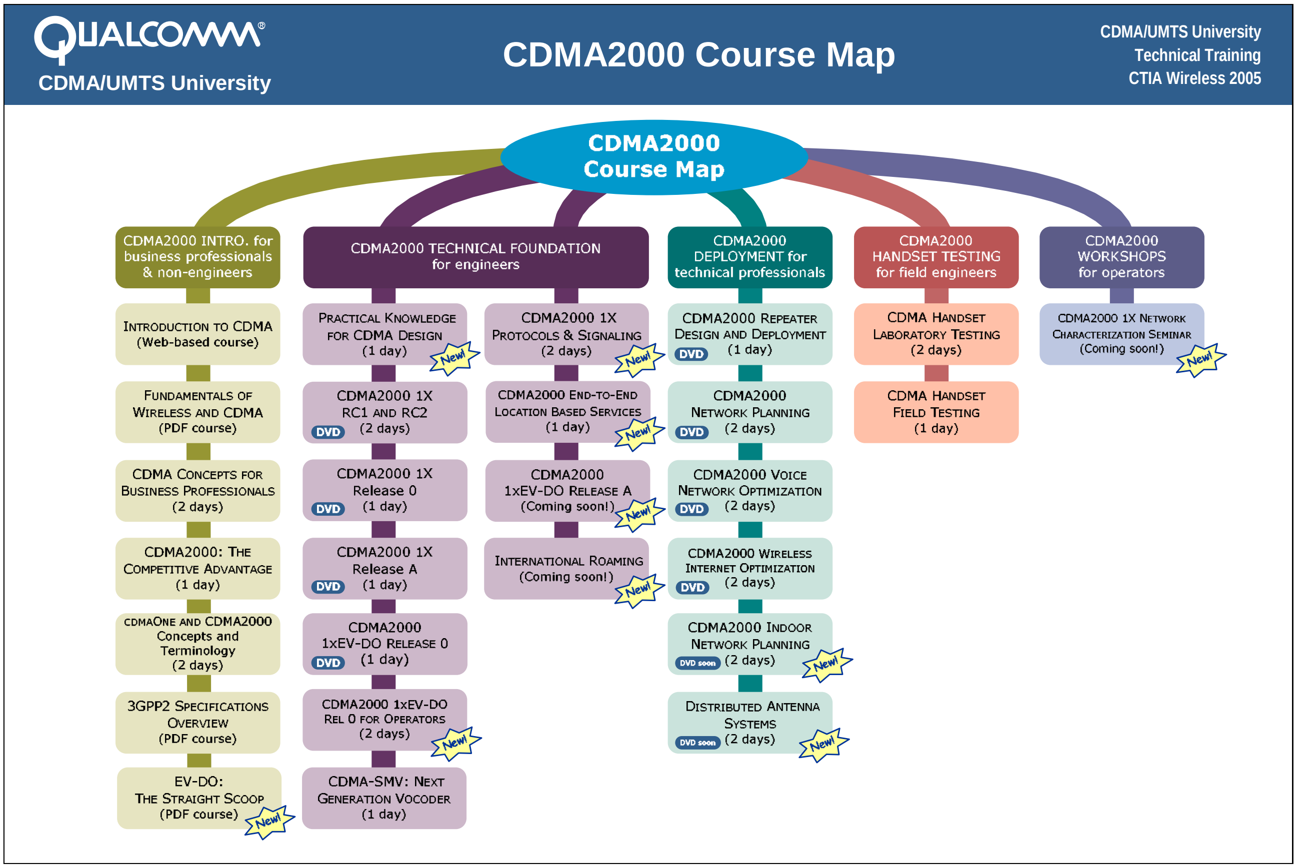

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- **Handset Testing** courses **–** for field engineers
- **Workshops** – for operators

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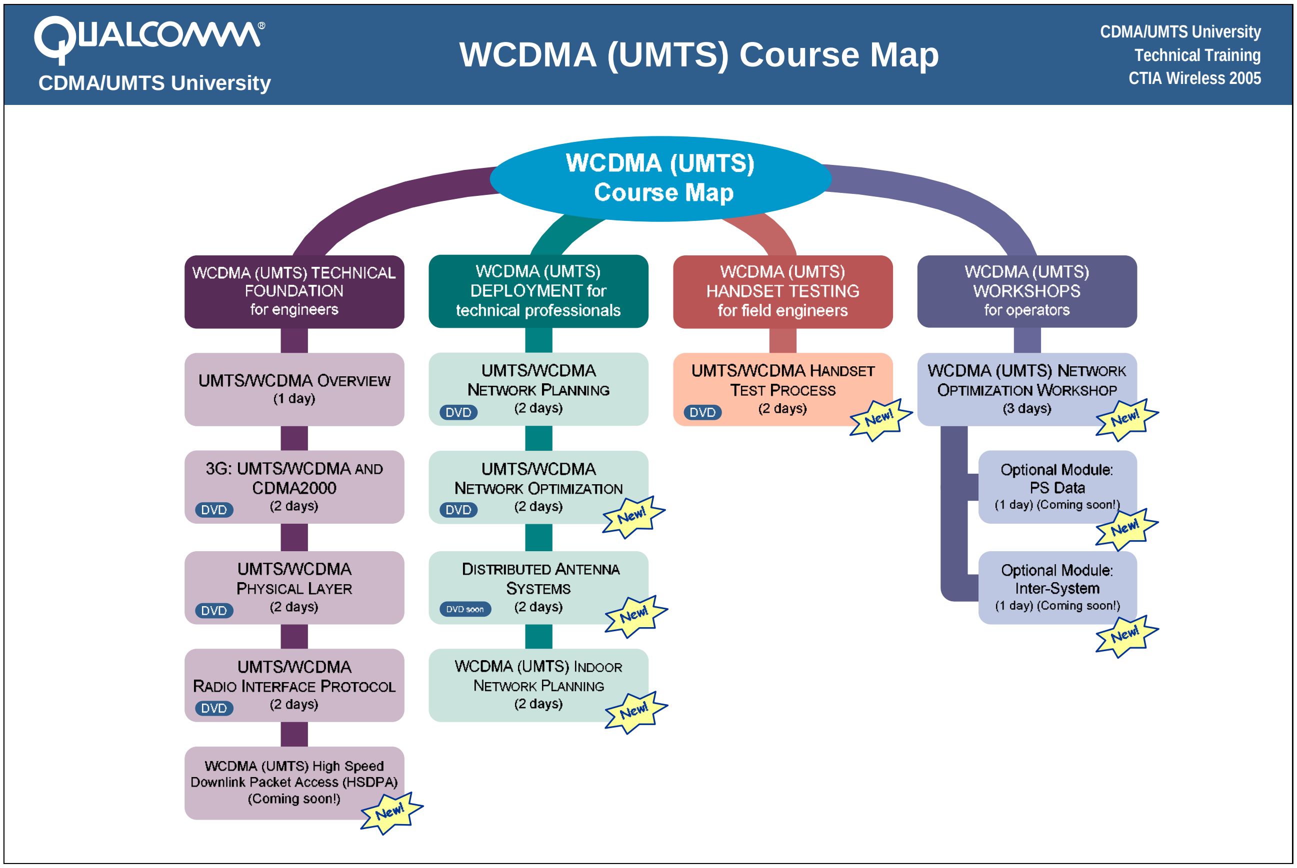

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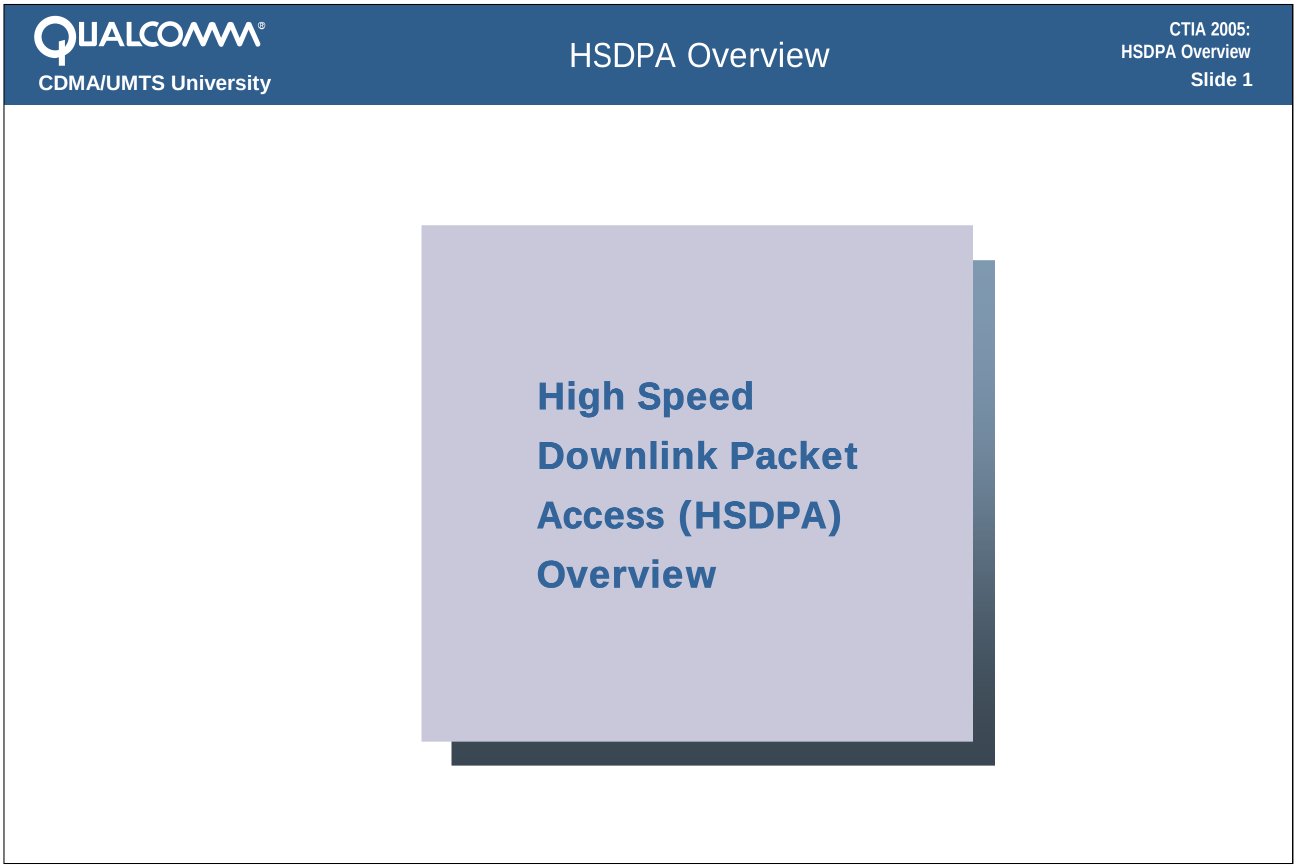
QUALCOMM
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HSDPA Overview
CTIA 2005:
HSDPA Overview
Slide 1
High Speed
Downlink Packet
Access (HSDPA)
Overview

Notes

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Seminar Learning Objectives

CTIA 2005: HSDPA Overview
Slide 2

- Introduce WCDMA Release 5 and High Speed Downlink Packet Access (HSDPA).
- Understand the motivations for deploying HSDPA.
- Review the WCDMA architecture and the Release 99 channels.
- Describe the HSDPA channels and their function.
- Illustrate the maximum HSDPA data rate.
- Illustrate issues that affect data rate in a real world deployment.
- Discuss other implementation considerations.

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WCDMA Evolution

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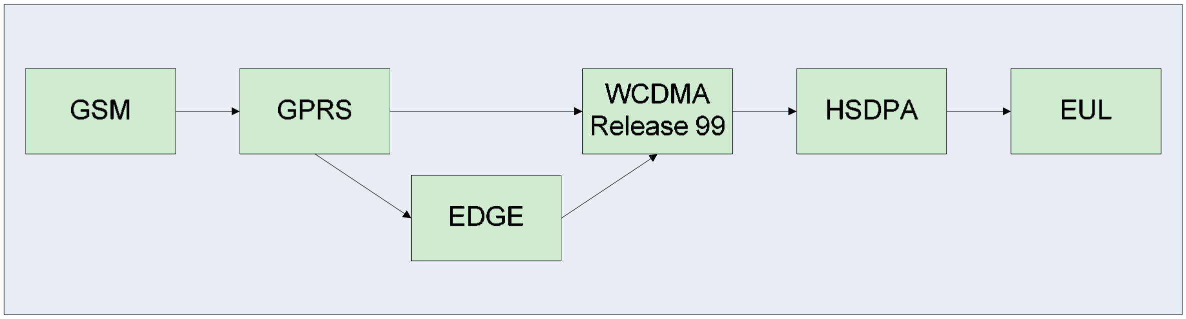
HSDPA Overview
Slide 3



	Downlink Peak Data Rate (Typical Deployment)	Downlink Peak Data Rate (Theoretical Maximum)
GSM	9.6 kbps (CS)	9.6 kbps (CS)
GPRS	40 kbps[1]	171 kbps
EDGE	120 kbps[2]	473 kbps
WCDMA Release 99	384 kbps	2.0 Mbps
HSDPA	10.0 Mbps	14.4 Mbps
EUL	*Uplink only*	

Assumptions for Typical Peak Data Rates

1. CS2, 4 Time Slots at 10 kbps per slot. Assumed C/I=15 dB.
2. MCS6, 4 Time Slots at 30 kbps per slot. Assumed C/I=15 dB.

