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Polar Codes: From Theory to Practice

Presented by the Broadcom Foundation.
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Polar Codes: From Theory to Practice

- **When can we use polar codes?**
  - Limitations: Decoding area, power, latency, …
  - Current implementable lengths: 32K, 64K, 128K
  - LDPC codes are superior at these lengths!
- **Goal:** Achieve faster polarization to improve performance of polar codes at finite lengths
- **Achievement:** A factor of 2 reduction in the code length at rates close to capacity
- **Strategy:** Reduce the scaling exponent $\mu$

\[ n = \beta_{P_e} W (C - R)^{-\mu} \]

- **Method:** Construct larger polarization kernels
  - Size of the conventional polarization kernel: 2x2
  - Sizes of proposed polarization kernels: 8x8 and 16x16

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CMOS/Silicon Photonic 3D-Integrated Source Synchronous Parallel Optical Receiver with Adaptive Power Reduction
128 Gb/s CMOS/Silicon Photonic 3D-Integrated Optical Receiver Consuming 5mW and Occupying 0.018 mm²

- Growing multi-core architectures strain chip-to-chip interconnects
  - Optical links enable higher bandwidth for chip-to-chip communication
  - Apps: Multi-core CPUs, memory/processor interface and data-center switches

- 4-Channel 3D integrated source synchronous optical Rx in 28nm FDSOI CMOS/silicon photonic
  - 4 ultra compact (0.3 x 0.06 mm²) double-sampling Rx channels operating up to 32 Gb/s with OMA sensitivity of -8.8dBm
  - Wideband (4-11 GHz) injection-locked source synchronous clocking
  - Adaptive power reduction at lower data-rates using FDSOI body-biasing
  - Fully integrated photonics with WDM, and waveguide-coupled photodiodes
  - Copper-pillar 3D integration: Low parasitic (<20 fF) and dense (40 µm pitch)
TEJASVI ANAND
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN — UNITED STATES

Energy Proportional Wireline Communication System
Power Scalable High-Speed Serial Link for Wireline Communication

- **Conventional link**
  - Idle for ~85% of the time → Constant power

- **Proposed link**
  - Power-off when idle → Power scaling

- **Benefits to data centers**
  - Annual savings for North America ≈ $870M

- **Challenges**
  - Power-on time ≈ 0 ns
  - Off-state power ≈ 0 mW

**Solution: A 7Gb/s Rapid-on/off Transceiver**

- 20 ns power-on time
- 740 µW off-state power
- Data rate ↓100x → Power ↓44x

Source: T. Anand, ISSCC.2015
AMR SULEIMAN
MASSACHUSETTS INSTITUTE OF TECHNOLOGY — UNITED STATES

An Energy-Efficient Hardware Implementation of HOG-Based Object Detection at 1080HD 60 fps with Multi-Scale Support
A 45 mW Object Detector Accelerator for High Definition Video at 60 fps

- The system can process 1920 x 1080 at 60 fps with energy of 0.364 nJ/pixel using 45nm technology
- Applications: Surveillance, robotics, portable devices, automotive, etc.

Features
- Detection accuracy and robustness
- Real-time and high frame rate
- High resolution
- Energy-efficiency

- 2.4x increase in detection accuracy, using multi-scale support with optimized image pyramid
- 4.5x reduction in energy consumption using parallel detectors, voltage scaling and image pre-processing
HYUNWOO CHO
KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY — KOREA

A 79 pJ/b 80 Mb/s Full Duplex Transceiver and 42.5 µW 100 kb/s Super-Regenerative Transceiver for Body Channel Communication

Presented by the Broadcom Foundation.
A 79 pJ/b 80 Mb/s Full-Duplex Transceiver and a 42.5 μW 100 kb/s Super-Regenerative Transceiver for Body Channel Communication (BCC)

