Freescale Technology Forum

Design Innovation.

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LTE: Downlink Physical-Layer Overview and Throughput Simulation Results

PM104

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Agenda

- Overview of LTE
  - LTE philosophy
  - LTE performance requirements
- LTE Physical Layer
  - General description
  - Physical channels
  - Channel coding
  - Modulation
- Throughput simulation results
  - Freescale's LTE downlink simulator
  - Downlink shared channel
  - Control channel

3GPP – LTE Philosophy and Criteria

- Philosophy
  - LTE focus is on:
    - Enhancement of the Universal Terrestrial Radio Access (UTRA)
    - Optimization of the UTRAN architecture
  - With HSPA (downlink and uplink), UTRA will remain highly competitive for several years
  - LTE project aims to ensure the continued competitiveness of the 3GPP technologies for the future
- Criteria
  - Demand for higher data rates
  - Expectations of additional 3G spectrum allocations
  - Greater flexibility in frequency allocations
  - Continued cost reduction
  - Keeping up with other (unlicensed) technologies (eg WiMAX)

Performance Requirements for LTE

Category	Requirement
Peak data rate	DL: 100 Mbps in 20 MHz BW (5 bps/Hz) UL: 50 Mbps in 20 MHz BW (2.5 bps/Hz)
Control-plane latency	< 100 ms for Idle to Active mode transition
Control-plane capacity	> 200 users per cell in Active state within 5 MHz
User-plane latency	< 5 ms for 1 user with 1 data stream and small IP packet
Average user throughput	DL: 3-4 times of HSDPA per MHz UL: 2-3 of HSUPA per MHz
Mobility	Optimized for 0-15 km/h Support with high performance for 15-120 km/h Support for 120-350 km/h or even 500 km/h
Coverage	All targets met for 5 km cells Slight degradation for 5-30 km cells Support for 30-100 km cells
Spectrum flexibility	Support for 1.25 – 20 MHz Bandwidths Paired or unpaired spectrum allocations

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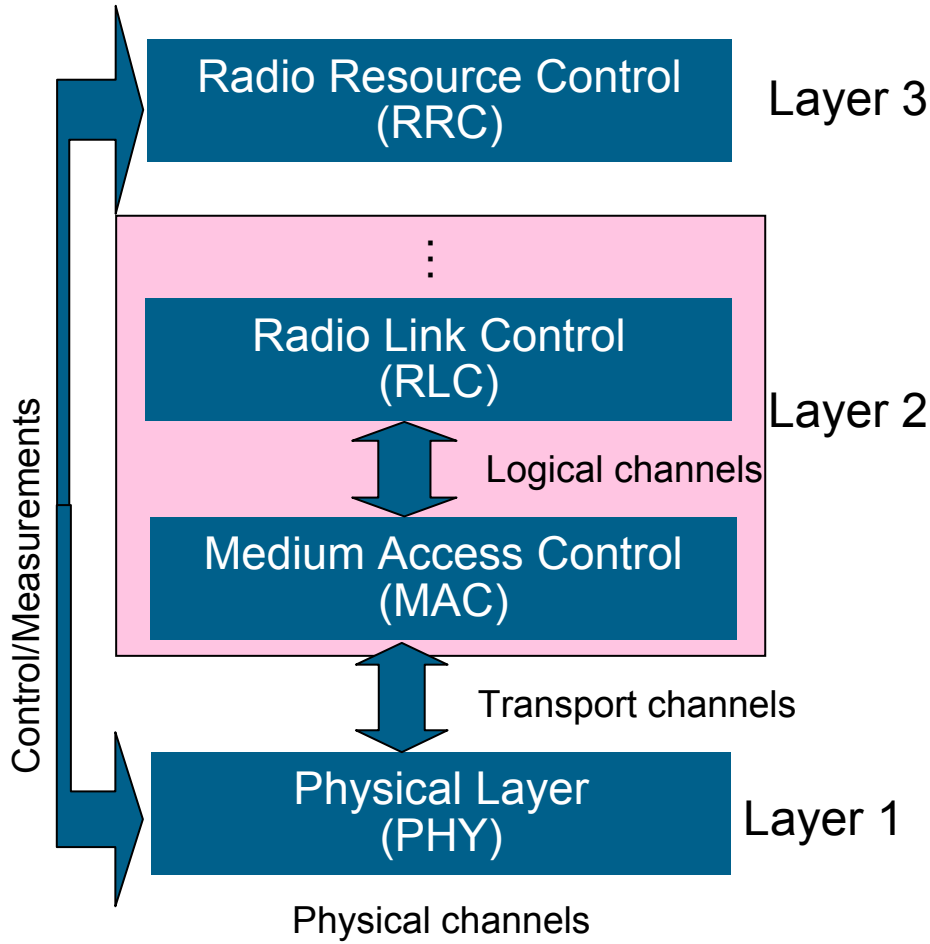
LTE Protocol Architecture Around the Physical Layer

- PHY interfaces MAC sub-layer of Layer 2 and RRC of Layer 3
- PHY offers a transport channel to MAC
  - Transport channel characterized by how information is transferred
- MAC offers logical channels to the RLC
  - Logical channel characterized by the type of information transferred.



