DVB-T2 Rotated Constellation Demapping on a GPU

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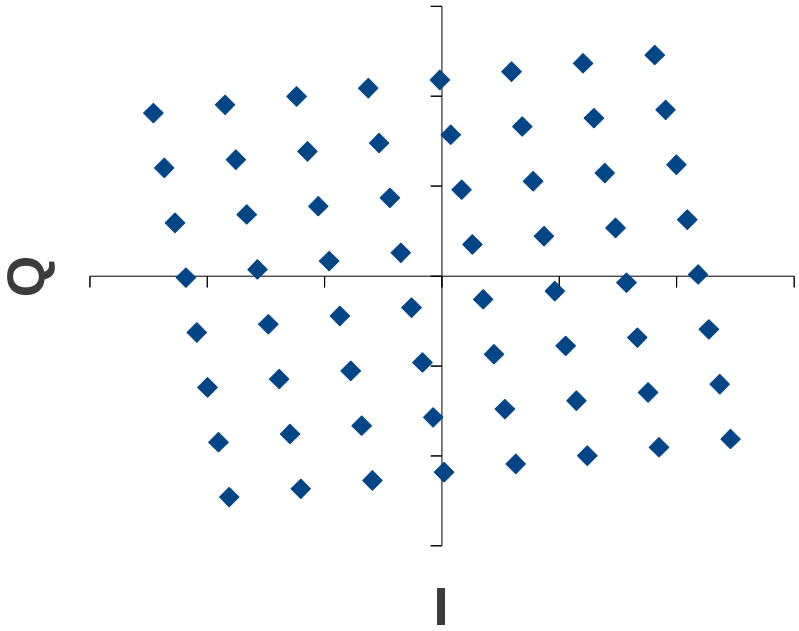
Background

- We would like to build a software-defined DVB-T2 receiver
- **SDR'10**: Complexity analysis of software defined DVB-T2 physical layer
  - LDPC decoder and Constellation Demapper very computationally demanding
- **SDR'11**: An efficient GPU-based LDPC decoder for Long Codewords
- **Now** we tackle the constellation demapper
  - Measure performance of various algorithms implemented on a GPU

DVB-T2 Rotated QAM

- DVB-T2 is the successor to the DVB-T digital television standard
- Optionally features Signal Space Diversity (SSD) through the use of rotated QAM constellations
- Combined with time-interleaving of I/Q components
  - Provides redundancy
- Non-rotated: Odd bits conveyed by I-axis, even by Q-axis
  - One dimensional demapping

DVB-T2 Rotated QAM



Rotated 64-QAM diagram

- With rotated constellations, axes become inter-dependent
- Two-dimensional demapping needed

Algorithms

- There are various simplified algorithms presented in the literature
- We chose to compare four algorithms:
  - Maximum Likelihood (ML)
    - Optimal
  - Max-Log simplification
  - Minimum-Mean-Squared-Error (MMSE) decorrelation
  - MMSE with Interference Cancellation MMSE-IC

Maximum Likelihood

- Demapper produces Log-Likelihood Ratio (LLR) values for each bit
  - These are passed on to the soft-bit channel decoder (LDPC)
- ML:

$$\mathbf{LLR}(b_i) = \ln\left(\frac{\sum_{\mathbf{x}\in C_i^1}\left(e^{-\frac{D(\mathbf{x})}{2\sigma^2}}\right)}{\sum_{\mathbf{x}\in C_i^0}\left(e^{-\frac{D(\mathbf{x})}{2\sigma^2}}\right)}\right)$$

Max-Log

- Simplifies ML a bit by making the approximation:

$$\ln\left(\sum_{i\in[1,n]}\left(e^{a_i}\right)\right) \approx \max_{i\in[1,n]}\left(a_i\right)$$

- ... giving:

$$\mathbf{LLR}(b_i) \approx \frac{1}{2\sigma^2}\left[\min_{\mathbf{x}\in C_i^0}\left(D(\mathbf{x})\right) - \min_{\mathbf{x}\in C_i^1}\left(D(\mathbf{x})\right)\right]$$

MMSE Decorrelation

- Kyeongyeon Kim, Kitaek Bae, and Ho Yang. *”One-dimensional soft-demapping using decorrelation with interference cancellation for rotated QAM constellations.”*
- Derotation and decorrelation of I and Q components
  - Similar to MIMO detector methods
- After decorrelation, one-dimensional demapping is possible
  - Also enables use of LUTs

MMSE-IC

- Addition to MMSE, also presented in same paper
- Interference cancellation additionally removes influence of strongest channel component (I or Q) on weakest channel component
- This further improves demapper performance

Implementation

- Implemented using NVIDIA CUDA
- Tested on NVIDIA GeForce GTX 570 GPU
  - 480 CUDA cores
- Designed to interface to GPU LDPC decoder
- Process 128 T2-frames at once
  - T2-frame = 16200 or 64800 bits
- Each GPU thread calculates LLR values for m bits in the case of 2^m-QAM

Performance: Demappers

Modulation	ML	Max-Log	MMSE	MMSE-IC
16-QAM	0.0101	0.0070	0.0028	0.0032
64-QAM	0.0255	0.0218	0.0022	0.0024
256-QAM	0.0832	0.0788	0.0019	0.0021

- Execution times (seconds) for one batch of 128 frames
- ML and Max-Log complexity increase about linear with number of constellation points.
- After decorrelation, MMSE is one-dimensional
- 256-QAM faster than 16-QAM in MMSE due to fewer total threads

Perf. : Demapper + LDPC

Modulation	ML	Max-Log	MMSE	MMSE-IC
16-QAM	70.8	72.5	75.4	75.0
64-QAM	64.1	66.0	78.2	78.1
256-QAM	44.9	45.9	80.0	80.0

- Throughput (Mbps), for GPU Demapper and LDPC decoder together
- DVB-T2 standard requires up to 60.8 Mbps throughput
- MMSE demappers achieve this for all modulation schemes!

Conclusions

- We have tested four implementations of rotated QAM demappers on a GPU
- We achieve real-time performance with both the demapper and LDPC decoder running on the same GPU
- Unfortunately, we were unable to produce SNR-BER performance results due to incomplete fading channel models
- Next step: Continue implementation of DVB-T2 SDR receiver (GNU Radio?)

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Thank you for listening!

Questions?