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:
  o Concept proving
  o 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

Resource Element Selection

SSS -> PSS
CRS
PBCH
PHICH
PCFICH
PDCCH
PDSCH

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

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

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

\[ N_C = 1600 \]
\[ c_{init} = N_{cell} \]
\[ x_1(0) = 1 \]
\[ x_1(n) = 0, n = 1, 2, \ldots, 30 \]
\[ c_{init} = \sum_{i=0}^{30} x_2(i) \cdot 2^i \]
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
- OFDM Demodulation
- Frequency Offset Estimation & Correction
- Channel Estimation
- ZF Equalization
- PBCH, PHICH, PCFICH & PDCCH Decoding
- PDSCH, DLSCH Decoding
- ZF Equalization
- Data Received From USRP Device
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.