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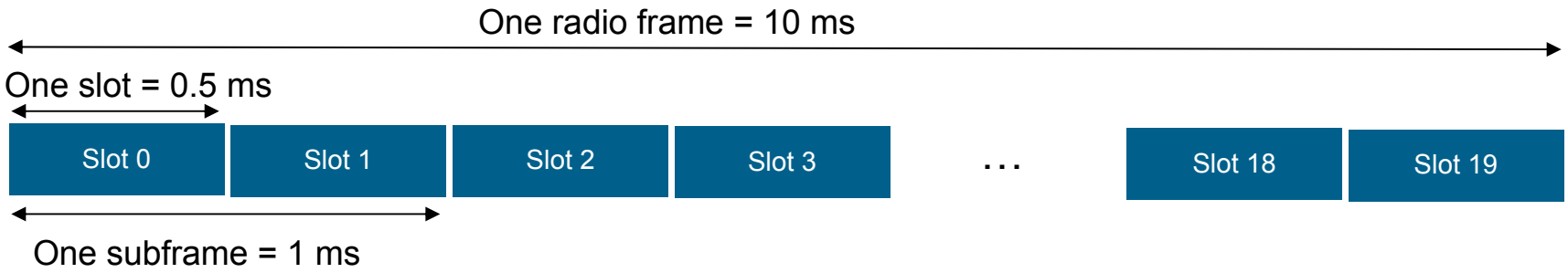
Layer 1 General Description

- Multiple access
  - OFDMA in the downlink
  - SC-FDMA in the uplink
- Duplexing
  - Frequency-division duplexing (FDD) for paired spectrum
  - Time-division duplexing (TDD) for unpaired spectrum
  - Half-duplex FDD for paired spectrum (optional)

Frame Structure



- Frame structure type 1 applicable to FDD and half duplex FDD
- Each 10 ms radio frame is divided into ten equally sized sub-frames
- Each sub-frame consists of two equally sized slots

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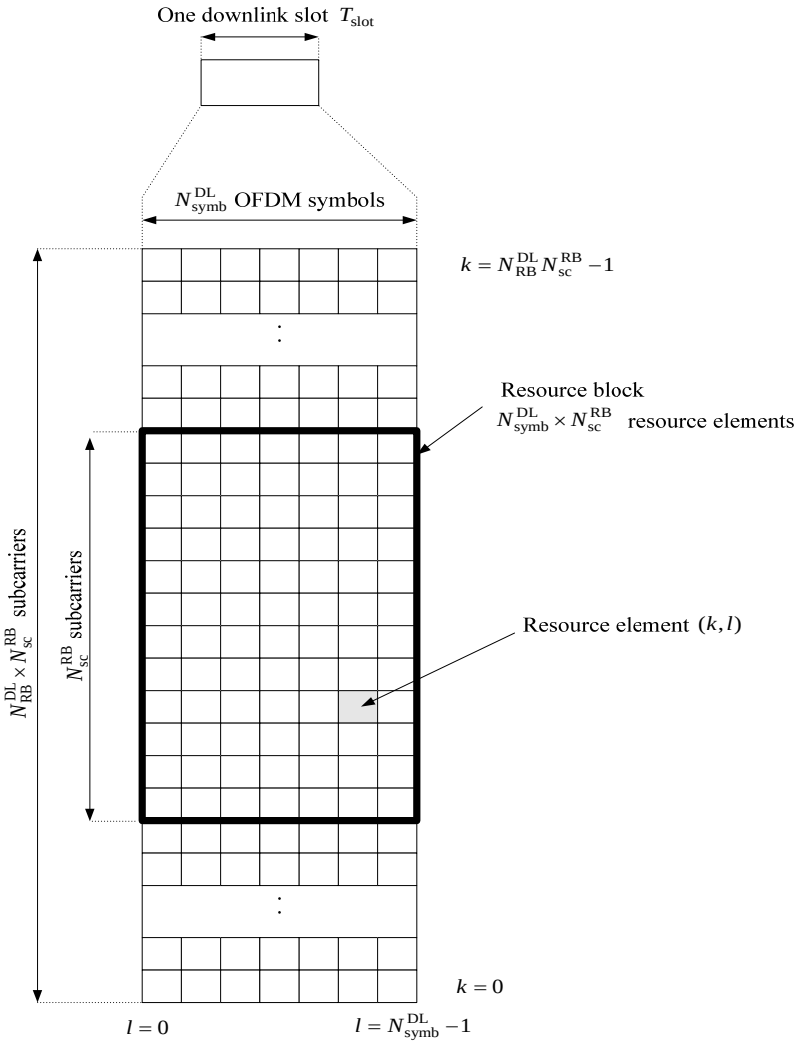
Slot Structure and Resource Elements