The chart on the slide shows the evolution of WCDMA from GSM, GPRS, and EDGE to the presently deployed Release 99. HSDPA is included in Release 5 of the specifications.

Following Release 5, whose enhancements provide benefits for the Downlink, Release 6 introduces the Enhanced Uplink (EUL), which will provide faster data services for the Uplink.

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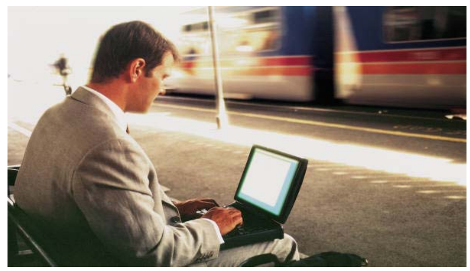
High Speed Downlink Packet Access (HSDPA)

CTIA 2005: HSDPA Overview
Slide 4

What are the drivers and motivations for migrating to HSDPA?

- **Data Rate**
  - Demand for high data rate multimedia services
  - Demand for higher peak data rates
- **Throughput**
  - Cost per megabyte
- **Capacity**
  - Improved Link Adaptation dependent on Radio Conditions



Data Services and High Speed Downlink Packet Access (HSDPA)

Data Services are expected to grow significantly within the next few years. Current 2.5G and 3G operators are already reporting that a significant proportion of usage now involves data. There will therefore be an increasing demand for high-data-rate, content-rich multimedia services.

Current Release 99 WCDMA systems offer a maximum practical data rate of 384 kbps. However, in Release 5 of the specifications, the 3rd Generation Partnership Project (3GPP) has included a new high-speed, low-delay feature referred to as High Speed Downlink Packet Access (HSPDA).

HSDPA provides significant enhancements to the Downlink compared to WCDMA Release 99 in terms of peak data rate, cell throughput, and round trip delay. This is achieved through the implementation of a fast channel control and allocation mechanism that employs such features as Adaptive Modulation and Coding and fast Hybrid-Automatic Repeat Request (H-ARQ). Shorter Physical Layer frames are also employed.

Downlink Limiting Factors in Release 99:

- **Limited Peak Data Rate**
  - Maximum implemented Downlink of 384 kbps
- **Capacity and Throughput**
  - Link adaptation due to channel conditions
    - Fast Closed Inner Loop Power Control
    - Slower Outer Loop
  - Modulation and coding
    - QPSK
    - Convolutional Coding (R=1/2,1/3) or Turbo Coding (R=1/3)
  - Minimum TTI of 10 ms

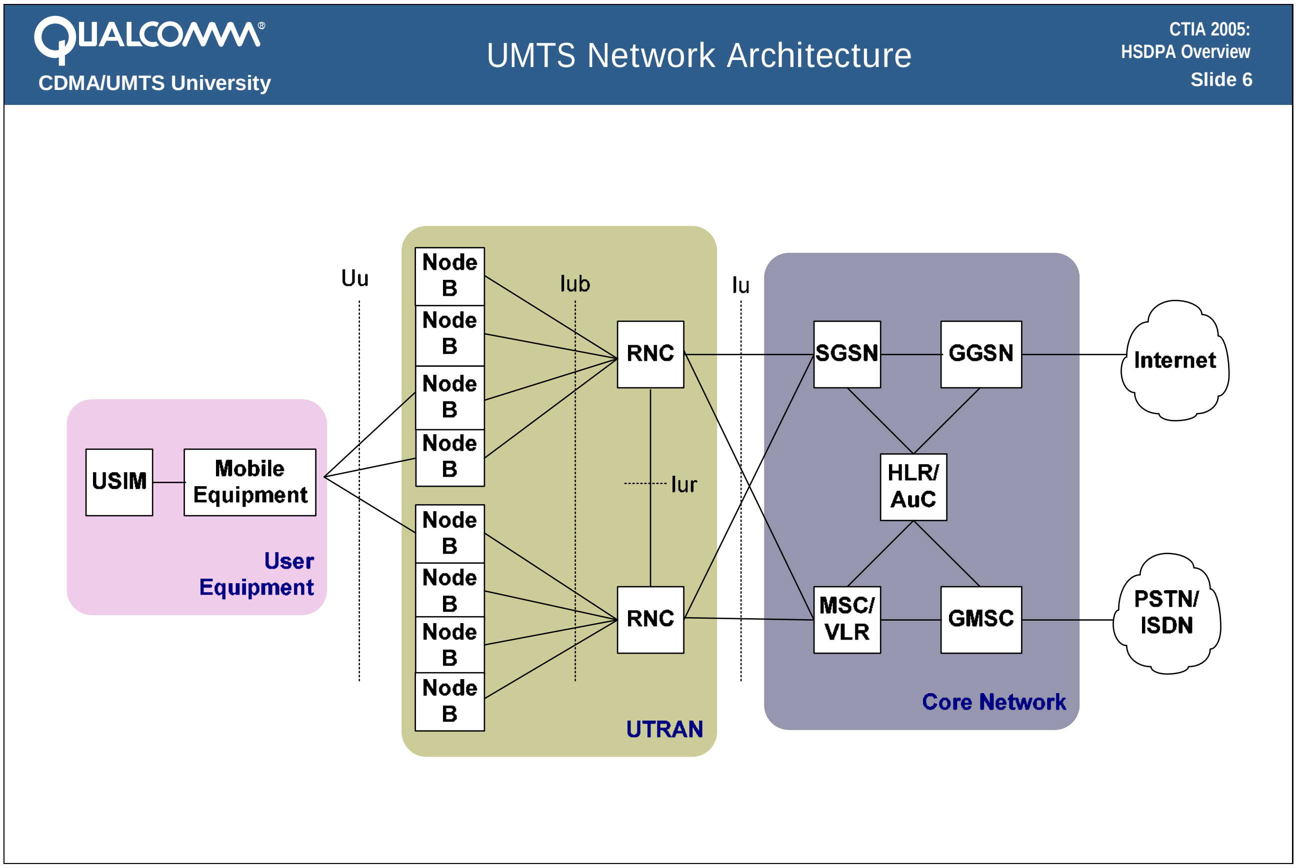
Release 99 Limitations

Although the WCDMA Release 99 standard allows for maximum data rates of up to 2.0 Mbps, it has only been widely implemented with a maximum data rate of 384 kbps in Dedicated Mode. Dedicated Mode is the predominant method employed for data services in Release 99. The use of dedicated resources can be a limitation, especially for data applications with bursty characteristics where the management of a limited set of resources can be problematic.

Capacity is controlled both by the maximum available PA power and by the power requirement of each data service. In Dedicated Mode, fast power control is used to achieve a target E_b/N_o on the Downlink. However, the required E_b/N_o setpoint is changed at a much slower rate. This can result in wasted resources whereby a better-than-required E_b/N_o is achieved for the required Block Error rate (BLER).

Other Release 99 features:

- Release 99 offers a single modulation option of QPSK regardless of channel quality.
- For coding, both convolutional and turbo are allowed.
- The minimum Transmission Time Interval (TTI) in Release 99 can be problematic because of the inherent round trip delay.



UMTS Network Architecture

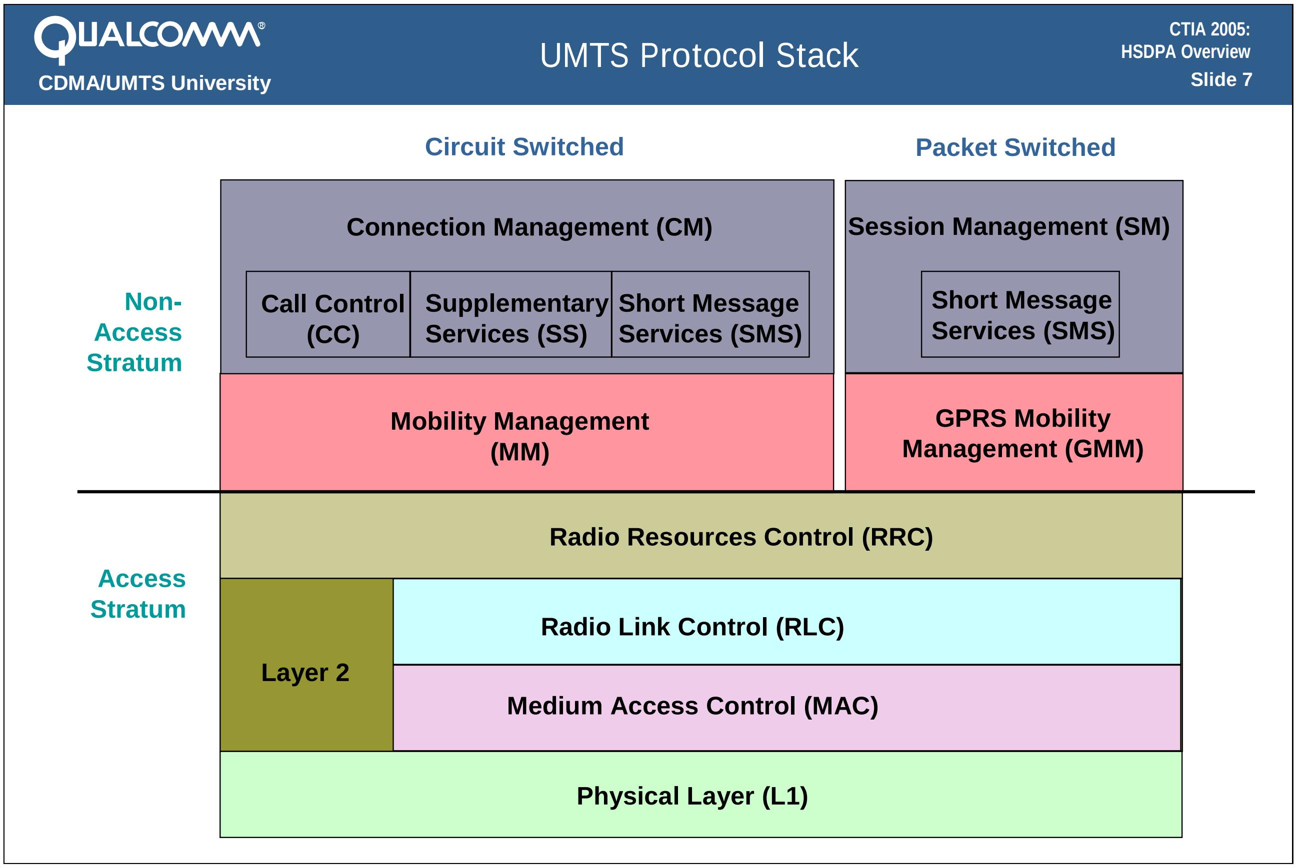
A UMTS system consists of three major subsystems:

- **User Equipment (UE) –** May be a mobile, a fixed station, a data terminal, etc. Includes a Universal Subscriber Identity Module (USIM), which contains all of a user's subscription information.
- **Universal Terrestrial Radio Access Network (UTRAN) –** Includes all of the radio equipment necessary for accessing the network: Node Bs that provide radio links to the UEs, and Radio Network Controllers (RNC) that control the radio resources and interface to the Core Networks.
- **Core Network –** Includes all of the switching and routing capability for connecting to either the PSTN (circuit-switched calls) or to a Packet Data Network (packet-switched calls), for mobility and subscriber location management, and for authentication services.

UMTS standards specify the operation of the following interfaces:

- **Uu –** between UE and Node B
- **Iub –** between Node B and RNC
- **Iu_{ps}** – between RNC and SGSN
- **Iu_{cs} –** between RNC and MSC

Adding HSDPA to an existing UMTS network requires no new network entities, but hardware and/or software changes may be required for each entity. Most of the changes are concentrated in the UE, Node B, and RNC.

