Multi-Channel Noise/Echo Reduction in PulseAudio on Embedded Linux

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Outline

- Communication device
- Echo cancellation
- Multi-channel noise/echo reduction
- PulseAudio architecture
- Results
- TI OMAP3 based (DM3730)
  ARM Cortex-A8, 1 GHz, 512 MB RAM
- < 10W, Power over Ethernet (PoE)

- Two audio codecs
  - 4-channel mic array
  - handset, headset
Problem: Mic = Target Speaker + Echo + Noise
Acoustic Echo and Noise Reduction
Multi-Channel Audio Processing

- M = 4 ... # Microphones
- D ... Microphone Signal
- X ... Playback Signal
Adaptive Beamformer

SSL ... Sound Source Localization
FBF ... Fixed Beam Former
BAC ... Beamformer Adaption Control
ABM ... Adaptive Blocking Matrix
AIC ... Adaptive Interference Canceller
PulseAudio Echo Cancellation

R ... Resampling
NR ... Noise Reduction
PulseAudio Contributions

During 3.0 and 4.0 development cycle

- ARM NEON optimizations (remapping, sample conversion, mixing)
- Resampling improvements
- Support for multi-channel EC with different input/output sample specs
- module-remap-source
- Single and multi-channel AEC Implementations (not yet public)
Noise/Echo Reduction Results

Near-End Speaker $S$

Echo Signal $Y$

Double Talk

Microphone Input $D$

Ambient Noise $V$

Speex Output

WebRTC Output

bct 4-channel Output

Time (s)
Runtime Components and Optimization

![Runtime Components and Optimization Diagram](image)

**ARM (baseline)**

**ARM NEON**

- **Inverse FFT**
- **Postfilter**
- **GSC (BAC+ABM+AIC)**
- **FBF**
- **SSL**
- **Forward FFT**
- **Conversion**

2.6x Speedup
Runtime Comparison

![Runtime Comparison Diagram](image-url)
Summary

• Multi-channel audio processing on embedded Linux
• PulseAudio provides noise/echo reduction to application
• Separation of concerns:
  Hardware abstraction, signal processing, application
• Optimization required (algorithm design, implementation layer)
Questions?

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