Energy Efficient Echo-Hiding Extraction Method Based on Fine Grain Intermittent Power Control

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Agenda

- Introduction
  - Background, motivation, and our goal
  - Basics of audio steganography ~echo-hiding~

- Proposed extraction method of echo-hiding
  - Early termination of extraction
  - Skipping extraction based on reliability
  - Judgement of data embedding

- Experiments
  - Evaluation board for power-conscious applications
  - Experimental results

- Conclusion
Background

- Long term sensing is main interest in sensor nodes
- Reduction of active rate greatly reduces power consumption
  - Can be clocked-off or be powered-off while they are in idle
  - Suitable for sparse sensing because of shorter active time

Our Target

<table>
<thead>
<tr>
<th>Calculation Cost</th>
<th>Sampling Rate</th>
<th>Environmental Monitoring</th>
<th>Medical</th>
<th>Healthcare</th>
<th>Audio &amp; Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>Time</td>
<td>Power</td>
<td>Time</td>
<td>Power</td>
<td>Time</td>
</tr>
</tbody>
</table>

Active

Idle

Audio & Image

Medical

Environmental Monitoring

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Motivation: Audio Steganography

- Audio steganography can be used to low cost data distribution
  - Distributor play music with embedded data
  - Devices with microphone automatically extract data from music
  - User can get various information just like E-mail

Example: Smart Watch with Mic.

- Advertisement
- Shopping coupon
- Accessibility
Goal of This Work

- Suppose to use 450mAh and 3.0V rechargeable battery
  - Continue to extract embedded data for 1 week ⇒ under 6mW
  - Continue to search embedded data for 1 month ⇒ under 1mW

- Power switch controller can reduce active rate of not only a processor, but other main devices

Low power sensing by reduction of active rate in the extraction of audio steganography
Embed data as artificial echo

Specified numbers of samples
=> We call “frame”

Original signals

Artificial echo

Express symbol ‘0’

Delay d0

Express symbol ‘1’

Delay d1

Audio samples → FFT() → abs() → log() → IFFT() → acf() → Autocepstrum coef.

Use autocepstrum coefficients for extraction

Delay d0

Extract symbol ‘0’

msec

Delay d1

Extract symbol ‘1’

msec

Autocepstrum
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Conclusion
Our Basic Approach ~Majority-Rule Extraction~

- Decode frame width can become shorter than the encode frame width

Sender

<table>
<thead>
<tr>
<th>Symbol '1' embedded</th>
<th>Symbol '0' embedded</th>
<th>Symbol '1' embedded</th>
</tr>
</thead>
</table>

Encode Frame = 128ms

Decode Frame = 16ms

Receiver

? 1 1 1 1 1 1 ? 0 0 0 0 0 0 0 ? 1 1 1 1 1 1 1 ?

Majority-Rule

Success to extract symbol '0'

Majority-rule extraction is suitable for reduction of active rate
1. Early termination of extraction
2. Skipping extraction based on reliability
3. Judgement of data embedding
1. Early Termination of Extraction

The result of majority-rule can be decided before final decode frame.

=> Sensor node can sleep until next extraction process.
2. Skipping Extraction Based on Reliability

- Embedded data is transferred by multiple times (Data Carousel)

<table>
<thead>
<tr>
<th>Sender</th>
<th>Encode Frame N</th>
<th>Encode Frame N+1</th>
<th>Encoder Frame N</th>
<th>Encode Frame N+1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8</td>
<td>1 2 3 4 5 6 7 8</td>
<td>1 2 3 4 5 6 7 8</td>
<td>1 2 3 4 5 6 7 8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Receiver</th>
<th></th>
<th></th>
<th>Receiver</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 1 1 1</td>
<td>1 0 1 0 1 0 1 0</td>
<td>1 1 1 1</td>
<td>0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

- First 5 frames are same => Reliable
- No majority symbol => Unreliable

Sleep in 8 decode frames

Extract again

Majority-rule gives reliability to extracted data.
=> Retry extraction only in “unreliable” frames
3. Judgement of Data Embedding

Avoid unnecessary extractions

=> Reduce active time in the environment without embedded data
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Experimental Setup

- Format of Embedded Data

  Extracted by 8-decode frames

  Encode Frame = 128ms

  60 data frames

  3-times Data Carousel

  240 symbols Embedded

- Measured active rate of sensor node in the extraction of 240 symbols
- Encode frame width is 128ms and decode frame width is 16ms
- Suppose 3-times data carousel
Evaluation Board for Power-Conscious Application

Main Board
- Micro-controller
- Power switch controller

Daughter Board
- Sensor socket array

Music with
Embedded Data

Line-In (Mic) → OP-AMP → ADC 10bit 16kHz → Processor ARM Cortex-M3

Extracted Symbols

Turn ON/OFF Power Switch Commands

Power Switch Controller
The board was affected by noise and frequency response.
- Decreased the chance of early termination, and skipping extraction.

Active rate in the environment without embedded data was almost 1% => only 100uW.

- 60% reduction in extraction process.
- 99% reduction in the environment without embedded data.
Conclusion

- Energy efficient echo-hiding extraction method based on majority-rule extraction
  - Early termination of extraction
  - Skipping extraction based on reliability
  - Judgement of data embedding

- Experimental results shows
  - Reduced 60% power consumption in extraction process
  - Reduced 99% power consumption in the environment without embedded data
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