Implementation of Parallel Lattice Reduction-Aided MIMO Detector using Graphics Processing Unit

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Introduction

- Multiple Input Multiple Output (MIMO) technology
  - High data rate
  - Key technology in the next generation mobile communication
- MIMO-Detector
  - Maximum Likelihood (ML), Zero Forcing (ZF)
- Lattice Reduction (LR)
  - Provides a performance comparable to that of ML with a lot less complexity
  - Lenstra-Lenstra-Lovasz (LLL) algorithm
  - Complex LLL (CLLL)
- Graphics Processing Unit (GPU) – Parallel processor
  - Consists of multiple threads
  - Save operation time by parallel processing
- Implementation on WiMAX system
  - To verify a real-time applicability

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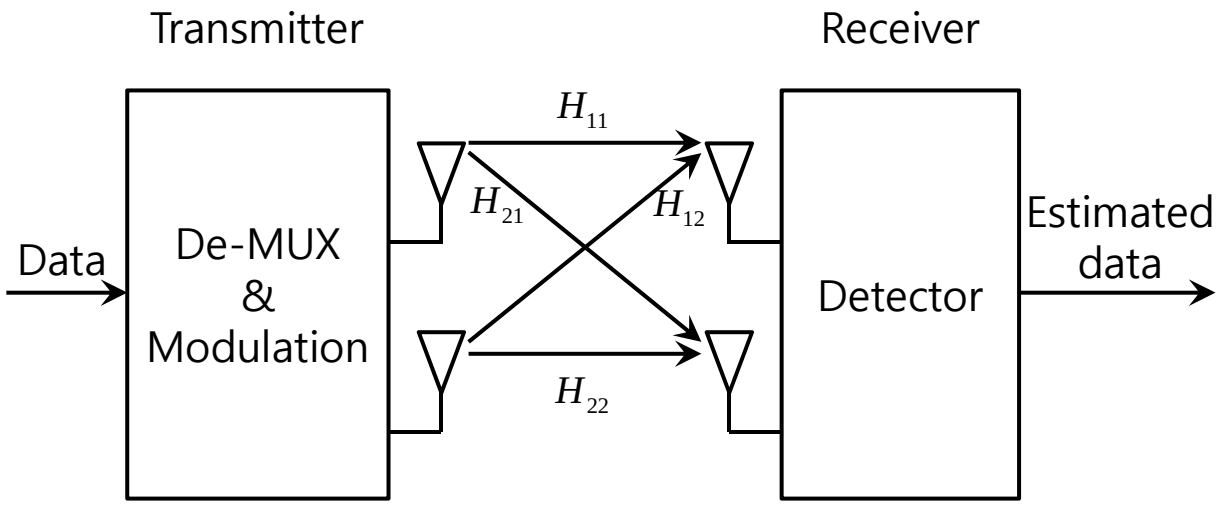
System Model [1]



- The # of antenna: 2 Tx antenna, 2 Rx antenna
- Modulation : 16-QAM
- Received signal : $\mathbf{y} = \mathbf{Hx} + \mathbf{n}$
  - $\mathbf{H}$ is 2X2 channel matrix
  - $\mathbf{H}$ follows Normalized Gaussian distribution
  - Assume that $\mathbf{H}$ is estimated perfectly
  - $\mathbf{n}$ is Gaussian noise vector

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System Model [2]

- Lattice Reduction-Aided Detector (LRAD)
  - LR is to transform $\mathbf{H}$ into a nearly orthogonal matrix $\tilde{\mathbf{H}}$ using unimodular matrix $\mathbf{T}$ consisting of integers
  - Quasi-orthogonality of $\tilde{\mathbf{H}}$ reduces the effect of noise enhancement

$$\tilde{\mathbf{H}} = \mathbf{HT}$$

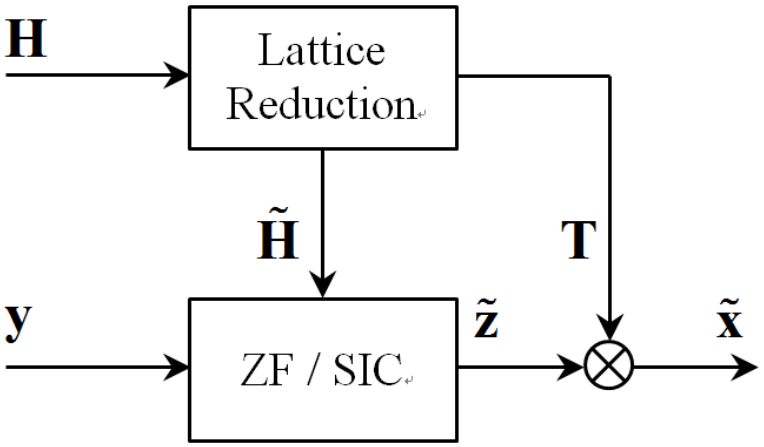
$$\mathbf{z} = \mathbf{T}^{-1}\mathbf{x}$$

$$\mathbf{y} = \mathbf{Hx} + \mathbf{n} = \mathbf{HTT}^{-1}\mathbf{x} + \mathbf{n} = \tilde{\mathbf{H}}\mathbf{z} + \mathbf{n}$$

