Lossless Audio Coding in the ETRI ACoM CfP Response Overview and Comparative Performance Analysis

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Outline

- Background & scope of this input document
- Lossless audio coding overview
- preLPC: motivation, role, and conservative integration
- Comparative performance analysis
- Conclusions and deltas vs. H.BWC TM3.0/TM4.0

Background & Scope

- Focus: lossless audio coding component of ETRI's ACoM CfP response (M75474)
- Common normative constraints
  - Exact reconstruction (strict lossless)
  - Decoder determinism (bitstream-driven tool selection)
  - Fixed-point processing for exact inverse operations
- Two complementary profiles share the same constraints but target different operating points
  - Dual-Mode Huffman-based profile: low complexity / predictable behavior
  - Rate-Optimized CABAC-based profile: richer tool combinations to minimize rate

Implementation Overview: What Was Actually Implemented

Baseline & Constraints

- Implemented on top of **H.BWC TM3.0** reference software
- A minor change on block split-related parameter

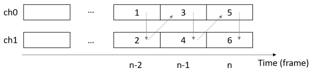
Integrated Toolset

- Tools in TM4.0 selectively adopted
  - Inter-channel LPC, Inter-/intra-channel LMS, ZLSB detection
- Dual-profile structure preserved
- **preLPC** newly implemented (CABAC-only)

Category	TM3.0 Baseline	TM4.0 Baseline	Proposed System (ETRI)
Coding structure	Two profiles	Rate-optimized profile	Two profiles
Inter-channel LPC	X	O	O
LMS for rate-optimized profile	X	O	O
ZLSB detection	X	O	O
preLPC availability	X	X	Enabled within CABAC-based profile
entropy coding	Huffman or CABAC	CABAC	Huffman or CABAC

Overall Codec Structure

- Block processing
  - Non-overlapping power-of-two blocks
  - Fixed decoding order: time progression first, then channel order within a block



  - Guarantees all prediction references are available (no circular dependencies)
- Encoder selects per-block configuration; decoder follows explicit signaling

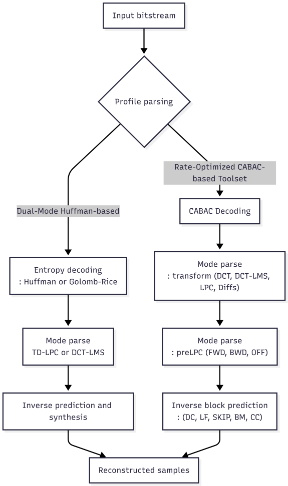
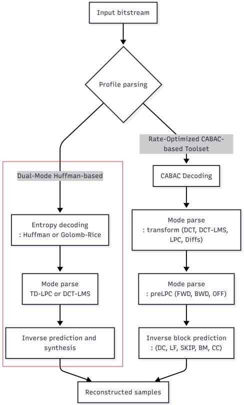


Figure: decoder pipeline

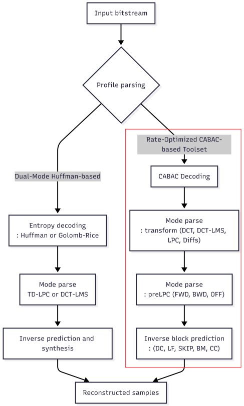
Profile 1: Dual-Mode Huffman-based

- Goal: low complexity, modest signaling overhead
- Per-block selection between:
  - **DCT-LMS**: transform-domain prediction
  - **TD-LPC**: time-domain linear prediction
- Residuals are coded using lightweight entropy coding
  - Huffman / Rice-family codes with limited local adaptation
- Intended to handle diverse signals while keeping implementation simple



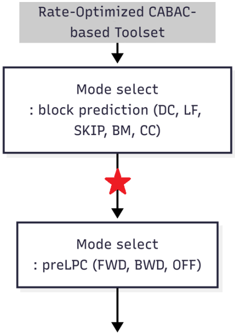
Profile 2: Rate-Optimized CABAC-based

- Goal: minimize coded rate under strict lossless constraints
- Per-block encoder search may select:
  - Block prediction modes (DC / line-fitting / skip / cross-channel / block matching, etc.)
  - Optional **preLPC** (only in selected residual paths)
  - Residual representation: transform-domain (DCT / DCT-LMS) or sample-domain (diff / LPC)
- Entropy coder: CABAC
- Decoder executes exactly the signaled configuration (deterministic reconstruction)



