S-72.2211 Mobile Communication Systems and Services

3G Evolution

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Drivers for 3G Evolution

- Increasing role of packet switched data
  - Data optimization requires fast Physical Layer algorithms to reflect burstiness of traffic
  - Simplification of RAN architecture for data traffic
- still, majority of traffic will continue to be speech traffic for some time

PHY/MAC Concepts for 3G Evolution

- TDMA on top of CDMA
  - short Transmission Time Interval (TTI)
- Fast Packet Scheduling
  - Dynamic (Channel dependent) channel assignment
- AMC replacing power control
- Hybrid ARQ (HARQ) retransmission protocol
- Higher order modulation

Hybrid ARQ

- Retransmission protocol
  - FEC is used in conjunction with ARQ
  - physical layer reliability information used when combining information from multiple transmissions
  - Cyclic Redundancy Check used to detect erroneous transmissions
  - user sends an Acknowledgment or Non-Acknowledgment upon receiving data correctly/incorrectly
- Rough example: a 2-bit transmission

Transmitted bits		1	1
First transmission,	Rx bits	1	0
	reliability	0.9	0.2
Retransmission 2,	Rx bits	0	1
	reliability	0.1	0.8

  - after two transmissions, ARQ would be confused
  - HARQ, using reliability information would produce correct output.

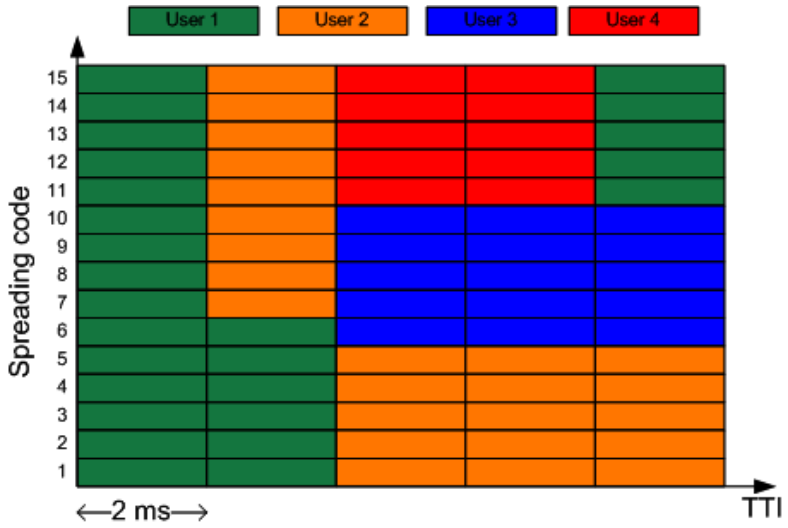
Evolved 3G Systems

- cdma2000 evolution: 1xEV-DO (EVolution-Data Optimized)
  - separate carriers for data optimization and voice services
  - Rev 0, 2001
    - DL optimization – up to 2.4 Mbps on 1.25 MHz carrier
  - Rev. A, 2004
    - UL optimization – up to 1.8 Mbps on 1.25 MHz carrier
    - DL enhancment – up to 3.1 Mbps on 1.25 MHz carrier
- WCDMA evolution: High Speed Packet Access (HSPA)
  - data optimization built on voice carriers
  - High Speed Downlink Packet Access (HSDPA), 2002
    - up to 10 (14.4) Mbps on 5 MHz carrier
  - High Speed Uplink Packet Access (HSUPA), 2004
    - up to 5.76 Mbps on 5 Mhz carrier

HSDPA

- backward compatible with Rel 99
  - Rel 99 and HSDPA transmissions may share the same carrier
- HSDPA uses spreading factor 16
  - up to 15codes can be used by HSDPA
  - higher data rates to a user by multicode transmission
  - terminals are capable to receive 5, 10 or 15 HSDPA multicodes
- the branches of the OVSF code tree not occupied by HSDPA can be used for Rel 99 dedicated channels (or vice versa)
  - semi-static (not TTI-to-TTI) split beween HSDPA and Rel 9
- short Transmission Time Interval (TTI), fast scheduling
  - 10 ms radio frame divided into 5 TTIs of 2 ms
  - a TDMA component on top on WCDMA
  - HSDPA users are scheduled on a shared channel, scheduled in each TTI
- no power control, hard handover, fast AMC and HARQ
- QPSK and 16-QAM modulation
- peak data rate with 15 multicodes, 16-QAM, no FEC: 14.4 Mbps
  - with channel coding: 10.2 Mbps