$$\tilde{\mathbf{x}} = \mathbf{H}^{+}\mathbf{y} = \mathbf{x} + \mathbf{H}^{+}\mathbf{n}$$

$$\tilde{\mathbf{z}} = \mathbf{T}^{-1}\tilde{\mathbf{x}} = \tilde{\mathbf{H}}^{+}\mathbf{y} = \mathbf{z} + \tilde{\mathbf{H}}^{+}\mathbf{n}$$

$$\tilde{\mathbf{x}} = \mathbf{T}\tilde{\mathbf{z}}$$



<Block diagram of LR-aided detector>

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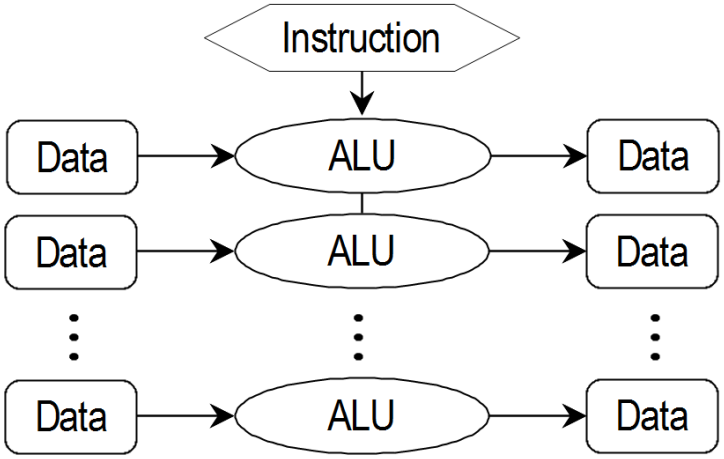
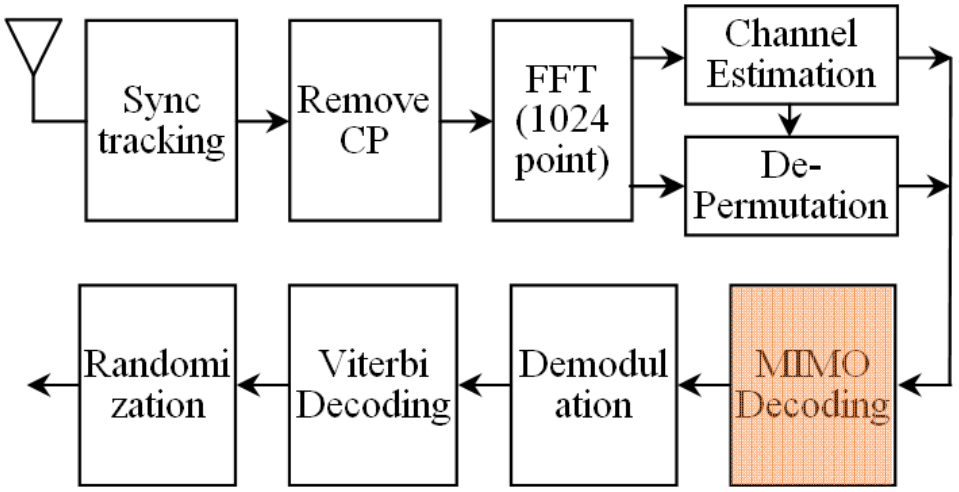
Implementation [1]

- GPU
  - SIMD(Single Instruction Multiple Data)
  - Consists of multiple blocks & threads





<Block diagram of WiMAX receiver system>

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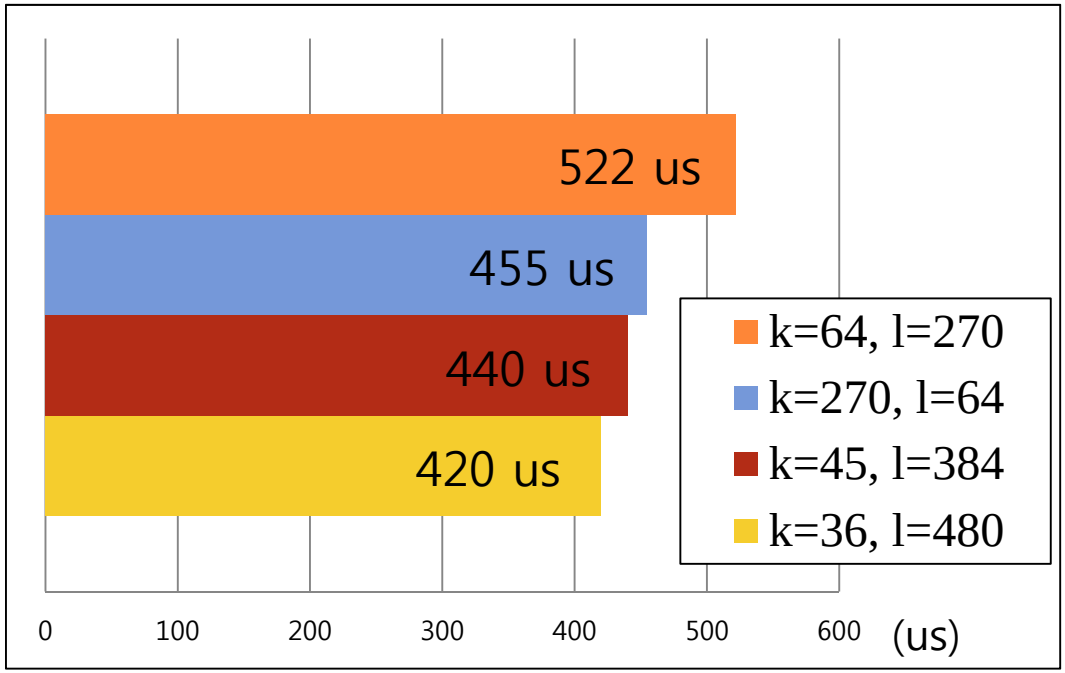
Implementation [2]