Transmission BW (MHz)	1.4	3	5	10	15	20
Slot duration	0.5 ms					
Subcarrier spacing	15 kHz / 7.5 kHz (MBSFN)					
Sampling frequency (MHz)	1.92	3.84	7.68	15.36	23.04	30.72
FFT size	128	256	512	1024	1536	2048
# downlink RBs (N^{DL}_{RB})	6	15	25	50	75	100
# subarriers / RB (N^{RB}_{sc})	12 / 24 (MBSFN)					
# OFDM symbols / slot (N^{DL}_{symb})	7 (normal CP) 6 (extended CP) 3 (extended CP in MBSFN)					
CP length (μs)	1 x 5.21, 6 x 4.69 (normal) 16.6 (extended)					

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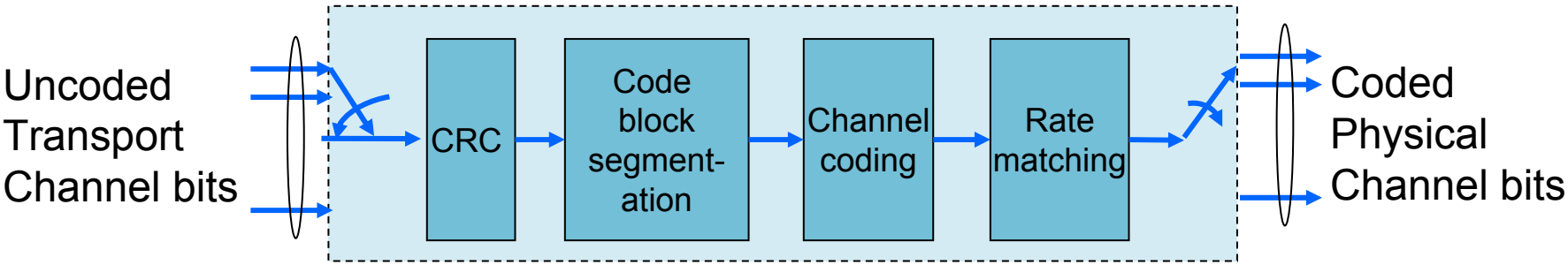
Downlink Physical Channels

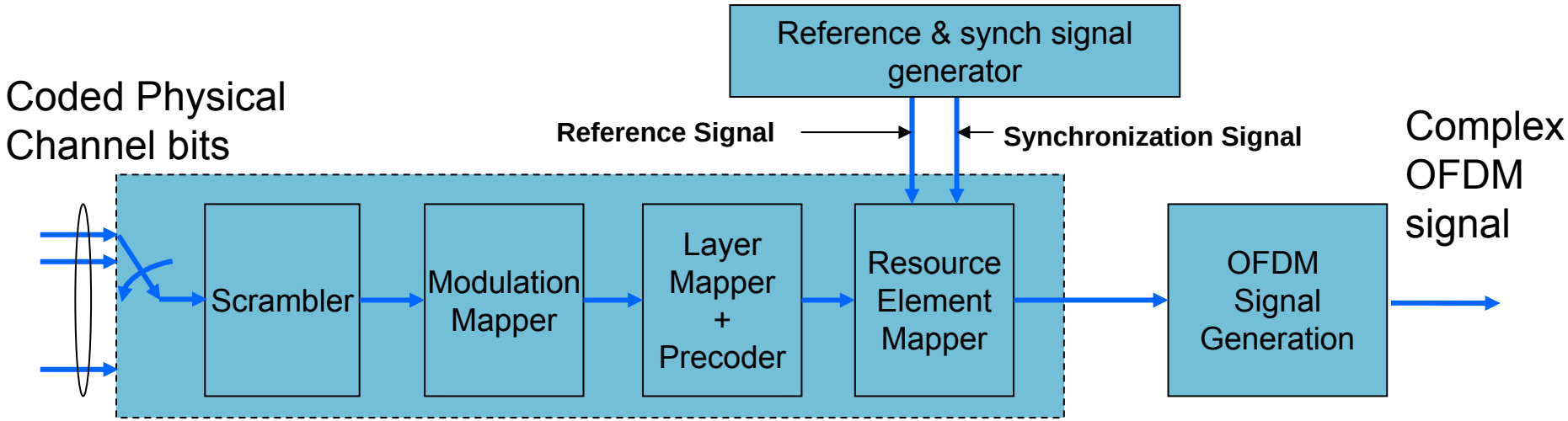
- Physical downlink shared channel (PDSCH)
  - Carries the downlink shared channel (DL-SCH) and paging channel (PCH)
- Physical downlink control channel (PDCCH)
  - Informs the UE about the resource allocation of PCH and DL-SCH, and Hybrid ARQ information related to DL-SCH
  - Carries the uplink scheduling grant
- Physical control format indicator channel (PCFICH)
  - Informs the UE about the number of OFDM symbols used for the PDCCHs;
  - Transmitted in every subframe.
- Physical broadcast channel (PBCH)
  - The coded broadcast channel (BCH) transport block is mapped to four subframes within a 40 ms interval
  - 40 ms timing is blindly detected
  - Each subframe is assumed to be self-decodable, i.e. the BCH can be decoded from a single reception, assuming sufficiently good channel conditions.
- Physical Hybrid ARQ Indicator Channel (PHICH)
  - Carries Hybrid ARQ ACK/NAKs in response to uplink transmissions.
- Physical multicast channel (PMCH)
  - Carries the multicast channel (MCH) transport channel