- **Project Goal: Ultra-Low-Power/Energy Wireless BAN**
  - BCC transceivers for both entertainment and healthcare devices
  - Entertainment (ET-mode): High speed, low-energy, full-duplex
  - Healthcare (HC-mode): Ultra-low-power with the high Q-factor

- **Key Implementation Details**
  - Extending Body Channel Bandwidth: from 100 MHz to **200 MHz**
  - ET-mode Transceiver: 20 – 60 MHz, 140 – 180 MHz dual band
    - **R-C notch filter**-based duplexer → Full duplex comm.
    - **Dual-band** Transceiver → High speed, low-energy
  - HC-mode Transceiver: 13.56 MHz ISM band
    - **R-C super-regenerative** transceiver → Ultra-low-power and high Q-factor

- **Lowest energy (79 pJ/b), highest speed (80 Mb/s), lowest power (42.5 μW) with Q-factor > 1000, ever reported**

<table>
<thead>
<tr>
<th></th>
<th>ET-mode TRX</th>
<th>HC-mode TRX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Rate</td>
<td>100Mb/s</td>
<td>800Mb/s</td>
</tr>
<tr>
<td>Power</td>
<td>3.7mW</td>
<td>6.3mW</td>
</tr>
<tr>
<td>Full-Duplex</td>
<td>x</td>
<td>O</td>
</tr>
<tr>
<td>Q-Factor</td>
<td>-</td>
<td>&gt;1000</td>
</tr>
</tbody>
</table>

Presented by the Broadcom Foundation.
BENJAMIN KLEIN
TEL AVIV UNIVERSITY—ISRAEL

From Image to Text and Back Using Deep Learning
From Image to Text and Back Using Deep Learning

- Allowing computers to understand images and sentences using deep neural networks
  - Creating a unified semantic representation for images and sentences
  - The tasks:
    - **Image search**
      Finding the best image that describes a given sentence
    - **Image annotation**
      Finding the best sentence that describes a given image
    - **Sentence synthesis**
      Generating a novel sentence that describes a given image

- Results
  - **Image search & image annotation**: Our algorithm **surpasses** the results of world-renowned research labs such as:
    - Google
    - Baidu
    - Stanford
    - Berkeley
    - University of Toronto
    - UCLA
  - **Sentence synthesis**: The sentences below the images on the right were created by our algorithm!

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A man in red shirt is climbing up the rock face
A skier is jumping over snow-covered hill
Low-Power High-Resolution Radar Design with TDC-Based Beamforming for Mobile Healthcare
Low-Power High-Resolution Radar Design with TDC-Based Beamforming for Mobile Healthcare

- **Applications:** Contactless vital-sign detection
  - Detection of respiration rate, heartbeat rate, sleep condition, wireless electrocardiograph, etc.
  - Embedded in smartphone and other handheld devices
  - Support comfortable home healthcare

- **Technologies:** Short-range pulse radar transceiver
  - Ranging based on 2nd-order $\Delta\Sigma$ TDC (Time-to-Digital Converter)
  - Beamforming technique, 5.7dB SNR improvement
  - Duty-cycling, 100 KHz data rate, < 5 mW
  - Prototyped in 65nm CMOS, achieving 7 mm resolution

- **Advantages:** Low power consumption, high ranging resolution, and low design complexity
A Stochastic Geometry Approach to the Coexistence of LTE and Wi-Fi in Unlicensed Spectrum
We propose a theoretical framework to analyze the overlaid LTE and Wi-Fi network in unlicensed spectrum

- Provide key performance metrics and design insights in a fundamental way

- **LTE with continuous transmission and no protocol change**
  - Wi-Fi is severely degraded by LTE with high eNB density (e.g., more than 10 dB SINR loss)

- **LTE with discontinuous transmission**
  - LTE needs to transmit with a short duty cycle to protect Wi-Fi (e.g., less than 50%)
    - Even shorter duty cycle may be required to protect Wi-Fi delay sensitive applications such as VoIP or video