- Operation time of GPU
  - Depends on the # of Blocks (k) and threads (l)
  - Due to the internal structure of GPU, it operates faster if the # of threads is multiple of 32 or
  - if the # of threads per block gets larger
  - Maximum # of threads per block is 512



<Operation time of MIMO decoder
according to the number of blocks and threads>

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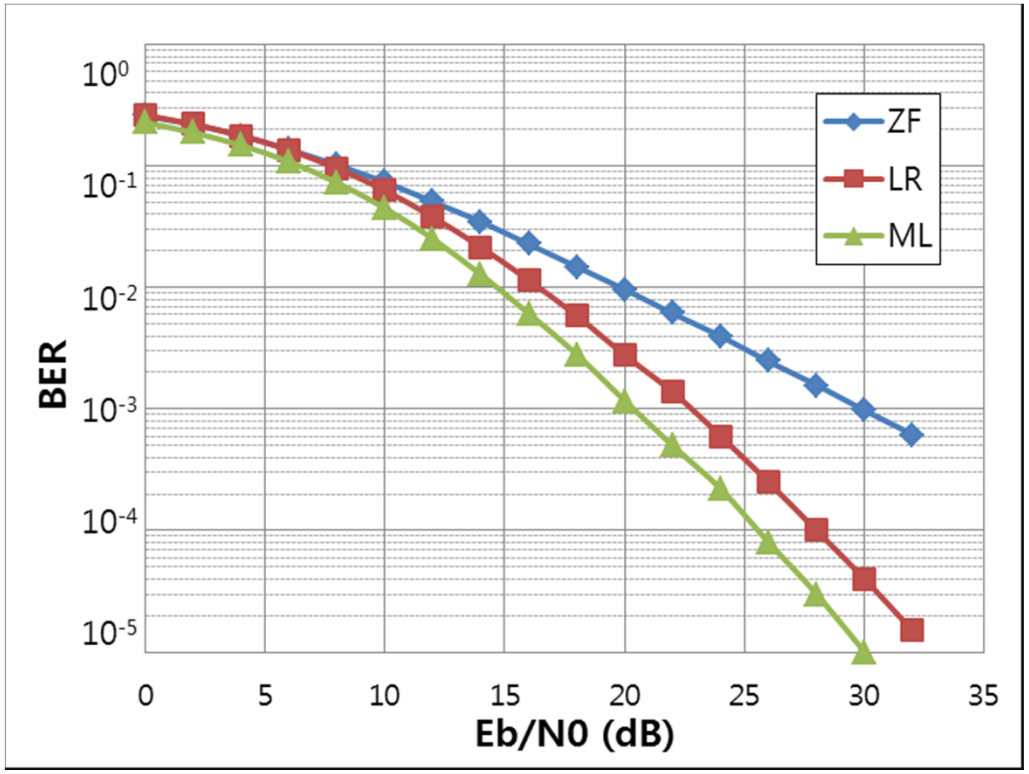
Performance Analysis [1]



<BER performance of ML, ZF and LR>
(2x2 MIMO, 16QAM, uncoded)

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Performance Analysis [2]

- Parallel processing capability of GPU

1 symbol	1 frame (17,280 symbols)
0.07ms	0.42ms

<Operation time of LR-aided detector processing 1 frame and 1 symbol>

- Real-time processing on WiMAX system
  - To achieve real time processing, the operation time for 1 frame should be less than 3ms

Algorithm	ML	LR	ZF
MIMO detector	3.84ms	0.42ms	0.04ms
all blocks except detector in the receiver	2.33ms		
Total	6.17ms	2.75ms	2.37ms

<Comparison of operation time of ML, LR and ZF algorithm on WiMAX system>

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Conclusion

- We have implemented LR-Aided Detector on the MIMO WiMAX system.
- CLLL algorithm has been adopted for implementing LRAD.
- The system has been coded on GPU for parallel processing.
- We demonstrate that operation time of LRAD is short enough for real-time processing of WiMAX.
- The performance of LRAD is quite comparable to that of MLD while the processing time of the former is less than that of the latter by nearly 9 times.
- We conclude that LRAD implemented on GPU can be widely applied to future communication systems.

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Q & A

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