Channel Coding of Physical Channels



- Cyclic redundancy check
  - Error detection capability for transport block and each code block
- Code-block segmentation
  - Segment the transport block into smaller code blocks of roughly equal length
- Channel coding
  - Rate 1/3 turbo code – Downlink shared, paging, and multicast channels
  - Rate 1/3 tail-biting convolutional code – Broadcast channel and downlink control information
  - Rate 1/16 block code – Control format indicator
  - Rate 1/3 repetition code – HARQ indicator
- Rate-matching
  - Includes sub-block interleaving, bit collection, and bit selection and pruning
  - Support hybrid ARQ transmissions

Baseband Modulation of Downlink Physical Channels



- Scrambler breaks long strings of 1s and 0s of the coded bits
- Modulation mapper converts scrambled bits into complex-valued symbols
- Layer mapper and precoder performs symbol transformations to enable multi-antenna transmission techniques
- Resource element mapper maps the physical channel symbols to the appropriate locations in the time-frequency grid
- OFDM signal generation converts the frequency domain symbols to time domain complex baseband signals for each antenna port for transmission

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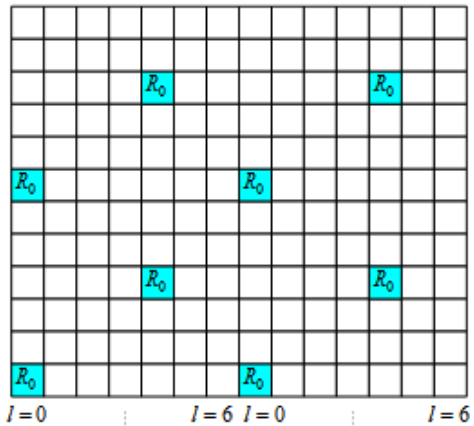
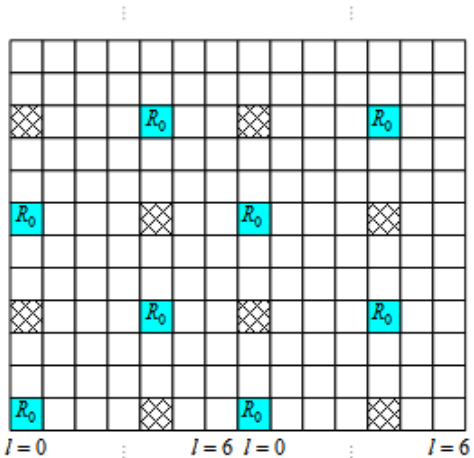
Downlink Reference Signals

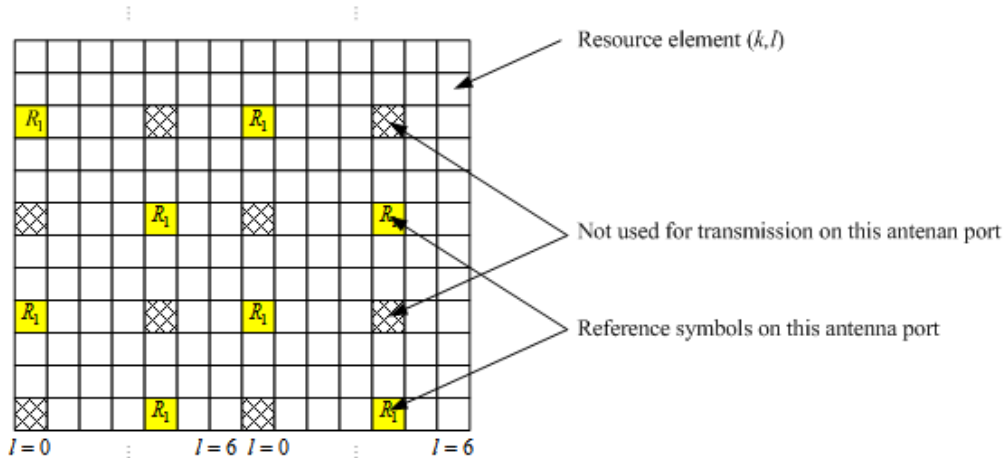
One antenna port



- Transmitted in all subframes not used for MBSFN transmission
- Primarily used for channel estimation and tracking purposes
- Pseudo-random QPSK signals generated using length-31 gold sequence
- Orthogonal across time, frequency, and antennas within a cell
- Orthogonal in the code-domain among neighboring cells

