Area and Power Efficient Design of Coarse Time Synchronizer and Frequency Offset Estimator for Fixed WiMAX Systems

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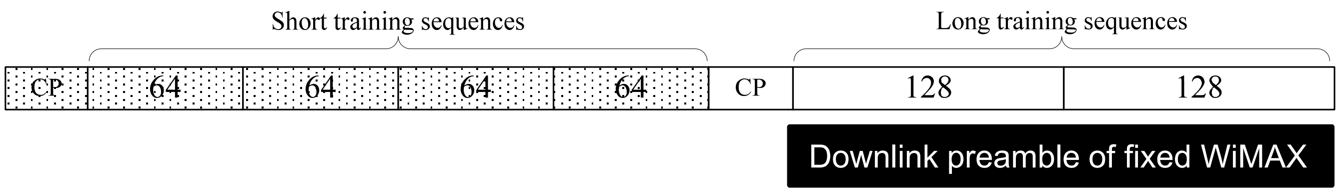
Outline

- Introduction
- Synchronization Problems and Conventional Architecture
- Proposed Architecture
- Performance Results
- Implementation Results
- Conclusion

Introduction

- Target System: Fixed WiMAX (IEEE 802.16d)
  - Wireless MAN.
  - Burst-mode OFDM.



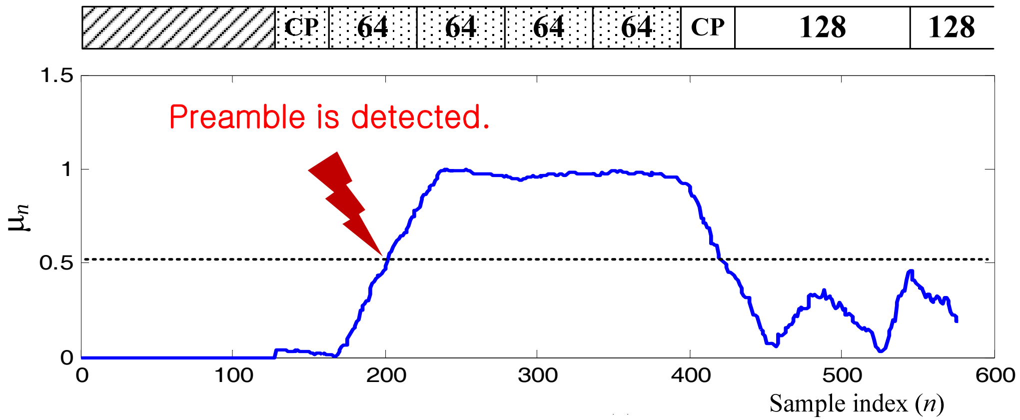
- Synchronizations in fixed WiMAX systems
  - Coarse time synchronization
  - Carrier frequency offset estimation
  - and so on.

Coarse Time Synchronization and Carrier Frequency Offset Estimation

- Coarse time synchronization
  - To determine the start of the preamble.
  - ***Long working time***. (~ 2 MAC frames)
- Carrier frequency offset (CFO) estimation
  - To estimate the mismatch of the CF between TX and RX.

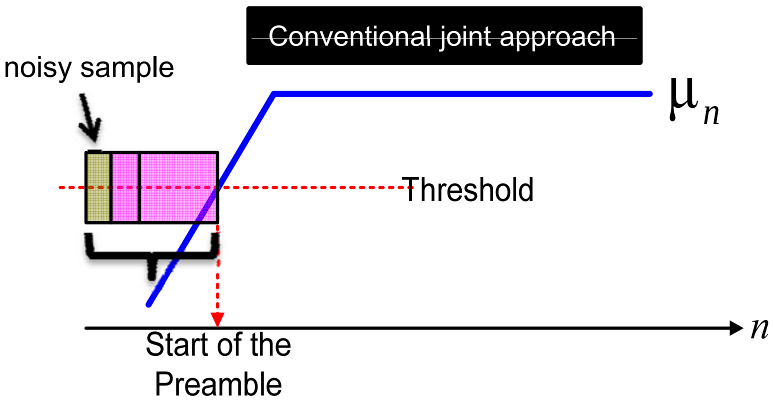
$$\mu_n = \left| \sum_{i=1}^{W} r_{n-i} \cdot r_{n-i-W}^{*} \right| \Big/ \left(\sum_{i=1}^{W} \left| r_{n-i} \right|^2 \right)$$