HSDPA Scheduling Example

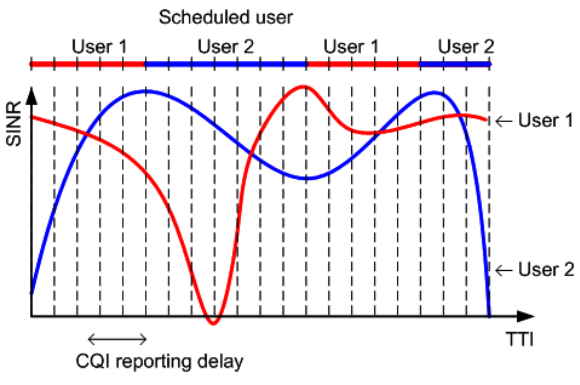


- Scheduling decision depend on channel quality of user, buffer status, and UE capability
  - here, users 3 and 4 are capable to receive 5 multicodes

Channel Dependent Scheduling

- scheduling decision is based on the channel states of multiple users
  - "multi-user diversity"
  - Channel Quality Indication (CQI) is reported by MS to BS on UL
  - delay in CQI reporting causes delays in scheduling decisions

- In this example: Max C/I scheduling
  - the user with the best C/I is scheduled
  - maximizes system capacity, unfair to users far from BS



HSDPA Transport Channels

- High Speed DL Shared Channel (HS-DSCH)
  - the SF=16 codes used for HSDPA in the TTI
  - shared by all the users in a TTI that receive HSDPA transmissions
- High Speed Shared Control Channel (HS-SCCH)
  - Informs the users that there is an allocation 2 slots ahead
- High Speed Dedicated Physical Control Channel
  - an UL channel used to transmit CQI information and HARQ acknowledgements

HSUPA

- AMC and HARQ to enhance UL throughput
- two TTIs: 10 ms and 2 ms
- scheduled mode: fast channel dependent scheduling
  - request-grant: MS request resources, BS grants them
  - scheduling on a TTI-to-TTI basis
  - power used for scheduled transmissions controlled by BS
- non-scheduled mode
  - allows user initiated transmissions
    - maximum data rate negotiated at call setup
- peak data rate:
  - 2 x SF2 + 2x SF4 with 2 ms TTI: 5.76 Mbps
- HSUPA enhancments available on Enhanced Dedicated CHannel (E-DCH)
  - additional support channels in DL and UL

Drivers of Evolution towards 4G

- further data optimization
  - targeting PS only RAN
  - higher data rates with robustness against multipath
    - getting rid of ISI once and for all: Frequency domain equalization and Orthogonal Frequency Domain Multiplexing
- delay reduction
  - setup delays: getting rid of lengthy negotiations in WCDMA bearer setup
  - round-trip delays
- simplified RAN architecture
  - more localized decision making (reduce delays)
  - base station directly connected to a gateway to internet
  - no RNC/BSC
  - base station becomes Internet router
  - no soft handovers
- Reducing UE power consumption
  - removing continuous transmissions of CDMA kind

LTE

- UTRA Long Term Evolution (LTE), Rel 8, 2008
- non-backward compatible, new stand-alone mobile communication system
- flexible bandwidth usage: form 1.25 to 20 MHz bandwidth
  - DL: OFDM
    - TDMA and (O)FDMA
  - UL: Single Carrier FDMA
    - intra-cell orthogonal uplink
    - with Cyclic Prefix to enable efficient frequency domain equalization
    - a single carrier transmission to keep Peak-to-Average Power ratios down and Power Amplifyer efficiency up
    - TDMA and FDMA
  - packet scheduling in both time and frequency
    - 1 ms TTI
    - exploit frequency selective fading, 180 kHz scheduling granularity

Trends in Mobile Communication, 2G → 4G

- Clear trends
  - less circuit switching (CS), more packet switching (PS)
  - more data optimization: higher data rates, wider bands
  - shorter frames/TTIs
  - more flexible spectrum use between cells
- Wavering trends
  - Intra-cell Orthogonality
  - multiple access: TDMA/FDMA→CDMA→TDMA/FDMA
    - but 2G TDMA/FDMA is fixed (CS), 4G TDMA/FDMA fully scheduled (PS)
  - hierarchicity of RAN & core NW architecture
    - with GPRS core increases complexity
    - in WCDMA RAN, RNC has larger role than BSC in GERAN
    - LTE, flat architecture - PS only
  - macordiveristy: hard → soft → hard handover