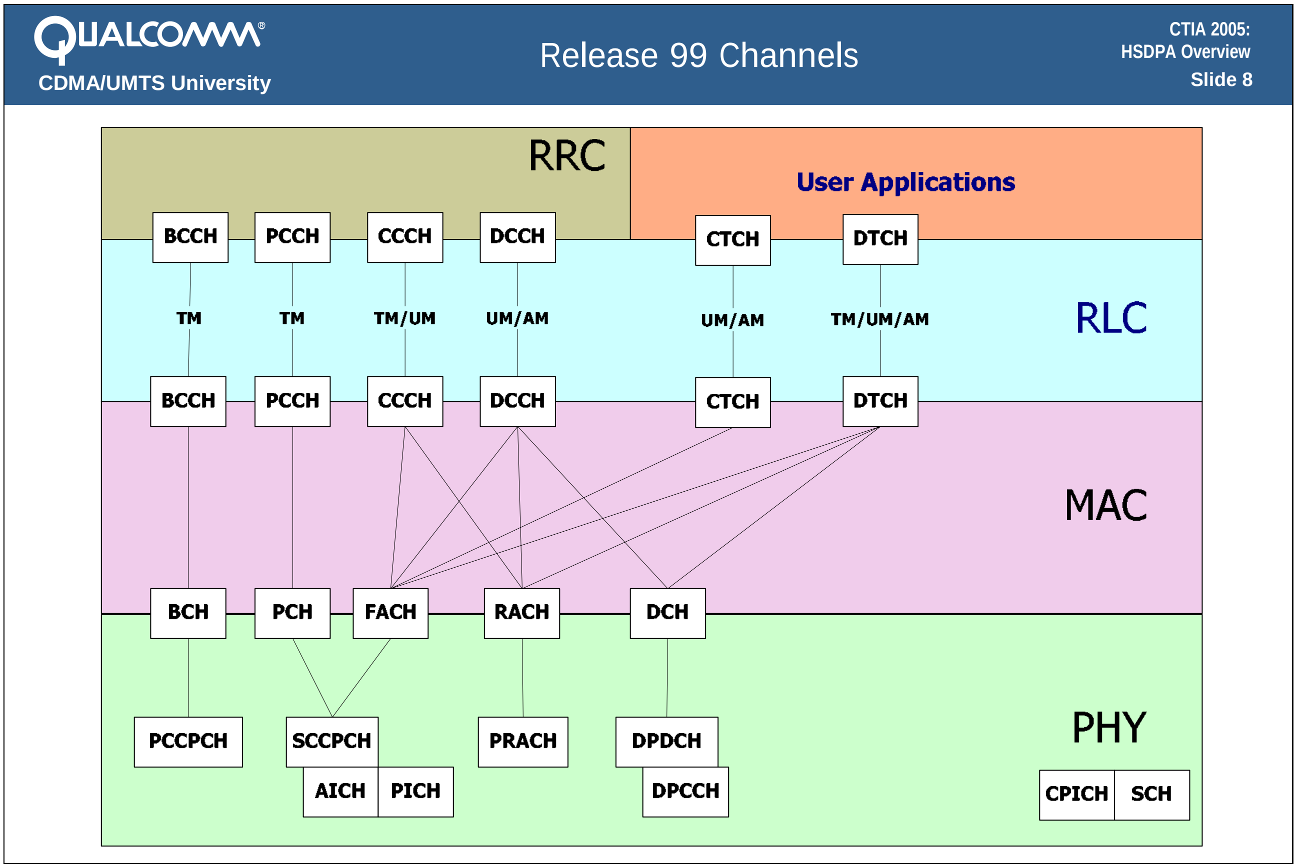


UMTS Protocol Stack

The UMTS signaling protocol stack is divided into an Access Stratum (AS) and a Non-Access Stratum (NAS). The Non-Access Stratum architecture evolved from the GSM/GPRS upper layers and is divided into Circuit Switched (CS) and Packet Switched (PS) protocols.

The Access Stratum consists of 3 layers:

- **Layer 3 –** The Radio Resource Control (RRC) layer handles establishment, release, and configuration of radio resources.
- **Layer 2 –** Consists of two sublayers. The Radio Link Control (RLC) sublayer provides segmentation, reassembly, duplicate detection, and other traditional Layer 2 functions. The Medium Access Control (MAC) sublayer multiplexes data and signaling onto the appropriate channels and controls access to the Physical Layer.
- **Layer 1 –** The Physical Layer transfers data over the radio link.



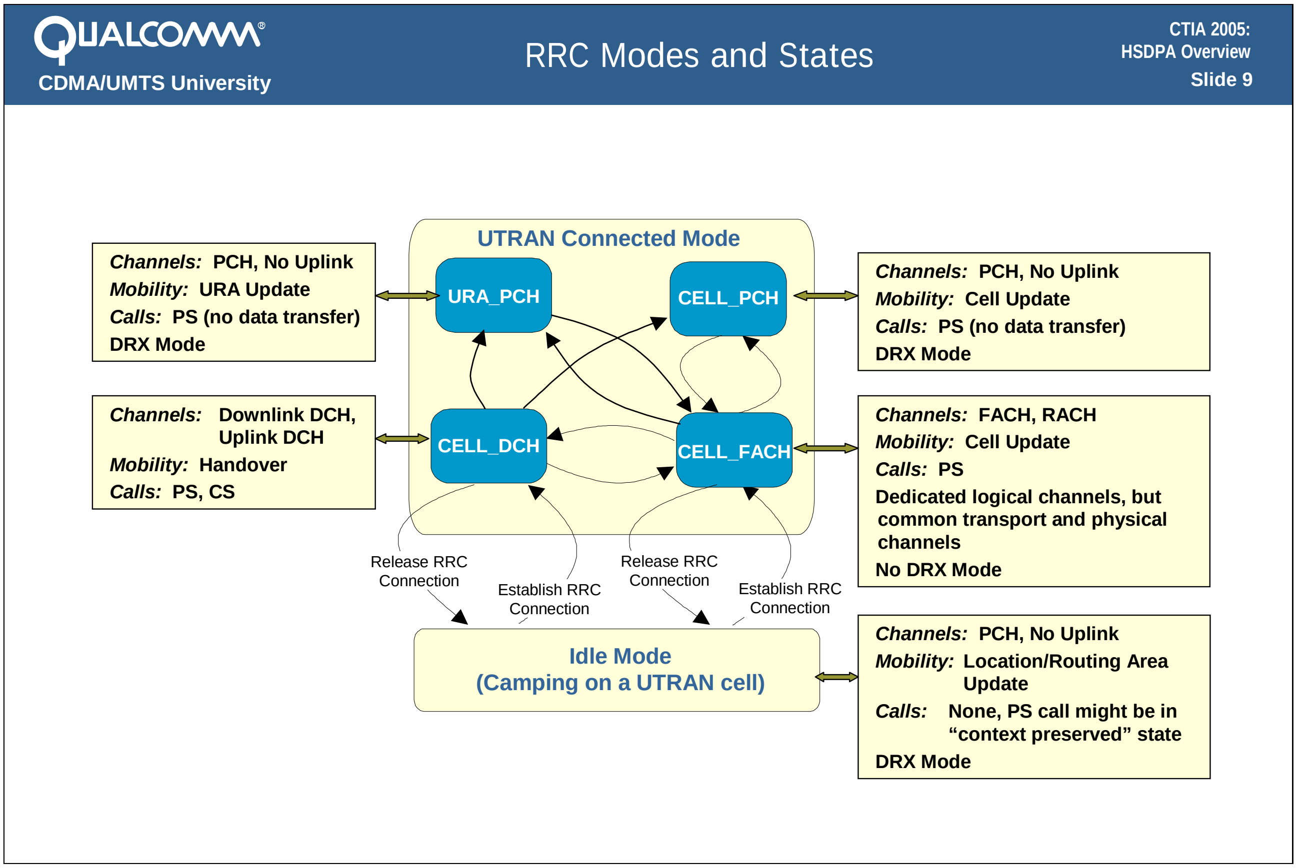
Release 99 Channels

This diagram shows possible mappings of logical, transport, and physical channels in the control and user planes for UMTS Release 99.

Some channels exist only in the Physical Layer (CPICH, SCH, DPCCH, AICH, PICH). These channels carry no upper layer signaling or user data.

Transport channels carry the following types of information:

- **Broadcast Control Channel (BCH) –** Broadcast information that defines overall system configuration
- **Paging Channel (PCH) –** Paging notification messages. A Paging Indicator Channel (PICH) is associated with a PCH to allow a UE to quickly determine whether it needs to read the PCH during its assigned paging occasion.
- **Forward Access Channel (FACH) –** Common Downlink signaling messages. Also carries dedicated Downlink signaling and user information to a UE operating in Cell_FACH state. An Acquisition Indicator Channel (AICH) is associated with a FACH channel.
- **Random Access Channel (RACH) –** Common Uplink signaling messages. Also carries dedicated Uplink signaling and user information to a UE operating in Cell_FACH state.
- **Dedicated Channel (DCH) –** Dedicated signaling and user information for a UE operating in the Cell_DCH state. DCH is mapped to a Dedicated Physical Data Channel (DPDCH). An associated Dedicated Physical Control Channel (DPCCH) carries Physical Layer control information, such as power control commands.



RRC Modes and States

RRC Modes:

- Idle Mode
- UTRAN Connected Mode

UTRAN Connected Mode:

- CELL_DCH
- CELL_FACH
- CELL_PCH
- URA_PCH

RRC Connection: Between UE and RNC

- Registration (Attach, Location/Routing Area Update, URA Update): Between UE and Core Network (SGSN or MSC)

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How do we do Packet Data in Release 99?

Mode	DCH	FACH
Channel Type	Dedicated	Common
Power Control	Closed inner loop at 1500 Hz - slow outer loop	None or slow (based on measurement reports)
Soft Handoff	Supported	Not supported
Setup Time	High	Low
Suitability for Bursty Data	Poor	Good
Data Traffic Volume	High	Low
Radio Performance	Good	Poor

Summary of PS Data on DCH and FACH

CELL_DCH and CELL_FACH are the two Release 99 techniques typically used for packet switched data in practice. The advantages and disadvantages of each approach are apparent:

- Whereas DCH is suited for high data traffic volumes (with a maximum rate of 384 kbps), setup time is slow, making it unsuitable and inefficient for bursty data such as a web browsing application.
- By contrast, FACH has a low setup time but is a common channel without power control or other mechanism to account for channel conditions. This makes it highly suitable for bursty traffic but unsuitable for larger traffic volumes.

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What Are the Goals of HSDPA?

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HSDPA Overview
Slide 11

HSDPA goals:

- ✓ Higher Data Rate
- ✓ Higher Throughput / Increased System Capacity
- ✓ Lower Delay

Notes

HSDPA Basic Concepts

- **Extension of Release 99 DSCH**
- **Common Channel for data transfer**
- **Multi-code operation**
- **Adaptive Modulation and Coding**
  - QPSK and 16QAM
  - Coding from R=1/3 to R=1
- **Fast retransmissions**
  - H-ARQ
    - Link level retransmissions
    - Chase combining/incremental redundancy
- **Fast scheduling**
  - Based on Channel Quality Feedback
- **2 ms Transmission Time Interval (3 slots)**

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Common Channel for Data Transfer

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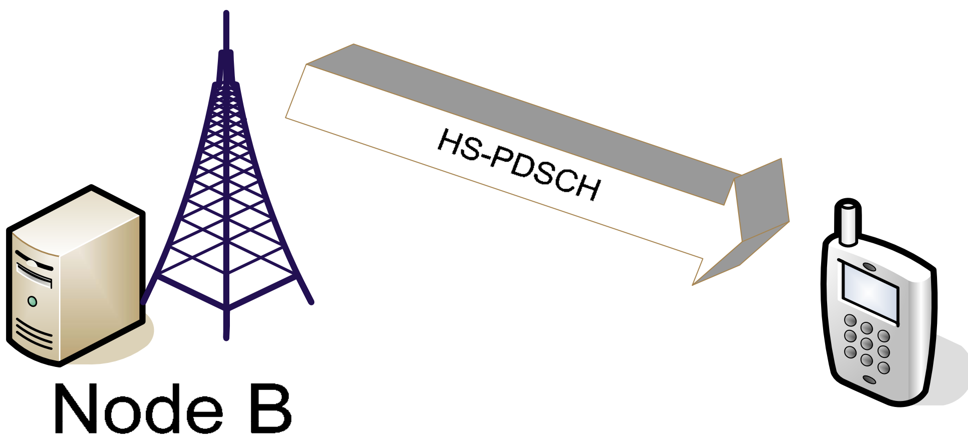
HSDPA Overview
Slide 13

Common Channel for data transfer using the HS-PDSCH:



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Multi-Code Operation

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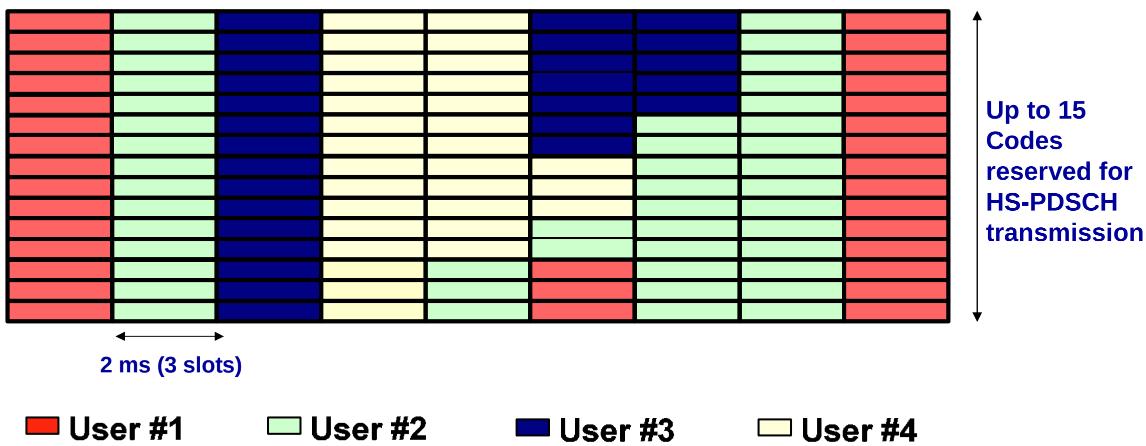
HSDPA Overview
Slide 14

- **Fixed Spreading Factor SF=16**
  - (Typical Spreading Factor for 128 kbps in Release 99)
- **1-15 codes can be reserved for HS-PDSCH.**
- **Can be TDM or CDM between users.**



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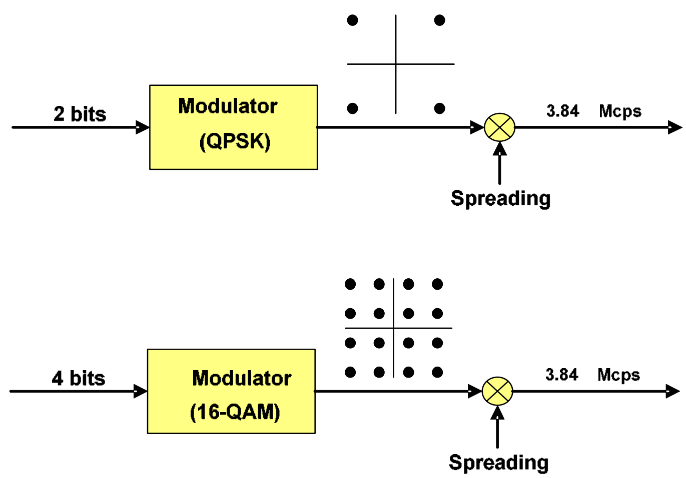
Adaptive Modulation and Coding