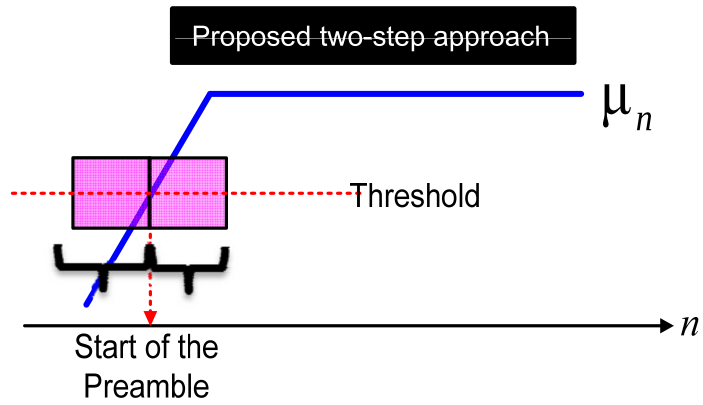
$$\varepsilon = \angle \left(\sum_{i=1}^{W} r_{n-i} \cdot r_{n-i-W}^{*} \right) \Big/ W$$



- These two estimation can be done ***jointly*** with a ***unified auto-correlator***.

Proposed Two-step Approach

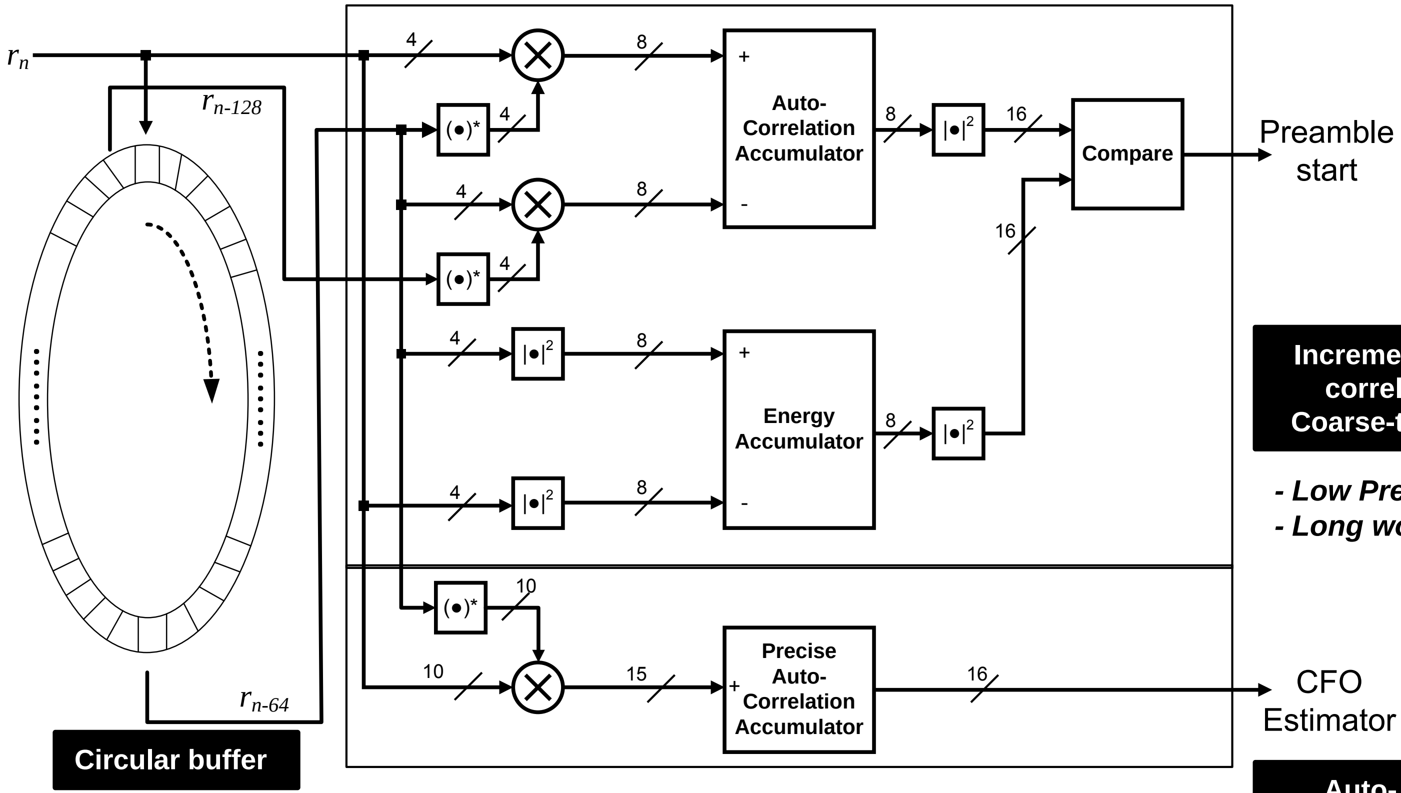




- Coarse time sync. (based on a threshold-comparison) and CFO estimation can be done ***jointly***.
- This is usually done in a ***unified auto-correlator***.
- ***The noisy samples*** in the window can degrade the CFO estimation performance.