Two antenna ports





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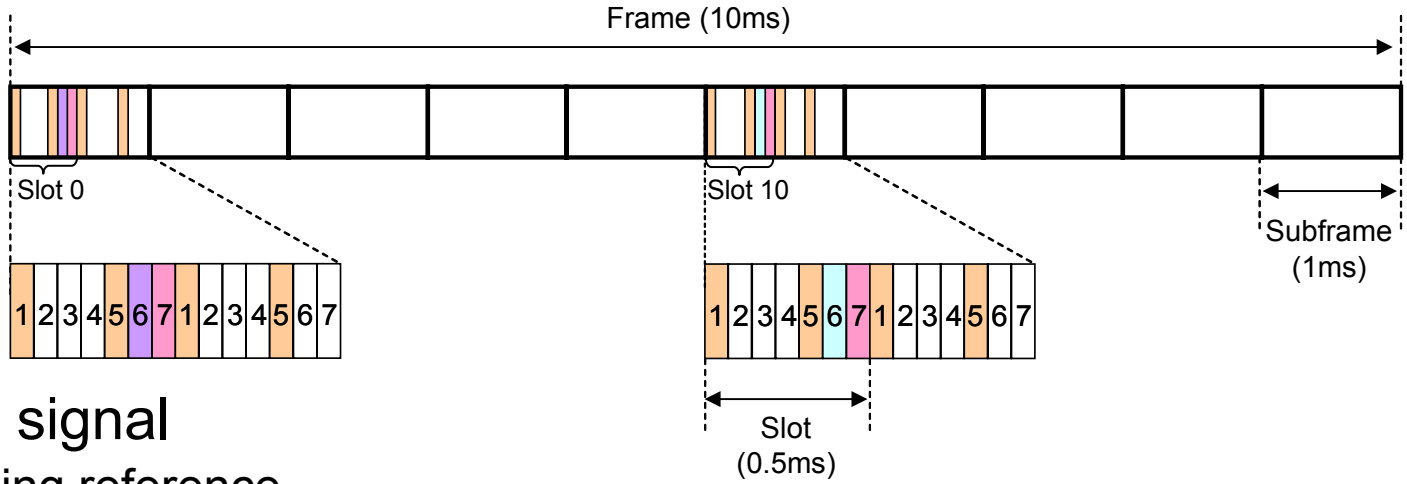
Downlink Synchronization Signals



- Primary synch signal
  - Half-frame timing reference
  - Frequency domain Zadoff-Chu sequence
  - Occupies only middle 62 subcarriers in frequency
- Secondary synch signal
  - Frame timing reference
  - Interleaved concatenation of two length-31 m-sequences

DL - RS

PSCH

1st SSCH

2nd SSCH

RS: Reference Signal
PSCH: Primary Synchronization Channel
SSCH: Secondary Synchronization Channel

* *Figure courtesy of Taeyoon Kim, Freescale*

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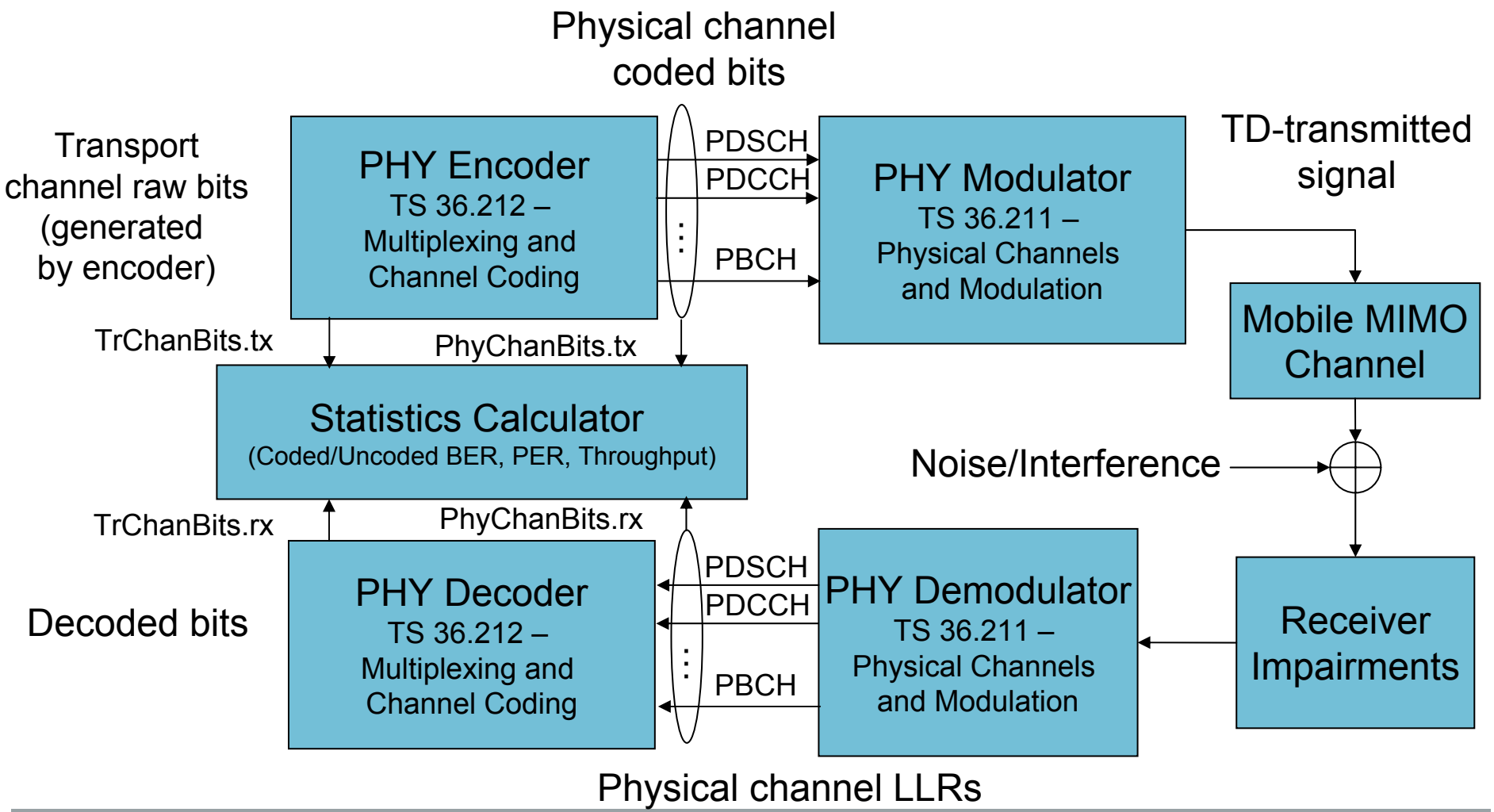
Freescale's Radio Link Simulator Architecture