- **Coding from R=1/3 to R=1**
- **HSPDA supports 16QAM modulation**
  - 4 bits per symbol versus 2 bits per symbol with QPSK



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Link Adaptation versus Power Control

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HSDPA Overview
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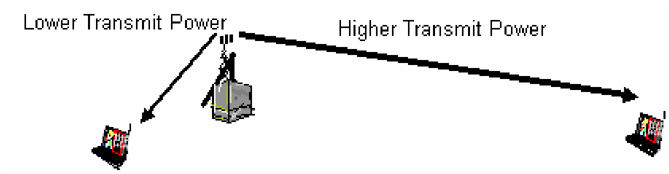
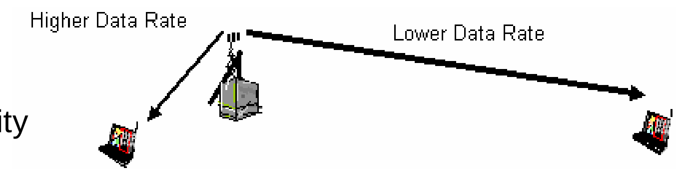
- **Release 99**
  - Uses fast power control with fixed data rate (DCH)



- **HSDPA**
  - Adapts the modulation and coding to the link quality

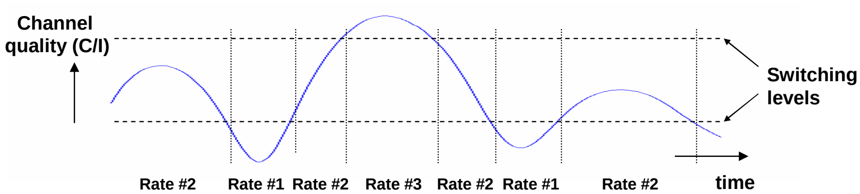


Fast Link adaptation:

Rate #1: e.g., QPSK, R=1/2

Rate #2: e.g., QPSK, R=3/4

Rate #3: e.g., 16QAM, R=3/4



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Scheduling Comparison

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HSDPA Overview
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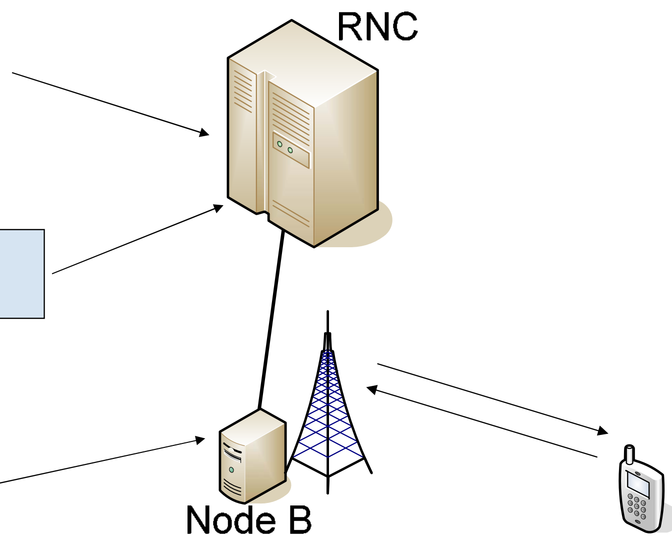
RELEASE 99
Scheduling
RLC ARQ
Resource Allocation

RELEASE 5 (HSDPA)
RLC ARQ

RELEASE 5 (HSDPA)
Scheduling
Link Adaptation
H-ARQ
Resource Allocation



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HSDPA Scheduling and Retransmissions

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- **Scheduling**
  - Done at the Node B
  - No interaction with the RNC
  - Based on Channel Quality Feedback from the UE
- **Retransmissions**
  - H-ARQ (link level retransmissions)
  - Done at the Node B
  - Based on UE feedback (ACK/NAK)
  - Soft combining at the UE

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H-ARQ

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HSDPA Overview
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Hybrid Automatic Repeat Request (H-ARQ)

- **Scheme combining ARQ and Forward Error Correction (FEC)**
- **FEC Decoder uses unsuccessful transmissions.**
- **Two schemes are supported:**
  - Chase Combining
    - Maximal Ratio Combining on transmissions of the same block
  - Incremental Redundancy (IR)
    - Additional Redundant Information sent after each unsuccessful transmission
- **Multiple H-ARQ processes are allowed.**
  - Enables consecutive assignments.

Notes

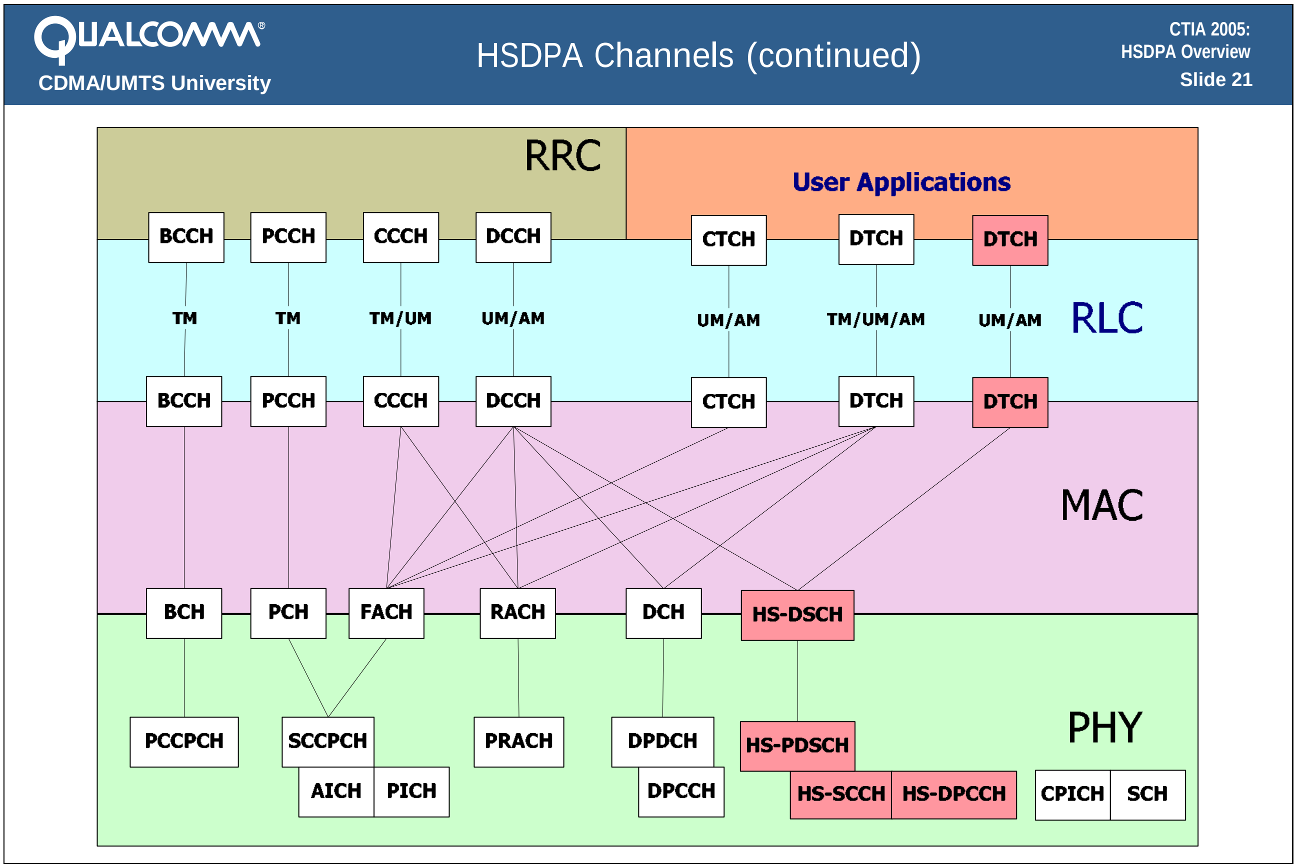
New HSDPA Channels:

- **Transport Layer Channel**
  - High Speed Downlink Shared Channel (HS-DSCH)
    - *Downlink* Transport Channel
- **Physical Layer Channels**
  - High Speed Physical Downlink Shared Channel (HS-PDSCH)
    - *Downlink* Physical Channel
  - High Speed Shared Control Channel (HS-SCCH)
    - *Downlink* Control Channel
  - High Speed Dedicated Physical Control Channel (HS-DPCCH)
    - *Uplink* Control Channel
- **HS-Channels always associated with a Release 99 DPCH.**

HSDPA Channels

HSDPA introduces three new Downlink channels and one new Uplink channel:

- **High Speed Downlink Shared Channel (HS-DSCH) –** A Downlink transport channel shared by several UEs. The HS-DSCH is associated with one or several Shared Control Channels (HS-SCCH). It operates on a 2 ms Transmission Time Interval (TTI).
- **High Speed Shared Control Channel (HS-SCCH) –** A Downlink physical channel used to carry Downlink control information related to HS-DSCH transmission. The UE monitors this channel continuously to determine when to read its data from the HS-DSCH, and the modulation scheme used on the assigned physical channel.
- **High Speed Physical Downlink Shared Channel (HS-PDSCH) –** A Downlink physical channel shared by several UEs. It supports Quadrature Phase Shift Keying (QPSK), 16-Quadrature Amplitude Modulation (16-QAM), and multi-code transmission. It is allocated to a user at 2 ms intervals.
- **High Speed Dedicated Physical Control Channel (HS-DPCCH) –** An Uplink physical channel that carries feedback from the UE to assist the Node B's scheduling algorithm. The feedback includes a Channel Quality Indicator (CQI) and a positive or negative acknowledgement (ACK/NAK) of a previous HS-DSCH transmission.



HSDPA Channels (continued)

Only dedicated logical channels may be mapped to HS-DSCH. The Dedicated Signaling Channel (DCCH) may be mapped to HS-DSCH, though the more important mapping is to DTCH, which carries user data. When DTCH is mapped to HS-DSCH, only Unacknowledged Mode (UM) and Acknowledged Mode (AM) channels may be used.

A UE operating in HSDPA mode also has at least one Release 99 dedicated channel (DCH/ DPDCH) allocated, to ensure that RRC and NAS signaling can always be sent, even if the UE cannot receive the high speed channels.

The HS-DPCCH is a Physical Layer control channel. It carries no upper layer information, and therefore has no logical or transport channel mapping.

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Functional Overview

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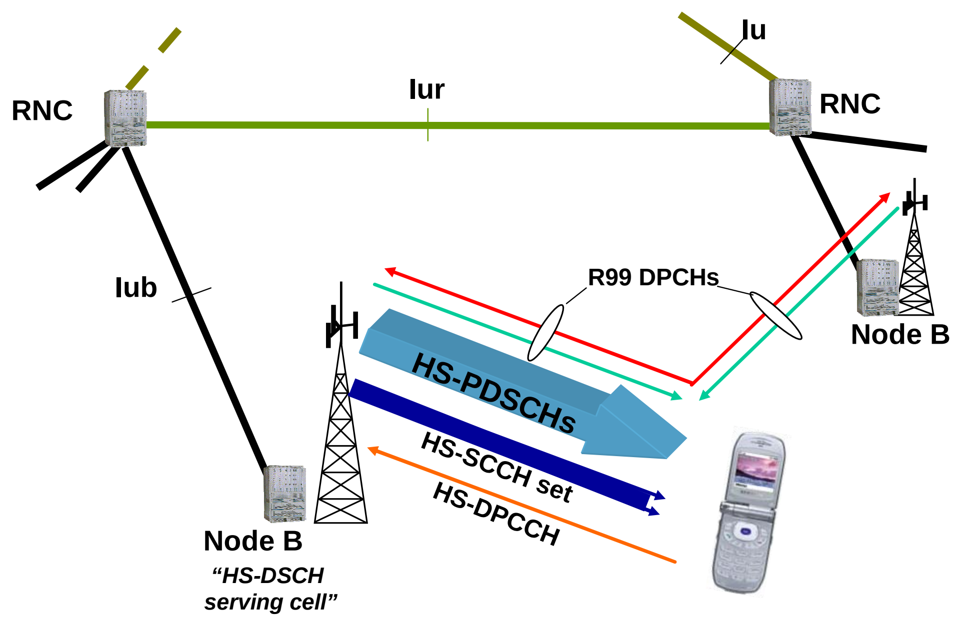

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HS-PDSCH

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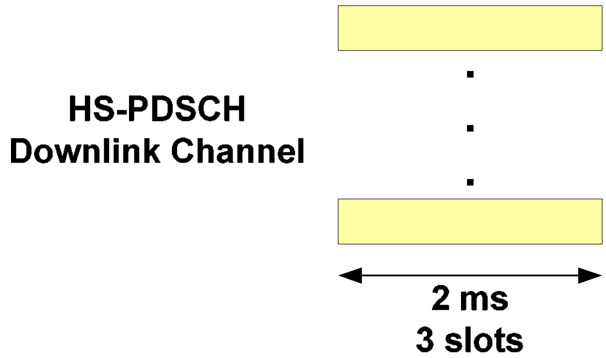

High Speed Physical Downlink Shared Channel (HS-PDSCH)

- Carries UE data.
- Up to 15 HS-PDSCH may be assigned simultaneously.
  - UE capability indicates maximum number of codes it supports.
- Always uses Spreading Factor 16.
- No Power Control
  - Amount of power is allocated by the Node B.