- The required precision of the auto-correlation is ***different***.

- Coarse time sync. (based on a threshold-comparison) and CFO estimation can be done in two steps.
- 1st Step: Coarse time sync. based on a ***less precise auto-correlation incrementally***.
- 2nd Step: CFO estimation based on a ***precise auto-correlation***.

Proposed Architecture



Incremental Auto-correlator for Coarse-time Sync.

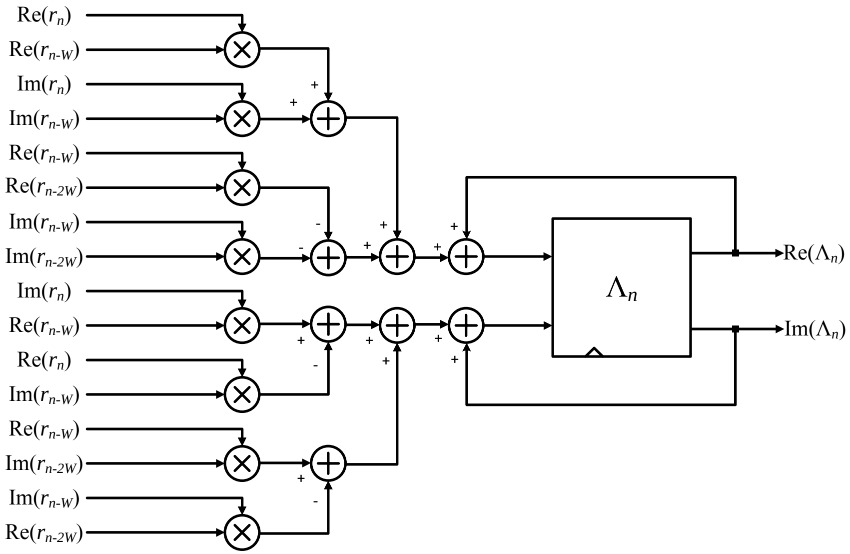
- Low Precision.
- Long working time.