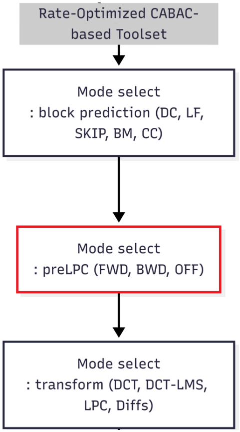
preLPC (1/2): Historical Motivation

- Observation: after block-level prediction, residuals may still contain short-term correlation
  - Limits transform coding and entropy coding efficiency
- Heritage: perceptual audio coding has long benefited from joint TD/FD prediction
  - Examples: LPC, TNS, FDNS in MPEG-D USAC and MPEG-H 3D Audio
  - Pre-whitening stages improve coding even when a primary prediction loop already exists
- Design intent in this proposal
  - Add an *optional* residual pre-whitening stage for the CABAC-based profile



preLPC (2/2): Role & Conservative Integration

- Role
  - Apply per-block pre-whitening *before* transform-domain LMS processing
  - Improves regularity of DCT coefficients & helps CABAC entropy coding
  - Adaptive direction (forward/backward) selected per block
- Scope
  - Enabled **only** in the Rate-Optimized (CABAC-based) profile
  - Disabled for incompatible sample-wise residual loops by design
  - Fully encoder-driven and explicitly signaled (single unambiguous decode path)



Performance Setup

- Test condition: EMG lossless configuration
- Compared systems
  - H.BWC TM3.0
  - H.BWC TM4.0
  - Proposed system
  - MPEG-4 SLS
- Metric: compression ratio (%) = (compressed bitstream size) / (original WAV size)
  - Lower is better
- Interpretation aids reported per use case
  - preLPC activation ratio (% blocks using preLPC)

Results: Compression Ratio and Key Observations

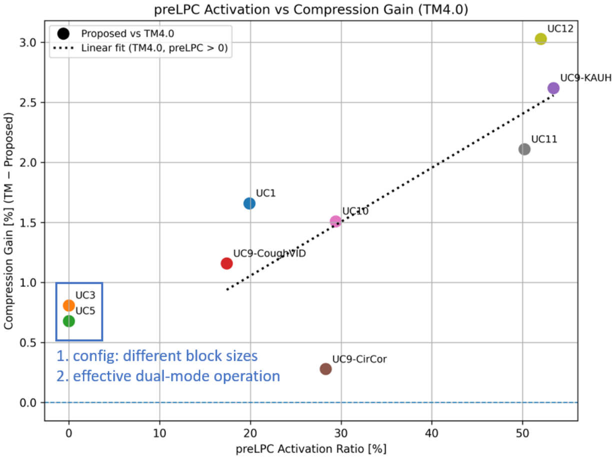
- Proposed system consistently achieves lower compression ratios than other systems across tested UCs
- Larger gains over TM4.0 are observed in use cases with higher preLPC activation
  - UC12, UC9-KAUH, UC11
- Performance improvements persist even when preLPC is not selected
  - Indicates contributions from the integrated toolset (e.g., ZLSB, inter-channel LPC, inter-/intra-channel LMS)

Use Case	Compression Ratio [%]				preLPC Activation Ratio [%]
	MPEG-4 SLS	H.BWC TM3.0	H.BWC TM4.0	Proposed system	
UC1	74.51	69.72	70.88	69.22	19.9
UC3	68.94	63.32	58.10	57.29	0.0
UC5	66.32	62.53	62.95	62.27	0.0
UC9-CoughVID	19.94	17.08	17.08	15.92	17.4
UC9-KAUH	34.30	31.79	31.79	**29.17**	**53.4**
UC9-CirCor	62.90	57.10	57.32	57.04	28.3
UC10	53.50	52.34	53.09	51.58	29.4
UC11	39.43	38.35	38.73	**36.62**	**50.2**
UC12	52.65	52.25	54.39	**51.36**	**52.0**

Table 1: Lossless compression ratios and preLPC activation ratio

Performance Analysis (2/2): preLPC Activation vs. Gain

- Observed Trend
  - Use cases with higher preLPC activation ratios tend to exhibit **larger compression gains over TM4.0**.
- Interpretation
  - preLPC operates in an **opportunistic manner**, being activated only when rate reduction is expected.
- Important Observation
  - Several use cases with **0% preLPC activation** still show performance improvements over TM4.0.
  - This confirms that gains arise from the **combined effect** of the unified toolset and the use of **larger block sizes**.



Conclusion

- The proposed system achieves lower compression ratios than H.BWC TM3.0/TM4.0
- Gains reflect tool complementarity
  - preLPC provides additional reductions when residual correlation persists
  - Other integrated tools improve performance even when preLPC is not activated

Thank You for your attention

Questions or Comments?

Backup slide - Reference Results: preLPC Behavior against TM3.0

- The proposed system **consistently outperforms H.BWC TM3.0** across all evaluated use cases.
- A **positive correlation** is observed between preLPC activation ratio and compression gain for most UCs.
- Large gains for some UCs with low or zero preLPC activation indicate that overall improvements are **not solely attributable to preLPC**.
- Additional gains originate from the **integrated toolset** inherited from the TM4.0 unified path.
- These results are provided as **supplementary reference**, while the main analysis focuses on comparison against TM4.0.