HS-PDSCH

When the UE decodes the HS-SCCH and determines that there is an HS-DSCH assignment in the next TTI, it decodes the assigned HS-PDSCHs. Each HS-PDSCH uses an OVSF of length 16. If multiple HS-PDSCHs are assigned simultaneously to one UE, they must use consecutive OVSF codes. The HS-SCCH indicates the first OVSF code and the number of codes for each assignment.

A UE is a member of one of 12 categories, as a function of its hardware capabilities. Each category represents different values of the following parameters:

- Number of simultaneous HS-PDSCH codes (5, 10, or 15)
- Maximum transport block size
- Inter-TTI interval – minimum time between consecutive assignments.
- Incremental redundancy buffer size – used to soft-combine symbols from retransmissions

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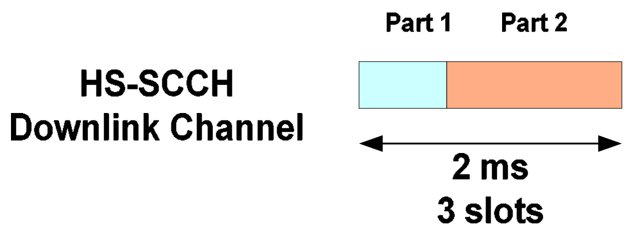

High Speed Shared Control Channel (HS-SCCH)

- 1st slot carries modulation information.
  - OVSF code assignment
  - Modulation scheme
- 2nd and 3rd slots carry transport block size, Hybrid ARQ parameters.
- UE Identity encoded over each slot.
- UE assigned up to 4 HS-SCCHs to monitor.
- Uses Spreading Factor = 128
  - Code not fixed

HS-SCCH

Whenever the UE is operating in HSDPA mode, it continuously monitors up to four HS-SCCH channels. Each HS-SCCH transmission carries scheduling information about the next HS-DSCH assignment and the Physical Layer parameters of the associated HS-PDSCH.

- **OVSF Code Assignment** – The HS-SCCH indicates which of the OVSF codes allocated to the HS-PDSCHs will be used. HS-PDSCH uses multi-code transmission, which means that multiple OVSF codes may be assigned to one UE at the same time
- **Modulation Scheme** – HS-PDSCH uses either QPSK or 16-QAM modulation. This can change from one assignment to the next, and HS-SCCH indicates which method is used.
- **Transport Block Size** – The HS-SCCH indicates how much data will be sent during the next assignment.
- **Hybrid ARQ (H-ARQ) Parameters** – The H-ARQ protocol supports retransmissions and incremental redundancy. These parameters allow the UE to differentiate new transmissions from retransmissions.
- **UE Identity** – Multiple UEs may be monitoring the same set of HS-SCCHs. Each UE has an assigned identity called the H-RNTI. The information sent on the HS-SCCH is scrambled using the H-RNTI so that a UE can determine whether the corresponding HS-DSCH assignment carries its data or data belonging to another UE.

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HS-DPCCH

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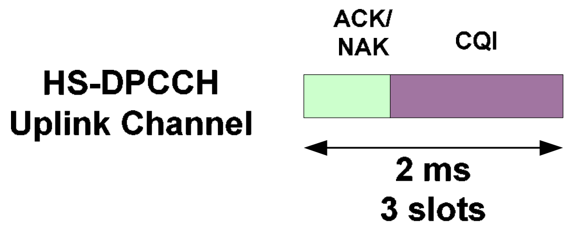


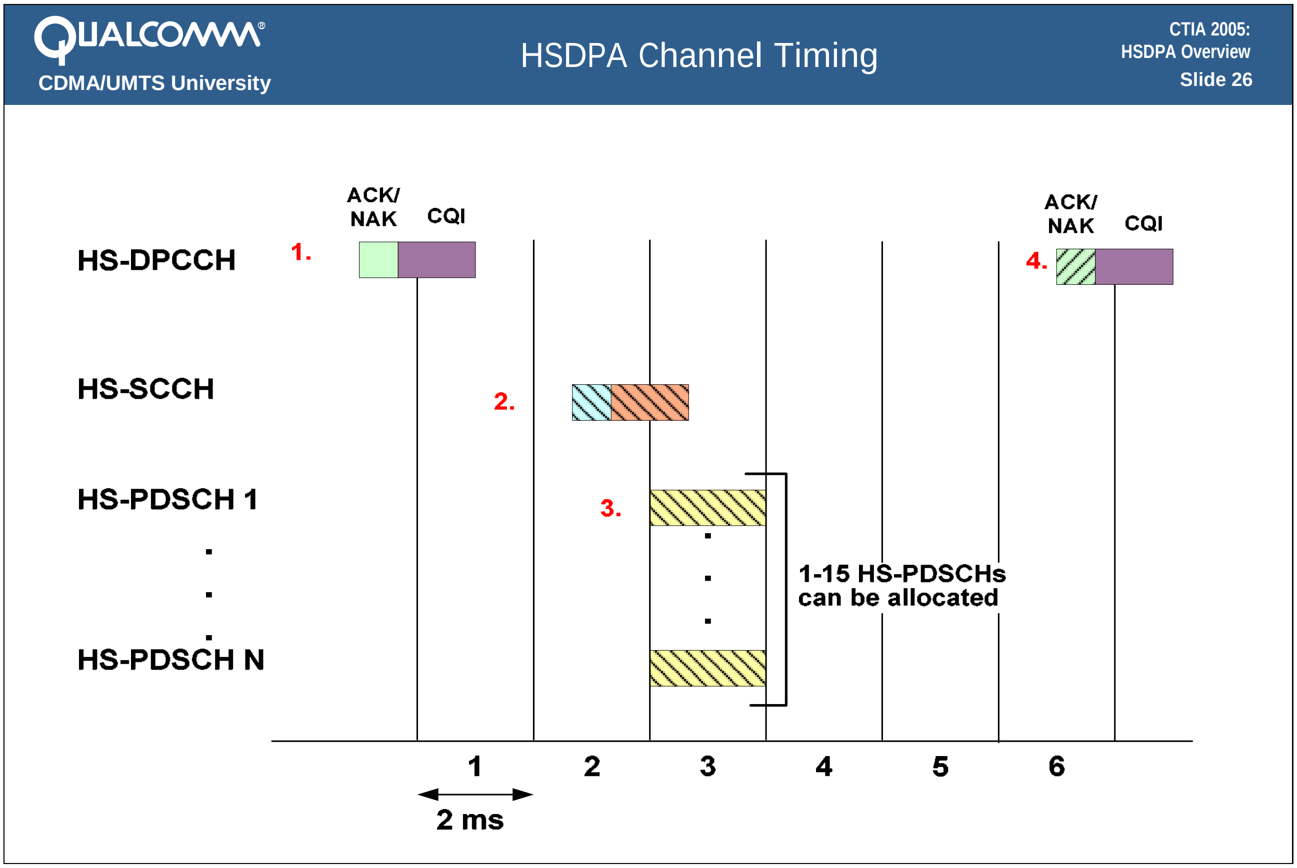
High Speed Dedicated Physical Control Channel (HS-PDCCH)

- 1st slot carries ACK or NAK for received HS-DSCH blocks
- 2nd and 3rd slots carry Channel Quality Indicator (CQI)
  - UE measures Downlink CPICH channel quality
  - CQI indicates the highest data rate for error rate < 10%
  - Frequency of CQI reports configured by UTRAN
- DTX during ACK/NAK and/or CQI slots if nothing to send
- Uses Spreading Factor = 256

HS-DPCCH

Whenever the UE is operating in HSDPA mode, it uses the HS-DPCCH to give feedback to the serving Node B. This feedback consists of two parts:

- **ACK/NAK** – The UE sends a positive or negative acknowledgement for each HS-DSCH assignment. UTRAN may configure the UE to repeat the ACK/NAK, up to a maximum of 4 transmissions. The first ACK/NAK for a given HS-DSCH assignment is sent 5 ms (7.5 slots) after the end of the HS-DSCH transmission.
- **Channel Quality Indicator (CQI)** – The UE measures the channel quality of the downlink CPICH and computes a CQI value. The value is an index into a table, and corresponds to the maximum data rate that the UE can decode with an error rate of less than 10%, assuming the channel conditions do not change. UTRAN may configure the UE to repeat the CQI, up to a maximum of 4 transmissions. UTRAN may also configure the periodicity of CQI reporting, ranging from 2 ms to 160 ms.



HSDPA Channel Timing

HSDPD channel timing is based on a time interval of 2 ms, or 3 slots.

This slide illustrates a single HSDPA channel assignment. Consecutive assignments to a single UE allow the theoretical maximum HSDPA data rate to be achieved.

1. The UE measures the Downlink channel quality and sends a Channel Quality Indicator (CQI) report on the HS-DPCCH. An ACK or NAK from a previously received block may also be included in this transmission.
2. If the Node B decides to send data to the UE, it sends information on the HS-SCCH to assign the physical channel and give the UE information about how the data was encoded.
3. During the next 2 ms HS-DSCH transmission time, one or more HS-PDSCHs carry the UE's data. The HS-SCCH transmission overlaps the HS-PDSCH transmission.
4. After the UE decodes the data, it sends an ACK or NAK on the HS-DPCCH. The UE must send the ACK or NAK 5 ms after the end of the HS-DSCH transmission. If the UE sends a NAK, the Node B may send the data again during a later time slot, or may choose not to retransmit the data. A CQI report may also be included in this transmission.

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Data Rate Example

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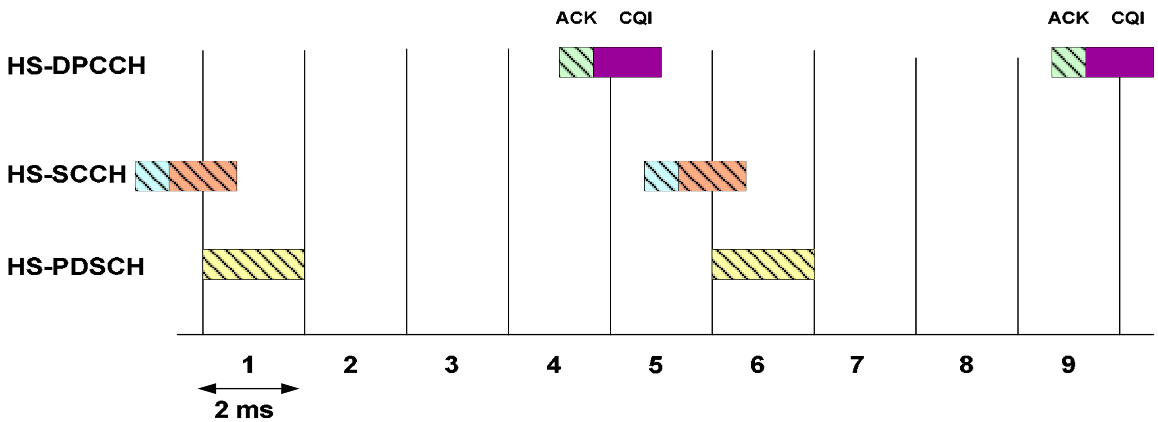
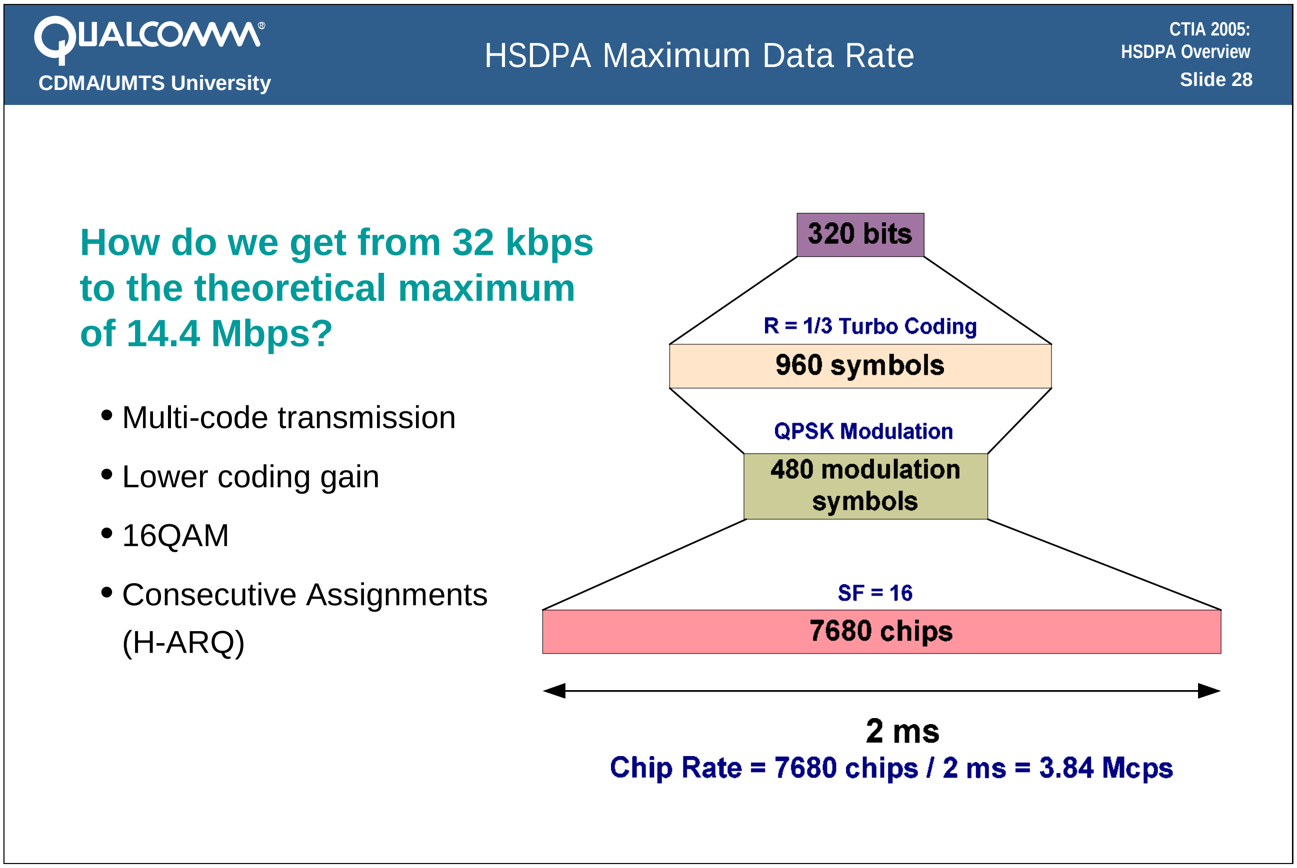


Data Rate Example

Assuming a transport block size of 320 bits, the data rate achieved in this example with a UE using the channel allocation timing shown above is **32 kbps** (320 bits every 10 ms).