Auto-correlator for CFO estimator

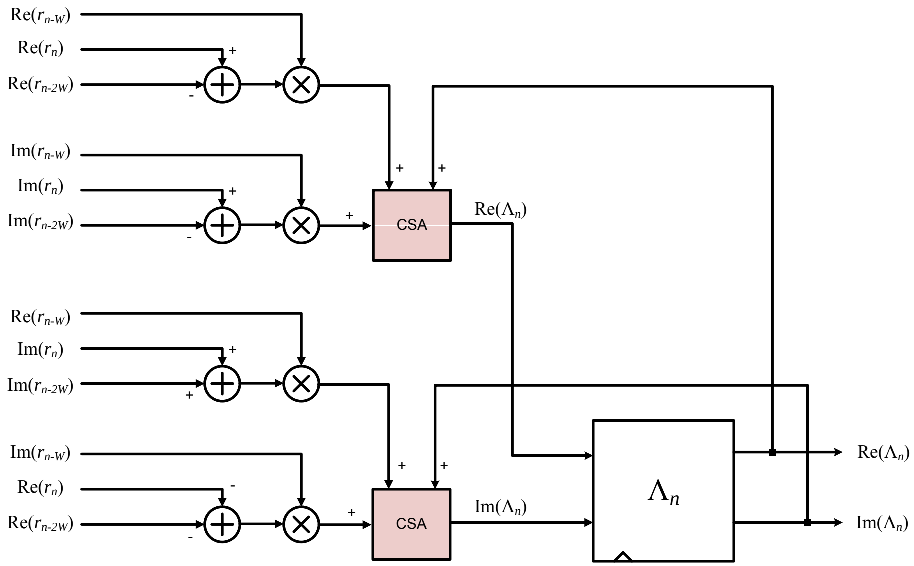
- High Precision.
- Only working in W sample window just after the frame is detected.

- Separate data-paths based on the two-step scheduling.
  - The required precision is different for each auto-correlator.
- Circular buffer implementation instead of shift-registers.