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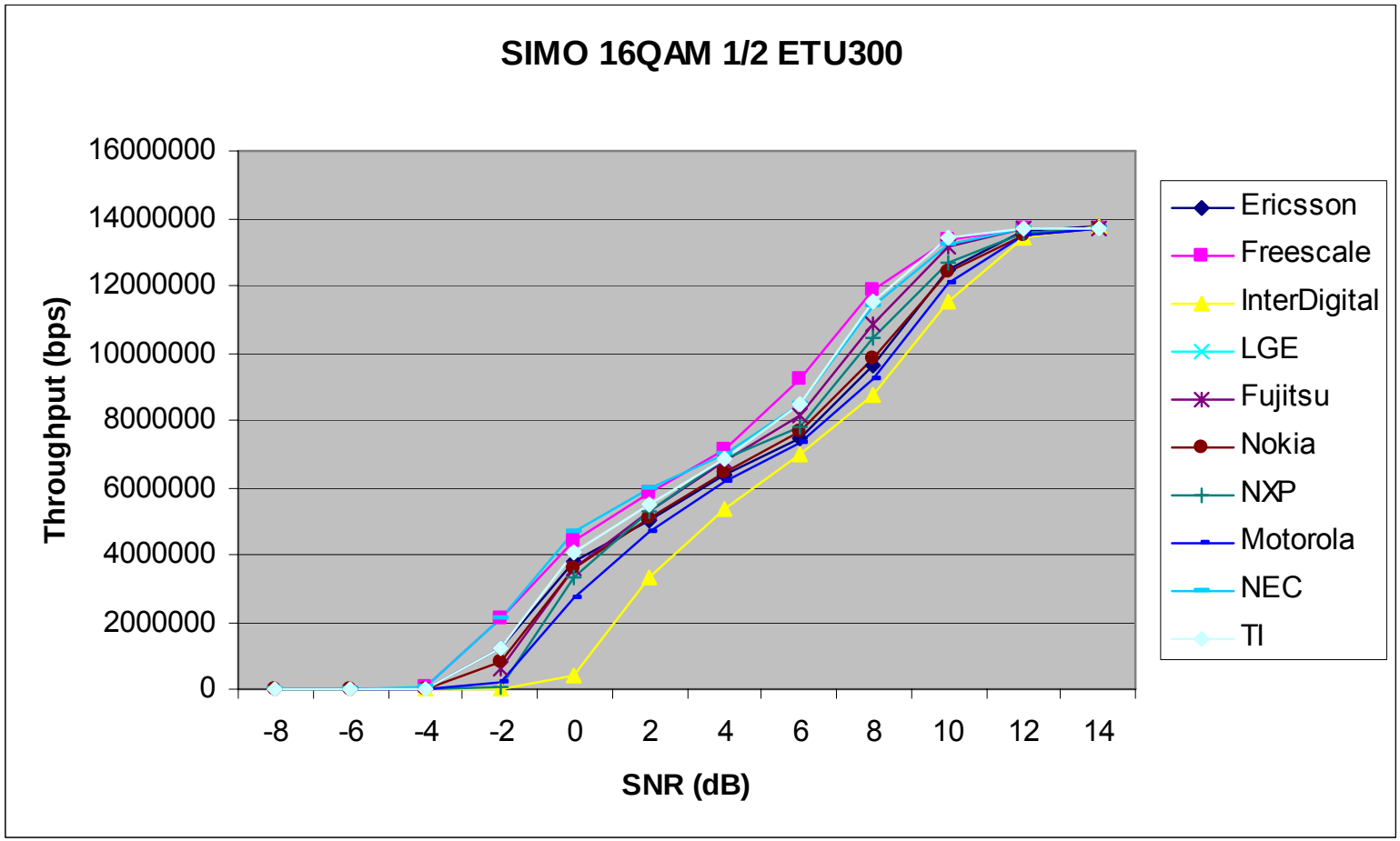
Example RAN4 PDSCH Simulation Results