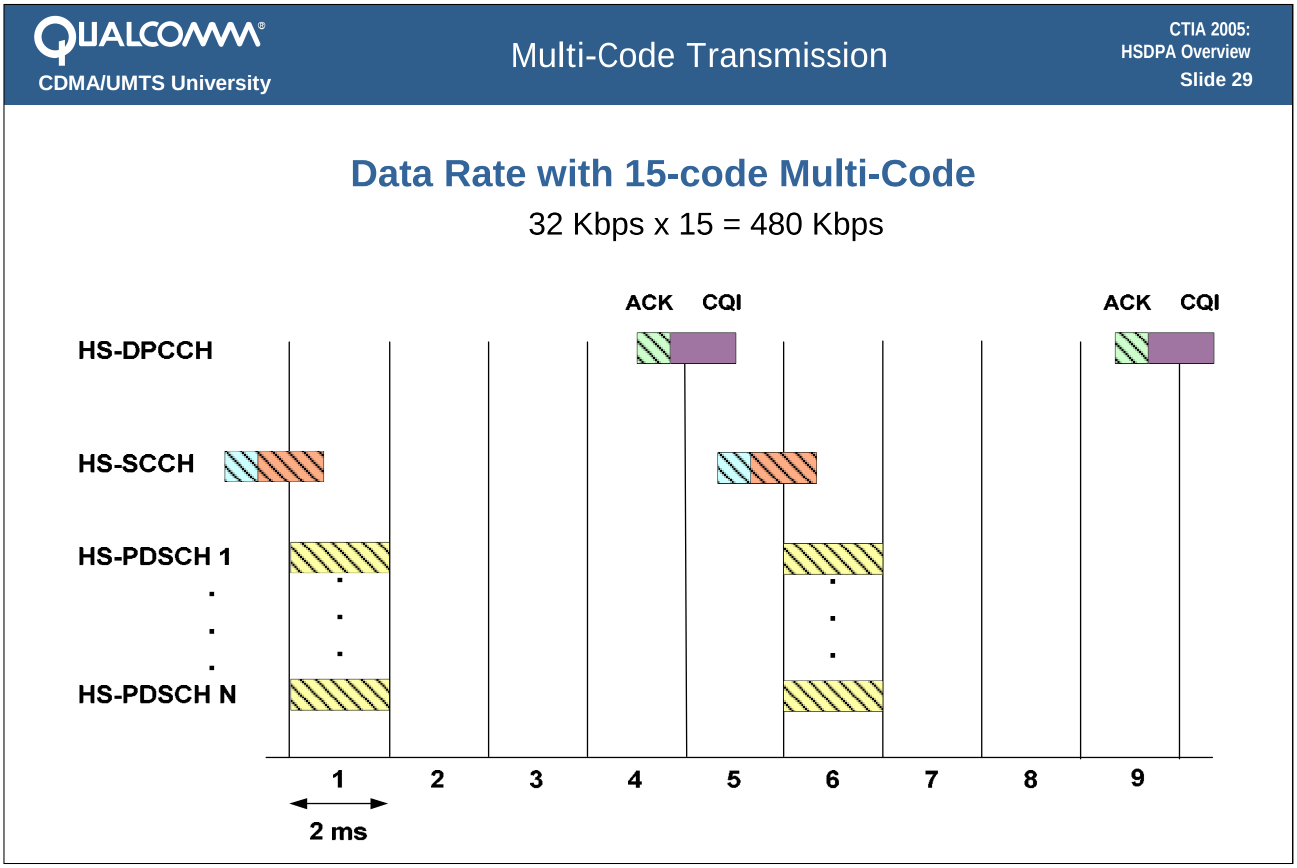
Notes



HSDPA Maximum Data Rate

The theoretical maximum data rate is 14.4 Mbps. The following techniques are used to achieve this data rate:

- **Multi-code transmission** – Up to 15 HS-PDSCH channels may be assigned to a single UE during one 2 ms TTI.
- **Lower coding gain** – The block size of 320 bits was chosen assuming a Turbo code rate of 1/3. Higher data rates can be achieved puncturing more bits to for a higher effective code rate (and thus lower coding gain).
- **16-QAM –** This modulation scheme increases the data rate over QPSK by a factor of 2.
- **Consecutive assignments** – The Hybrid Automatic Repeat Request (H-ARQ) procedure allows the Node B to send back-to-back assignments at 2 ms intervals.

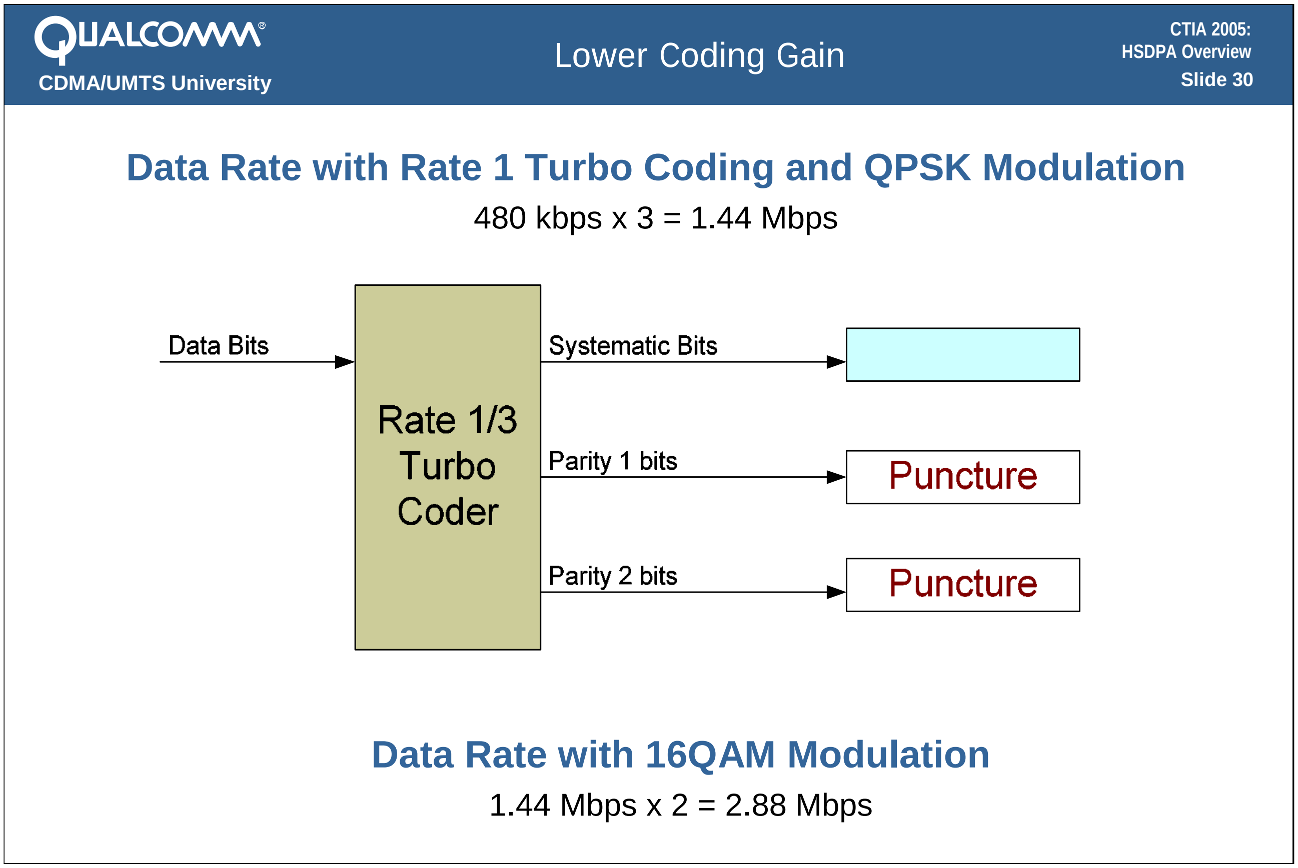


Multi-Code Transmission

HSDPA allows up to a 15-code multi-code. Each HS-PDSCH uses an OVSF of length 16. The Node B signals the number of codes to the UE in the HS-SCCH.

The number of codes supported by the UE is one factor in determining the UE's HSDPA category. The allowed choices are 5, 10, or 15 codes.

For a UE capable of handling the maximum number of codes, the data rate in the above example is 15 times greater than the single code assignment, or 480 Kbps.

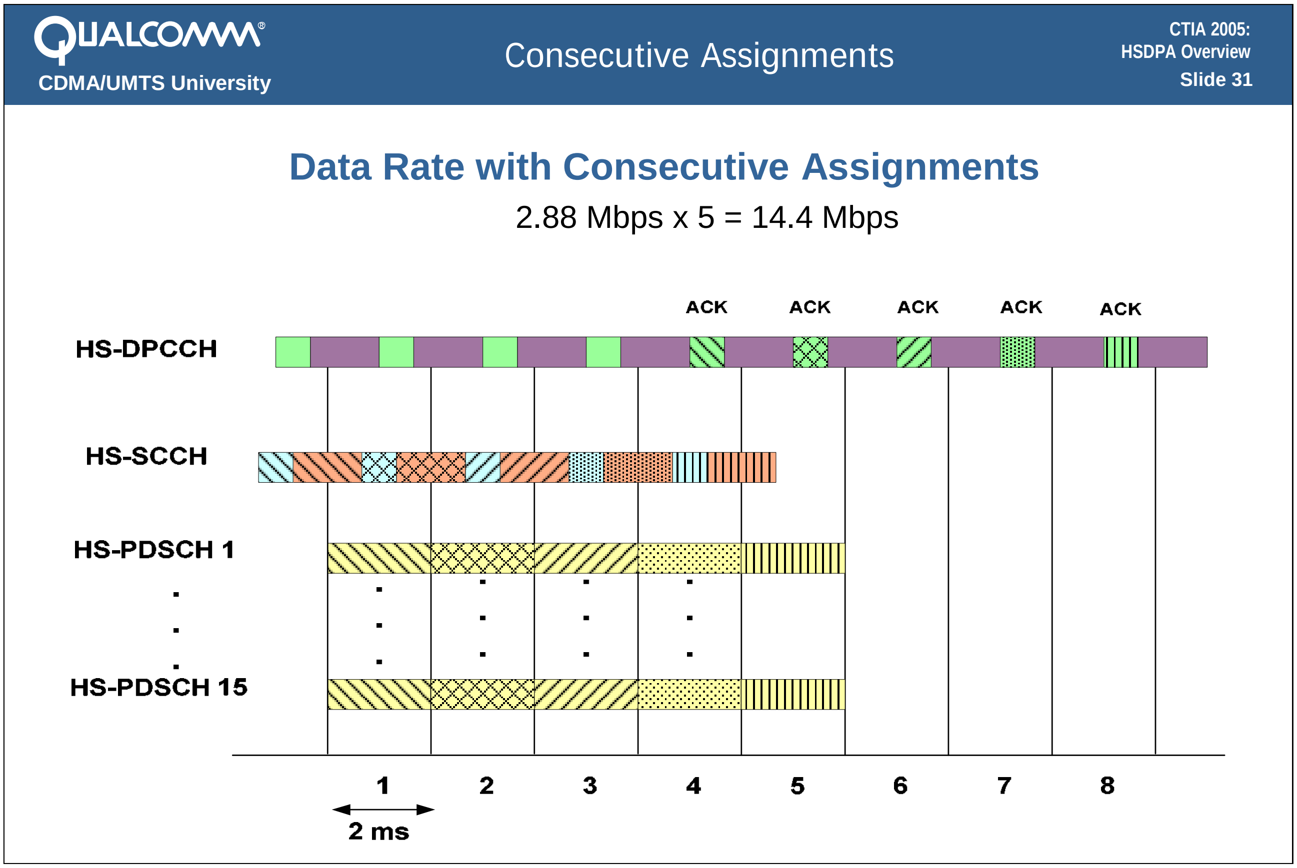


Lower Coding Gain

HSDPA allows the initial transmission of a data block to contain no parity bits, only systematic bits. Systematic bits are the original data bits that are input into the Turbo encoder. Sending only systematic bits produces an effective code rate of 1, resulting in a data rate 3 times the previous example, or 1.44 Mbps.