Efficient Auto-correlator Design



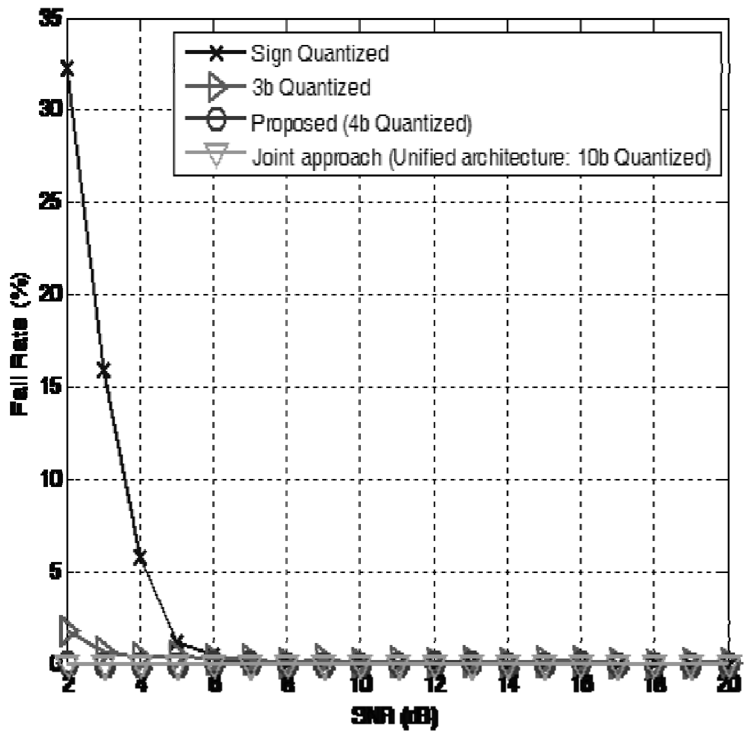
Straightforward Implementation



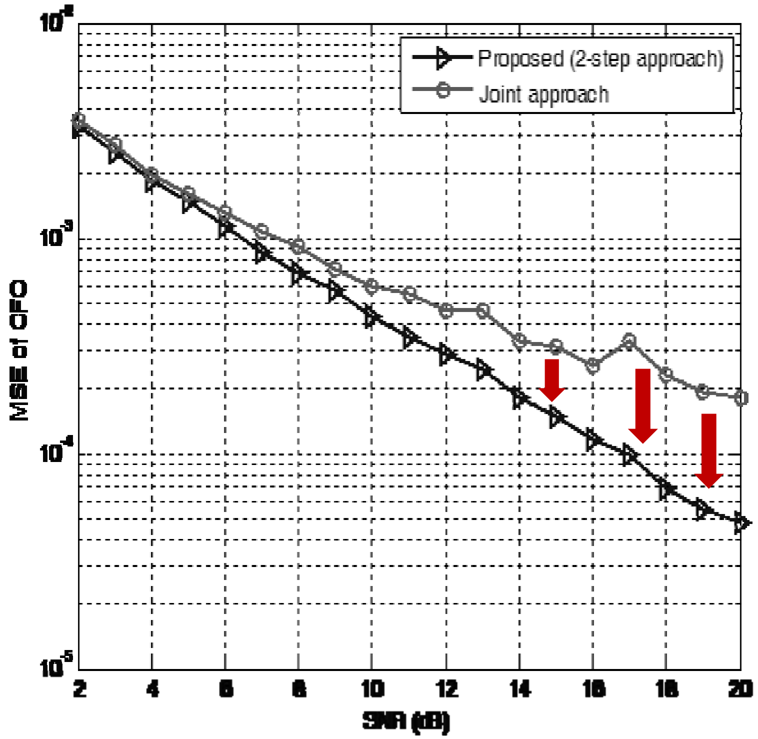
Proposed Implementation

- Total number of multipliers is smaller than that of straightforward implementation.
- More economical structure with CSAs.

Performance Results



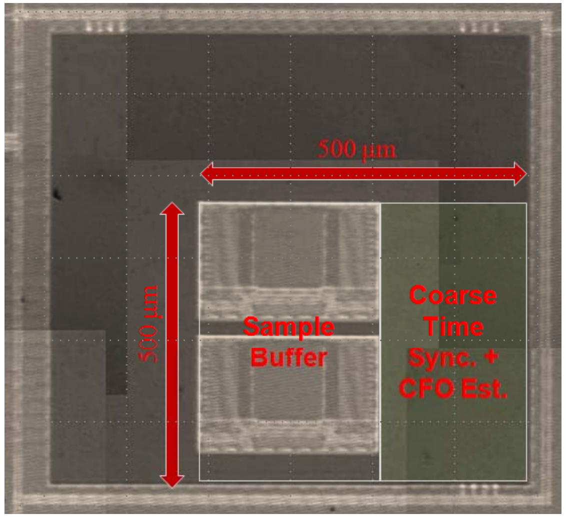
Coarse time sync. performance



CFO estimation performance

• Comparable performance of coarse time synchronization in spite of smaller hardware (we will see).
• More accurate CFO estimation thanks to the two-step scheduling.

Implementation Results



- 0.13 μm CMOS / Standard cell-based design.
- Total area is about 0.5mm x 0.5mm.
- Comparison of equivalent gate counts.

	Proposed	Joint Approach
Precise auto-correlator	4232	11321
Coarse time synch.	3688	
Etc.	754	750
Total	8674	12071

- Comparison of power consumption.

SNR (dB)	Proposed (mW)	Joint Approach (mW)
2	6.195	14.630
8	6.123	16.331
14	5.876	15.680
20	5.769	15.917

operated@20MHz.

Conclusion

- In fixed WiMAX systems, synchronization is very important in terms of performance and power.
- Based on a separate data-paths with a two-step approach, we can achieve power efficiency within smaller hardware.
  - Only 30% power consumption, 70% gate-counts