MATLAB LTE SYSTEM TOOlBOX For Development of LTE Physical Layer

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Outline

• Problem Statement: The Requirement
  o Challenges in LTE PHY Development
  o WHY MATLAB LTE System Toolbox?

• LTE Physical Layer Development in 3 stages
  o Stage 1
  o Stage 2
  o Stage 3

• Development Setup
• Results
• Conclusion
PROBLEM STATEMENT
Introduction

3GPP

LTE

- Higher Data Rate
- Lower Latency
- Higher Spectral Efficiency
- Higher Capacity
The requirement was to develop and prototype LTE Physical Layer for:
- Concept proving
- Capturing system requirement
CHALLENGES IN DEVELOPING PHY LAYER
• **Challenge #1**: Reading and understanding the specs

• **Challenge #2**: Creating an executable spec to investigate system performance and act as a golden test-bench

• **Challenge #3**: Evaluate algorithms which will meet performance requirements

• **Challenge #4**: Converting the Design for Dedicated Hardware
• **Challenge #1**: Reading and understanding the specs

• **Challenge #2**: Creating an executable spec to investigate system performance and act as a golden test-bench

• **Challenge #3**: Evaluate algorithms which will meet performance requirements

• **Challenge #4**: Converting the Design for Dedicated Hardware
• Two Approaches of Development:
  o Study, understand vast 3GPP standard and then carry out development (MATLAB/other software)
  o Use LTE system Toolbox of MATLAB for hand in hand understanding and development of LTE physical layer
WHY ???
“MATLAB LTE SYSTEM TOOLBOX”
• **Standard-compliant functions** for the design, simulation, and verification

• **Accelerates** LTE algorithm and physical layer (PHY) development

• Supports **golden reference verification**

• **Conformance testing**

• Enables **test waveform generation**

• Analyze **end-to-end communication** links

• Implementation **comply** with the LTE standard
LTE PHYSICAL LAYER DEVELOPMENT
3 Stage Development of LTE Physical Layer using LTE System Toolbox

- **Stage 1**: Development of Physical layer using high level functions
- **Stage 2**: Development of Physical layer using mid level functions
- **Stage 3**: Development of Physical layer using low level functions
Stage 1: DL Transmitter Development

- SSS
- PSS
- CRS
- PBCH
- PHICH
- PCFICH
- PDCCH
- PDSCH

Resource Element Mapping

OFDM Modulation
Stage 1: DL Receiver Development

- SSS
- PSS
- CRS
- PBCH
- PHICH
- PCFICH
- PDCCH
- PDSCH

Resource Element Selection

OFDM Demodulation
Stage 2: Individual Channel and Signal Development (one example)
Stage 3: Low level function development (Scrambling)

\[ \tilde{b}(i) = (b(i) + c(i)) \mod 2 \]

\[ c(n) = (x_1(n + N_c) + x_2(n + N_c)) \mod 2 \]
\[ x_1(n + 31) = (x_1(n + 3) + x_1(n)) \mod 2 \]
\[ x_2(n + 31) = (x_2(n + 3) + x_2(n + 2) + x_2(n + 1) + x_2(n)) \mod 2 \]

\[ N_c = 1600 \]
\[ c_{\text{init}} = N_{\text{ID}} \]
\[ x_1(0) = 1 \]
\[ x_1(n) = 0, n = 1, 2, ..., 30 \]
\[ c_{\text{init}} = \sum_{i=0}^{30} x_2(i) \cdot 2^i \]
Physical Layer Processing (DL)

**eNodeB Transmit Chain**
- Data from MAC Layer
- Generation of PSS, SSS & CRS
- PBCH, PHICH, PCFICH & PDCCH Encoding
- DLSCH & PDSCH Encoding
- OFDM Modulation
- Data Transmission By USRP Device

**UE Receive Chain**
- Data Received From USRP Device
- Cell Search & Synchronization
- IQ Offset Correction
- Frequency Offset Estimation & Correction
- OFDM Demodulation
- Channel Estimation
- ZF Equalization
- PBCH, PHICH, PCFICH & PDCCH Decoding
- PDSCH, DLSCH Decoding
- ZF Equalization
Physical Layer Processing (UL)

**UE Transmit Chain**

- Data from MAC Layer
- PUSCH DRS / PUCCH DRS Encoding
- SRS Encoding
- ULSCH, PDSCH / PUCCH Encoding
- SC-FDMA Modulation
- Data Transmission By USRP Device

**eNodeB Receive Chain**

- Data Received From USRP Device
- Frame Synchronization
- IQ Offset Correction
- Frequency Offset Estimation & Correction
- SC-FDMA Demodulation
- Channel Estimation
- ZF Equalization
- PUSCH, ULSCH / PUCCH Decoding
DEVELOPMENT
SET UP
End-to-End Development Setup
RESULTS
Results from Setup

- Cell search procedure completed successfully
- Broadcast message decoded in downlink
- Control information and data decoded
Displaying DCI Information...

DCIFormat: 'Format1'
CIF: 0
AllocationType: 0
Allocation: [1x1 struct]
  ModCoding: 0
  HARQNo: 0
  NewData: 1
  RV: 0
  TPCPUCCH: 0
  TDDIndex: 0

PDSCH settings after DCI decoding:
  RNTI: 1
  PRBSet: [50x1 uint64]
  NLayers: 1
  RV: 0
  Modulation: {'QPSK'}
  NTurboDecIts: 5
  TxScheme: 'Port0'

ans2 =

1

PDSCH decoded Successfully

>>
CONCLUSION
Conclusion

• **Top down approach** enabled the quick development of physical layer based eNodeB and UE reducing the time to prototype.

• The Communications System Toolbox Support Package for USRP Radio enabled to test the system over air without the need of converting the code for actual hardware.