The H-ARQ procedure provides a mechanism for sending the parity bits in a later assignment if the UE is not able to decode the block using only systematic bits; however this will reduce the UE's overall throughput.

Using 16QAM modulation instead of QPSK produces an increase in data rate by a factor of 2 or 2.88 Mbps



Consecutive Assignments

HSDPA allows the channels to be assigned in consecutive TTIs to the same UE. In the UE, a simultaneous Hybrid Automatic Repeat Request (H-ARQ) processes operate in parallel to decode consecutive assignments. Each H-ARQ process is responsible for decoding one assignment, and transmitting the associated ACK or NAK 5 ms after the end of that assignment.

The UE can achieve a maximum data rate that is 5 times greater than in the previous example, or 14.4 Mbps, if all of the following conditions are met:

- The UE supports 15-code multi-code.
- The Node B assigns all 15 OVSF codes every TTI.
- Every data block is correctly decoded (the UE always sends an ACK).

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H-ARQ and Consecutive Assignments

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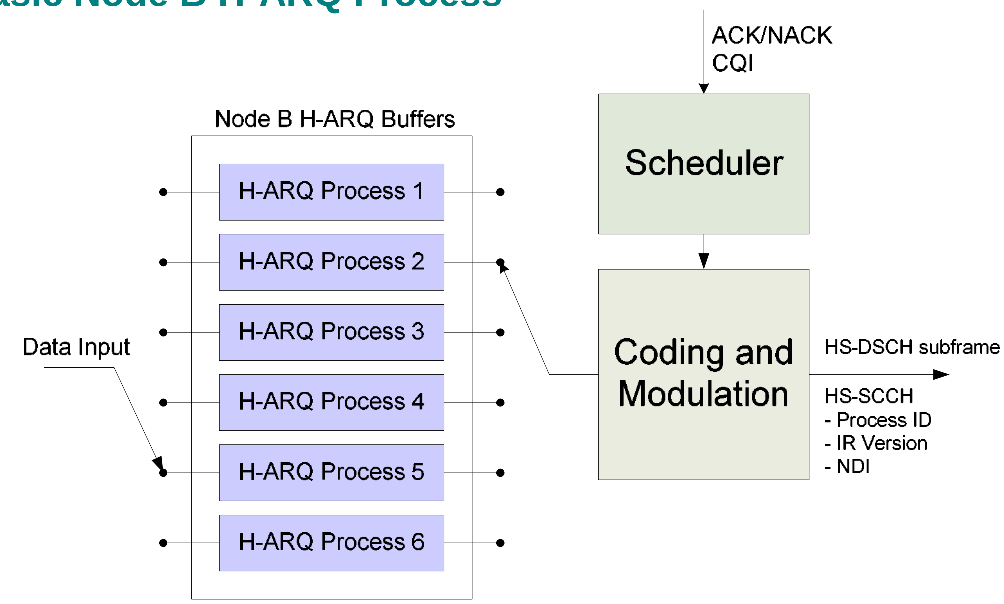
Basic Node B H-ARQ Process



Notes

Features of the H-ARQ Protocol

- Soft combining of multiple transmissions (Layer 1)
- Stop and Wait (SAW) protocol
- Synchronous ACK/NAK response
- Asynchronous retransmission
  - Minimum 10 ms
  - Typical 12 ms
- Priority pre-emption
  - Defer a lower priority retransmission by using another H-ARQ process
  - Flush previous block and send a new block (toggle New Data Indicator)

H-ARQ Protocol

The H-ARQ protocol supports the following features:

- **Soft combining** – If the UE NAKs a data block, the Node B may retransmit the data. The Physical Layer performs soft combining of the retransmitted symbols with those previously received.
- **Stop and Wait (SAW)** – Each H-ARQ process, up to a maximum of 8, operates independently on one data block until that block is correctly decoded or transmission is aborted by the Node B.
- **Synchronous ACK/NAK** – The UE transmits an ACK or NAK for a given block at a fixed time following reception of the data.
- **Asynchronous retransmission** – The Node B sends retransmissions any time after the Round Trip Time (RTT) has been met, where the minimum RTT is 10 ms and typical is 12 ms.
- **Priority Preemption** – The Node B can pre-empt a retransmission of a lower priority data block by choosing a different H-ARQ process, or by flushing the previous block and transmitting new data. The Node B H-ARQ process toggles the New Data Indicator (NDI) whenever it sends a new data block.

Review: How do we get to 14.4 Mbps?

- **Multi-code transmission**
  - Node B must allocate all 15 OVSF codes of length 16 to one UE.
- **Lower Coding Gain**
  - Effective code rate = 1
  - Requires very good channel conditions to decode.
- **16-QAM**
  - Requires very good channel conditions.
- **Consecutive assignments**
  - Node B must allocate all time slots to one UE.
  - UE must decode all transmissions correctly on the first transmission.

HSDPA Maximum Data Rate

To achieve the theoretical maximum data rate of 14.4 Mbps, the following assumptions are required:

- **Multi-code transmission** – All 15 HS-PDSCH channels must be assigned to a single UE during one 2 ms TTI. This uses up a significant portion of the OVSF tree, leaving very few codes for non-HSDPA users and overhead channels. Another OVSF tree could be allocated by using a Secondary Scrambling Code.
- **Consecutive assignments** – The Node B must send back-to-back assignments to a single UE, and the UE must be able to correctly decode every block without requiring retransmission.
- **Lower Coding Gain** – Using an effective code rate of 1 increases the data rate, but the channel conditions must be very good for the UE to correctly decode every data block on the first transmission.
- **16-QAM** – This modulation scheme works well only in very good channel conditions.

In a practical scenario, the practical maximum data rate will be considerably less than 14.4 Mbps, due to less than ideal channel conditions, the need for retransmission, and the need to share the channel with other HSDPA users and Release 99 users.

Subsequent slides discuss other factors that reduce the practical maximum data rate.

Factors Affecting Data Rate

- **UE Capability/Category**
  - **Number of Codes**
  - **Inter-TTI Interval**
    - Interval between consecutive assignments.
    - Depends on UE capability.
    - Allowed values are 1, 2, and 3.
- **Retransmissions**
  - NAK sent 5 ms after block received.
  - Minimum retransmit time is 10 ms.
  - Can be identical or different redundancy version.
- **ACK/NAK Repetition**
  - UE can be configured to repeat up to 4 times.
  - Disallows certain sub-frames for data transmission.

Notes

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UE Categories

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Category	Codes	Inter-TTI	Max TB size	IR Buffer Size	Peak Rate
1	5	3	7298	19200**	1.2 Mbps
2	5	3	7298	28800	1.2 Mbps
3	5	2	7298	28800**	1.8 Mbps
4	5	2	7298	38400	1.8 Mbps
5	5	1	7298	57600**	3.6 Mbps
6	5	1	7298	67200	3.6 Mbps
7	10	1	14411	115200**	7.2 Mbps
8	10	1	14411	134400	7.2 Mbps
9	15	1	20251	172800**	10.1 Mbps
10	15	1	27952	172800	14.0 Mbps
11*	5	2	3630	14400**	0.9 Mbps
12*	5	1	3630	28800	1.8 Mbps

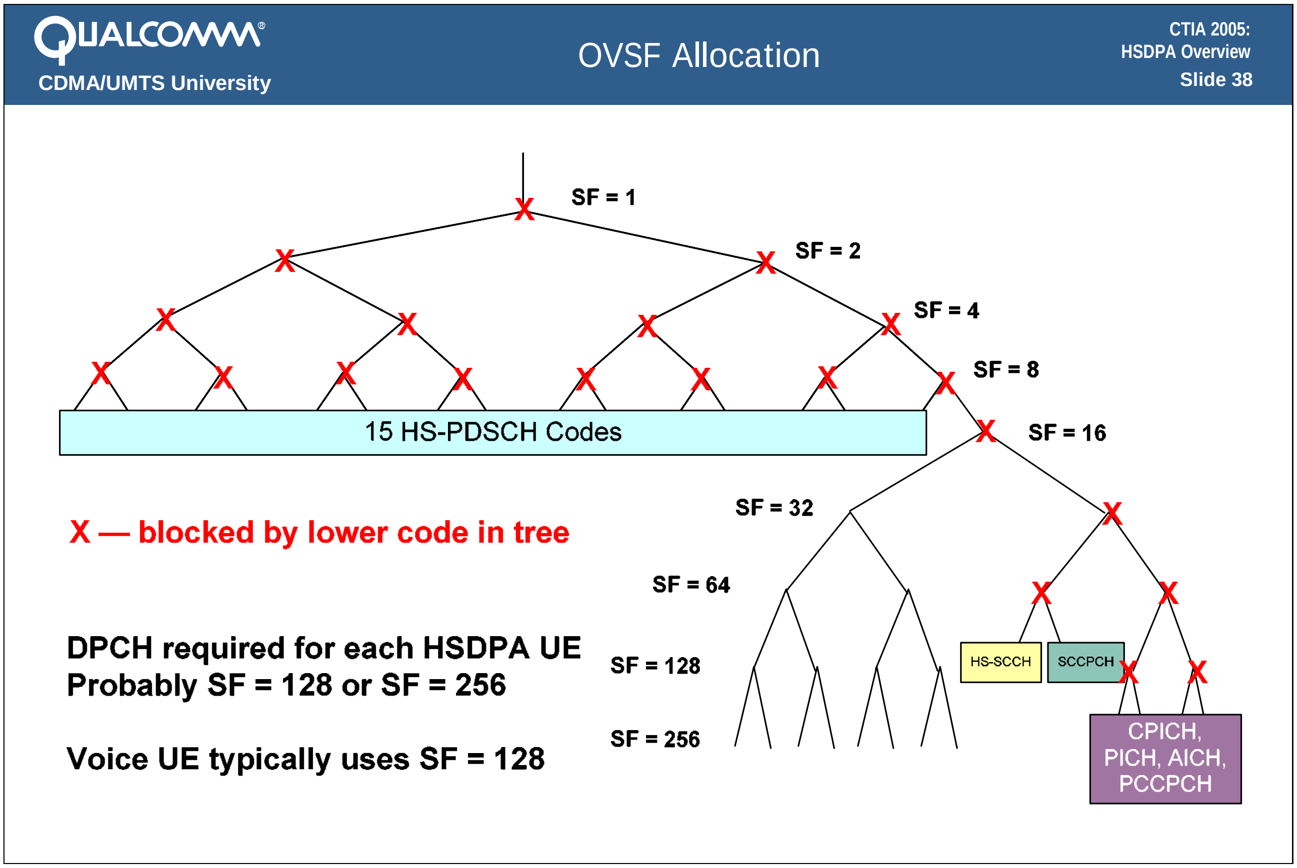
*** No 16-QAM**
****IR buffer size=maximum # of channel bits across all H-ARQ processes**

Notes

Other Considerations

- OVSF Allocation
- Node B Transmit Power Allocation
- CQI Report Processing
- Node B Scheduler
- Change of Serving Node B

Notes



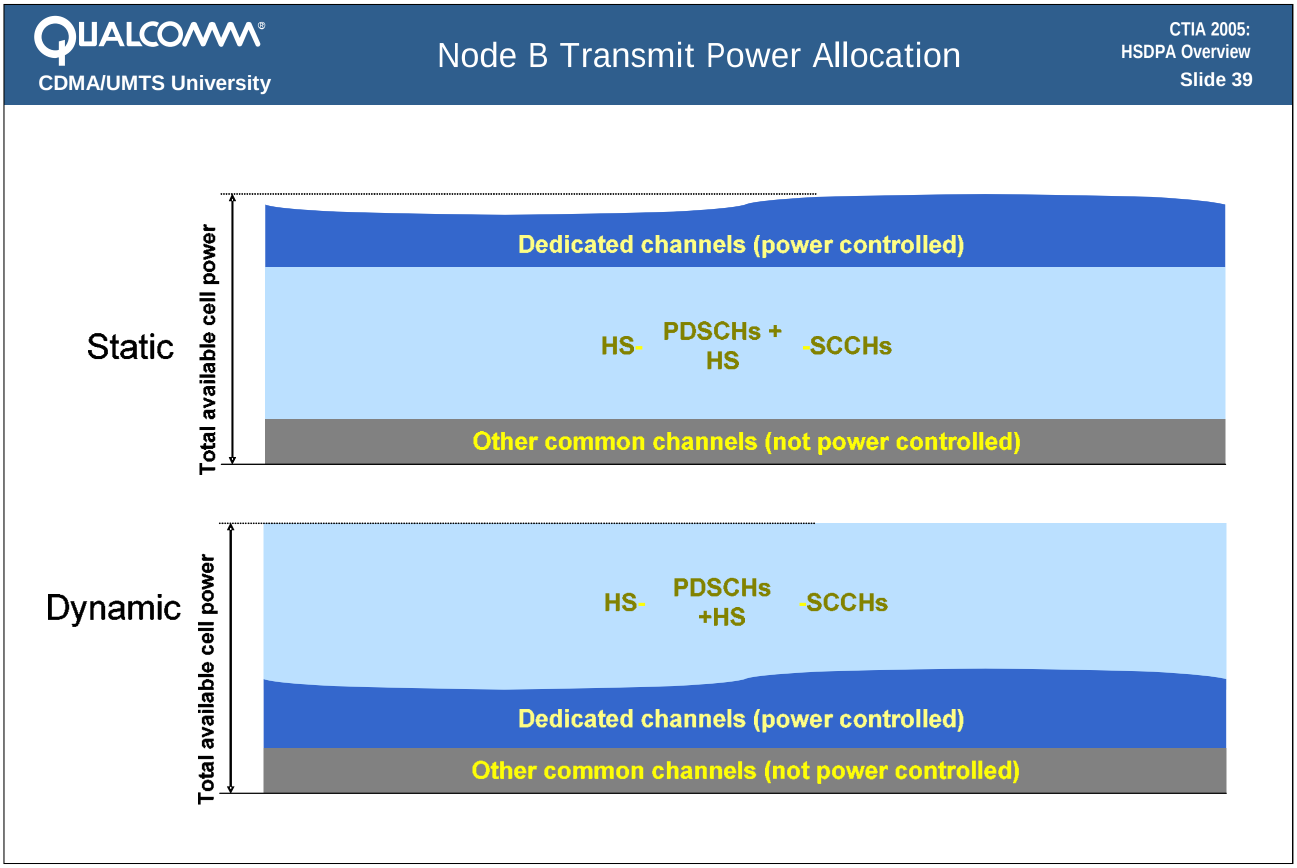
OVSF Allocation

Each HS-PDSCH uses an OVSF of length 16, which blocks all codes above and below it in the OVSF code tree. Each HS-SCCH uses an OVSF of length 128.