FDD 1x2 SIMO, 10MHz, 16-QAM 1/2, ETU300 channel

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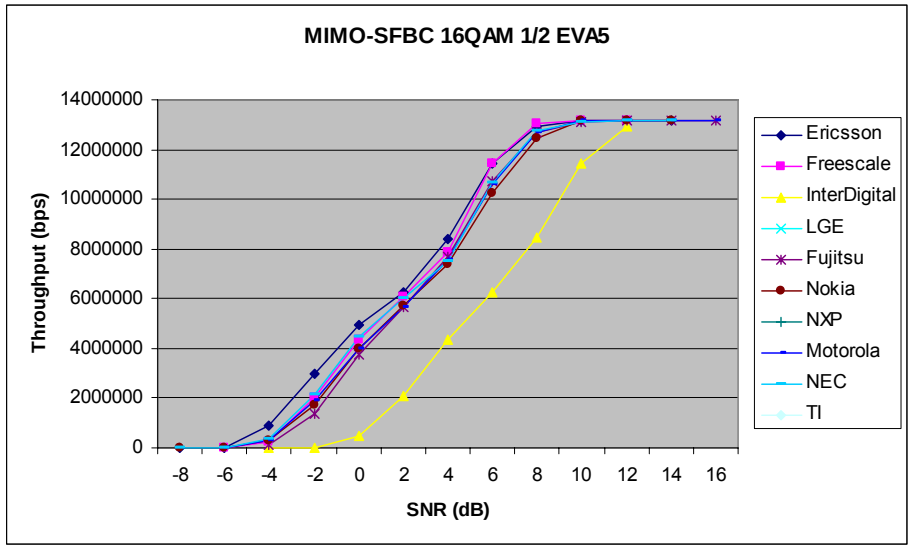
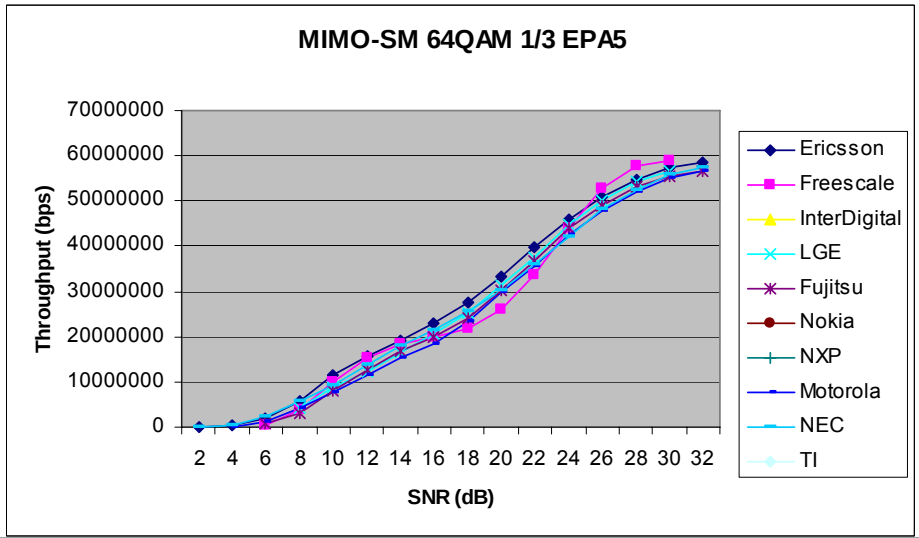
Example RAN 4 PDSCH Simulation Results

- FDD 2x2-SFBC, 10MHz,
- 1 codeword, 2 layers
- 16-QAM rate 1/2
- EVA5, non-ideal channel estimation



- FDD 2x2-SM with precoder feedback for whole BW,
- 10MHz MMSE receiver
- 2 x 64QAM 3/4,
- EVA5, non-ideal channel estimation