The illustration above shows a possible OVSF allocation if 15 HS-PDSCH codes are used and only 1 HS-SCCH.

- If only one HS-SCCH is used, then only one UE can operate in HSDPA during each 2 ms TTI.
- The overhead channels CPICH, PICH, AICH, and PCCPCH require codes of length 256.
- SCCPCH spreading factor is configurable, but SF = 128 is typical.
- Each HSDPA user requires a DPCH in addition to its high speed channel. The spreading factor of this channel is configurable.
- If voice users are supported in the same cell, they typically use codes with SF = 128.

The conclusion to be drawn is that using 15 HS-PDSCH codes is not practical unless the cell is dedicated to HSDPA users.



Node B Transmit Power Allocation

The Node B transmit power allocation algorithm is not specified by the standard, but two possible schemes are likely:

- **Static** – A fixed amount of power is allocated to the HS-PDSCHs and HS-SCCHs. Remaining power is distributed among common channels and power controlled dedicated channels. The overall transmit power fluctuates as a function of the power controlled channels.
- **Dynamic** – HS-PDSCH and HS-SCCH power is allocated dynamically as a function of the remaining available power, which fluctuates due to the power controlled dedicated channels. The overall transmit power of the cell remains constant.

The above diagram does not consider the Node B's power margin, whereby the Node B's power fluctuates. The Node B power does not really remain constant, due to the peak-to-average ratio of transmit power.

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CQI Report Processing

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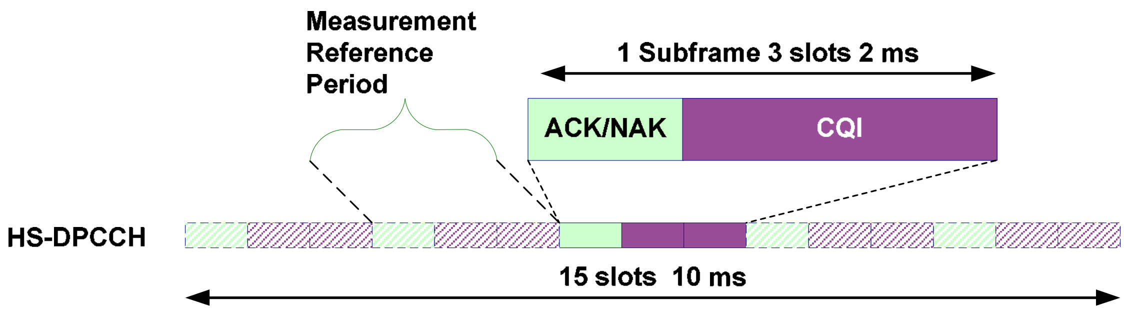
- **UE measures CPICH strength:**
  - Measure over 3 slots, ending 1 slot before CQI is sent.
- **UE reports index into CQI Table:**
  - Highest data rate for which UE can guarantee error rate < 10%.
- **Node B may filter CQI reports:**
  - Varying CQI means UE is in a fast changing environment.
  - Steady CQI means UE is in a stable environment.



CQI Report Processing

The Node B may use the UE's Channel Quality Indicator (CQI) reports in its scheduling algorithm. The details of this are implementation-dependent.

When the UE is required to perform CQI reporting, it measures the CPICH strength over a 3-slot period ending 1 slot before the CQI is sent. The value reported is an index into a table, where each row of the table maps to a combination of:

- Transport block size
- Number of HS-PDSCH codes
- Modulation Scheme (QPSK or 16-QAM)
- Reference power adjustment

The CQI reported corresponds to the highest data rate that the UE can decode with an error rate less than 10%, assuming the channel conditions and transmit power stay at the same level as in the reference period.

The reference power adjustment maps to a negative value when the channel conditions are so good that the UE can decode the highest data rate at a lower power level than is currently being used.

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CQI Report Processing – Example CQI Table: 5 Codes

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CQI	TB Size	Number of Codes	Modulation	Reference power adjustment □	CQI	TB Size	Number of Codes	Modulation	Reference power adjustment □
0	N/A	Out of range			15	3319	5	QPSK	0
1	137	1	QPSK	0	16	3565	5	16-QAM	0
2	173	1	QPSK	0	17	4189	5	16-QAM	0
3	233	1	QPSK	0	18	4664	5	16-QAM	0
4	317	1	QPSK	0	19	5287	5	16-QAM	0
5	377	1	QPSK	0	20	5887	5	16-QAM	0
6	461	1	QPSK	0	21	6554	5	16-QAM	0
7	650	2	QPSK	0	22	7168	5	16-QAM	0
8	792	2	QPSK	0	23	7168	5	16-QAM	-1
9	931	2	QPSK	0	24	7168	5	16-QAM	-2
10	1262	3	QPSK	0	25	7168	5	16-QAM	-3
11	1483	3	QPSK	0	26	7168	5	16-QAM	-4
12	1742	3	QPSK	0	27	7168	5	16-QAM	-5
13	2279	4	QPSK	0	28	7168	5	16-QAM	-6
14	2583	4	QPSK	0	29	7168	5	16-QAM	-7
15	3319	5	QPSK	0	30	7168	5	16-QAM	-8

Notes

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Node B Scheduler

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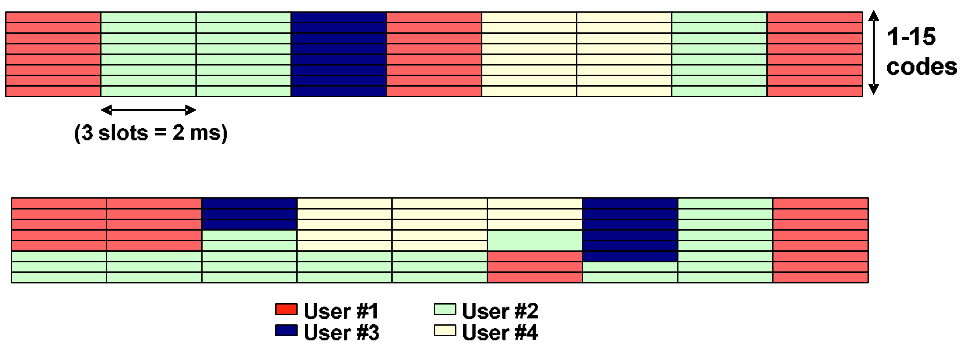
- **Scheme:**
  - Round Robin
  - Proportional Fair
  - CQI based
- **Multiplexing:**
  - Pure Time Division Multiplexing
    - Only one user allowed per 2 ms TTI
  - Combined Code and Time Division Multiplexing
    - Multiple users per 2 ms TTI
    - Assigned Consecutive Codes



Node B Scheduler

The Node B scheduler is responsible for deciding how to allocate the available HSDPA channels and transmit power among users. The standard puts no requirements on this algorithm, leaving it entirely implementation-dependent.

Some possible schemes:

- **Round Robin** – Each user is allocated the channel in a fixed rotation. The scheme could be simple, or modified to account for CQI and/or user priorities.
- **Proportional Fair** – Each user sees a throughput proportional to the peak rate that its link can sustain.
- **CQI Based** – Channel is allocated to the user in the best radio condition. This scheme provides the highest cell throughput, though at the cost of not serving users located in areas of poor coverage.

Scheduling algorithms for systems such as HSDPA are the subject of much research and analysis in the wireless industry.

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Change of Serving Node B – Repointing

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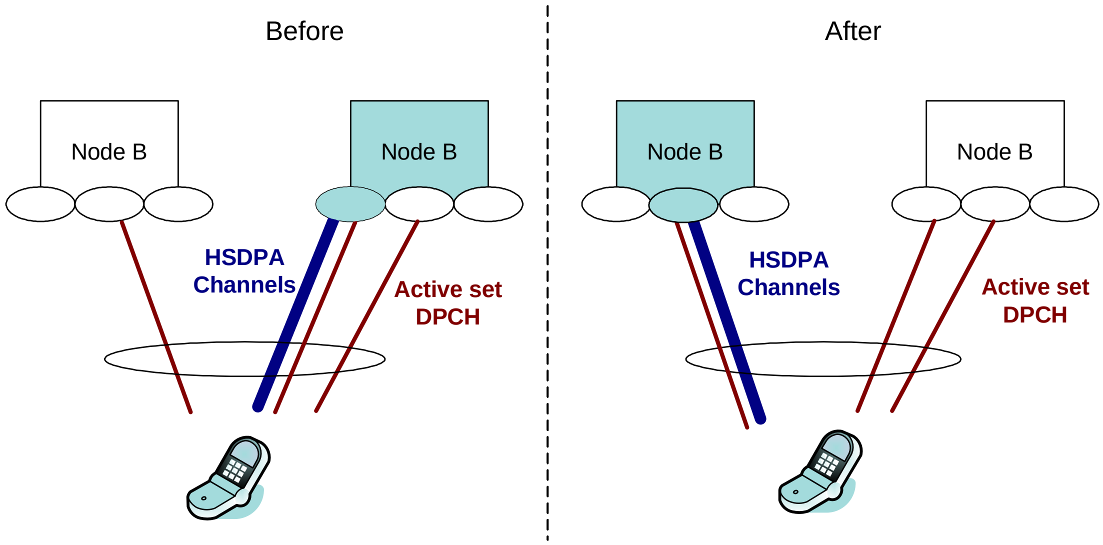

Serving Node B Change

HSDPA channels do not operate in soft handover. For a given UE, the Node B from which it receives the HSDPA channels is called the Serving Node B.

The UE may be in soft handover on the associated DPCH.

If the radio conditions change such that there is a better cell on another Node B for HSDPA operations, the Serving HSDPA Node B Change procedure is performed. This procedure occurs independently from the Active Set update procedure.

Change of Serving Node B – Repointing Considerations

Repointing considerations:

- Strongly depends on user mobility.
- Performed less frequently than Active Set updates.
- Can be based on Event 1d.
- Fast Cell Selection (FCS) not considered in Release 5

Intra-Node B repointing:

- UE and Node B H-ARQ buffers remain intact.

Inter-Node B repointing:

- H-ARQ buffers reset at change.
- Unacknowledged data resent by target Node B (AM).

Notes

Overall Comparison Summary

Mode	DCH	FACH	HSDPA
Channel Type	Dedicated	Common	Common
Power Control	Closed Inner Loop at 1500 Hz - Slow Outer Loop	Open Loop	Fixed Power
Soft Handoff	Supported	Not supported	Not supported
Setup Time	High	Low	Low
Suitability for Bursty Data	Poor	Good	Good
Data Traffic Volume	High	Low	High
Radio Performance	Good	Poor	Good

Summary of PS Data on DCH and FACH

CELL_DCH and CELL_FACH are the two Release 99 techniques typically used for packet switched data in practice. The advantages and disadvantages of each approach are apparent.

Whereas DCH is suited for high data traffic volumes (with a maximum rate of 384 kbps), setup time is slow, making it unsuitable and inefficient for bursty data such as a web browsing application.

By contrast, FACH has a low setup time but is a common channel without power control or other mechanisms to account for channel conditions. This makes it highly suitable for bursty traffic but unsuitable for larger traffic volumes.

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HSDPA Performance Summary

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- **Maximum Theoretical Data Rate:**
  - **14.4 Mbps**
    - 15 codes
    - 16QAM
    - Consecutive assignments (Inter-TTI spacing of 1)
    - Coding Rate of 1
  - **Virtually impossible to obtain in the field.**
- **Practical Peak Data Rate:**
  - **10.0 Mbps**
    - Full capability UE
    - Good RF conditions (High Cell Geometry)
    - Single UE
  - **Dedicated HSDPA carrier**

Notes

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What We Learned

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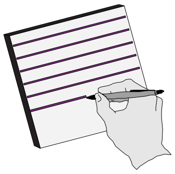
- ✓ WCDMA Release 5 and the High Speed Downlink Packet Access (HSDPA).
- ✓ Motivations for deploying HSDPA.
- ✓ WCDMA architecture and the Release 99 channels.
- ✓ HSDPA channels and their function.
- ✓ Maximum HSDPA data rate.
- ✓ Issues that affect Data Rate in a real world deployment.
- ✓ Other implementation considerations.

Notes



Comments/Notes