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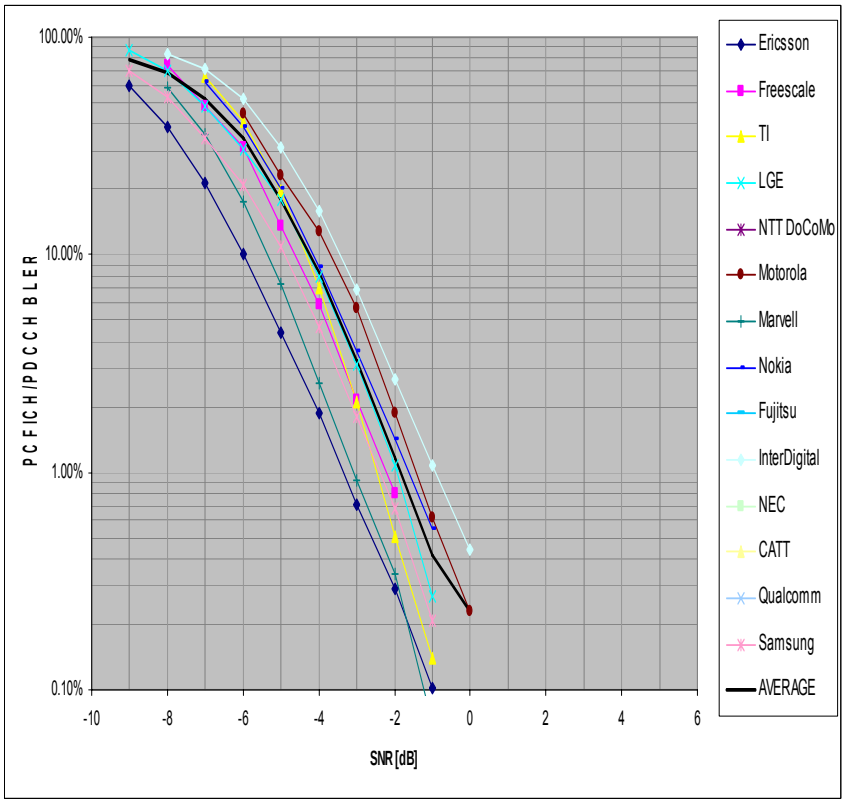
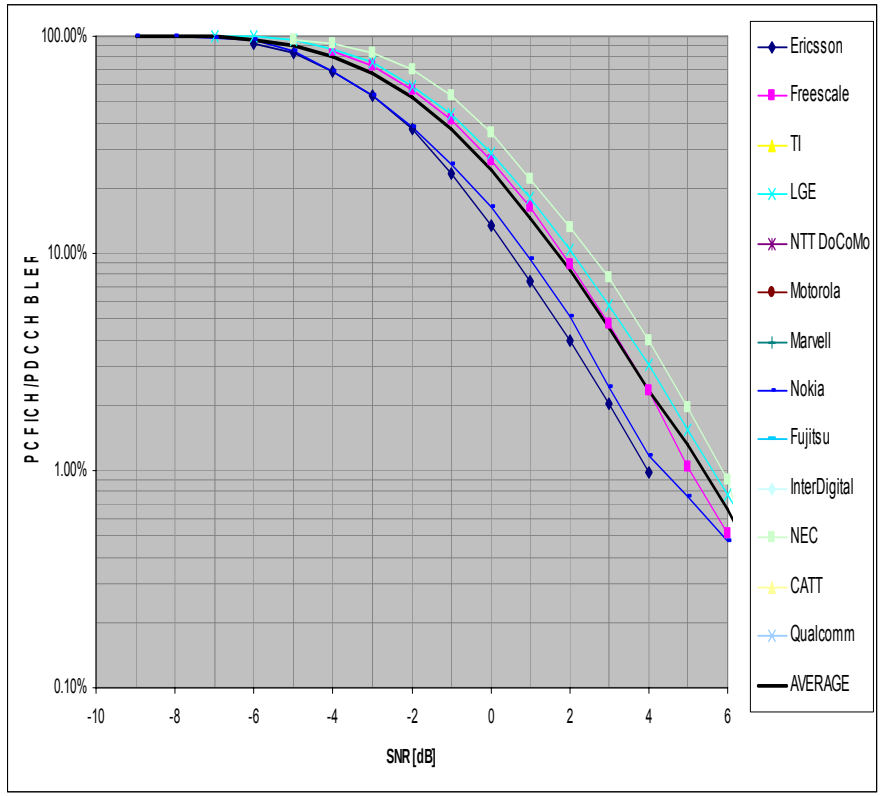
Example RAN4 PDCCH/PCFICH Simulations

Sim 46.6: FDD 1x2 10MHz 8CCE Format1 ETU70 low



Sim 47.10: FDD 2x2 SFBC 1.4MHz 2CCE Format2 EPA5 low



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References

- [1] Francois Coureau, “3GPP Evolution: LTE and SAE,” Beijing, China, 2004
- [2] TR 25.913 7.3.0, “Requirements for Evolved-UTRA and Evolved UTRAN,” March 2006
- [3] TS 36.201 v. 8.1.0, “E-UTRA: LTE Physical Layer – General Description,” Nov. 2007
- [4] TS 36.211 v. 8.2.0, “E-UTRA: Physical Channels and Modulation,” March 2008
- [5] TS 36.212 v. 8.2.0, “E-UTRA: Multiplexing and Channel Coding,” March 2008
- [6] TS 36.300 v. 8.4.0, “E-UTRA and E-UTRAN: Overall Description Stage 2,” March 2008

Related Session Resources

Session Location – Online Literature Library

http://www.freescale.com/webapp/sps/site/homepage.jsp?nodeId=052577903644CB

Sessions

Session ID	Title
PM101	LTE: MIMO Techniques in 3GPP-LTE

Demos

Pedestal ID	Demo Title

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