- **LTE with listen-before-talk and random back-off**
  - LTE needs to accept either lower channel access priority (e.g. larger contention window size) or more sensitive CCA thresholds (e.g., -80 dBm) to protect Wi-Fi
High-Performance Low-Power CTΣΔ Modulator for Broadband Applications

- **Project Goal:** Energy efficient CTΣΔ modulator for wireless portable devices
  - Applications: WLAN, high-definition video processing, medical imaging, sonar, broadband radar

- **Implemented Solutions**
  - Optimized gain distribution highly reduces analog power consumption
  - Single opamp biquad with passive compensation network
  - Wide bandwidth common gate summing node implementation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process (nm)</td>
<td>40</td>
</tr>
<tr>
<td>FS (GHz)</td>
<td>3.2</td>
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<tr>
<td>BW (MHz)</td>
<td>75</td>
</tr>
<tr>
<td>SNDR (dB)</td>
<td>64.9</td>
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<tr>
<td>Area (mm²)</td>
<td>0.09</td>
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<tr>
<td>VDD (V)</td>
<td>1.1</td>
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<tr>
<td>Power (mW)</td>
<td>22.85</td>
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<tr>
<td>Walden FoM(J/conv)</td>
<td>106</td>
</tr>
<tr>
<td>Schreier FoM(dB)</td>
<td>163</td>
</tr>
</tbody>
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ATSUTAKE KOSUGE
KEIO UNIVERSITY — JAPAN

High-Speed Non-Contact Interface Using Transmission Line Coupler
High-Speed Non-Contact Interface Using Transmission Line Coupler

- **Unreliable conventional wireline connectors**
  - Metal contacts are susceptible to contamination and fatigue
- **Proximity communication by near-field coupling**
  - Immune to mechanical damages caused by friction/vibration
  - Water-proof property providing superior detachable connecting environment
- **Transmission line coupler is impedance matched and wide BW**
  - Using both distributed capacitive and inductive couplings
  - Suitable for multi-drop bus application
  - Design techniques of the coupler and the transceiver are presented for various applications (smartphone, in-vehicle LAN, satellite)

<table>
<thead>
<tr>
<th></th>
<th>TLC</th>
<th>Capacitive</th>
<th>Inductive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Rate (Gb/s)</td>
<td>12</td>
<td>2</td>
<td>5.5</td>
</tr>
<tr>
<td>Distance (mm)</td>
<td>5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Coupler Size (mm²)</td>
<td>6</td>
<td>7.9</td>
<td>144</td>
</tr>
<tr>
<td>Power (pJ/b)</td>
<td>6</td>
<td>N/A</td>
<td>36</td>
</tr>
</tbody>
</table>
Video Signal Analysis in a Low-Complexity Domain Based on Compressed Sensing
Video Signal Analysis in a Low-Complex Domain Based on Compressed Sensing

Motivation: Analyze videos in a low-complex domain

Analysis in measurement domain through CS
- Developed a temporal correlation analysis in the measurement domain
  \[ f'_w = \sum_{i=1}^{4} \Gamma_i \cdot f_{B_i} \]
  \[ y_w = \sum_{i=1}^{4} \Phi \Gamma_i \Phi^* \cdot y_{B_i} \]
  - Find the best matched block in the reference frame for the current one “directly” in the measurement domain
- Found that inner characteristics of videos can be revealed by using measurements
  - There is a linear relationship between cross-covariance matrix in the measurement domain and that in the frequency domain
  - Proposed a texture classification method using compressive measurements

Advantage and achievements
- Deal with the compressed data rather than full data
- Computation complexity can be \( \frac{\text{length}(f)}{\text{length}(y)} \) less than the signal processing methods in pixel domain
- Better accuracy performance with only 14%-50% processing time compared to the existing methods

Compressed sensing (CS): Transforms the original pixel domain image \( f \) into its measurement domain projection \( y \). Advantage: \( \text{length}(y) \ll \text{length}(f) \).

Fig. 1 Construction of \( \Gamma_i \) (the spatial relation matrix between the block to be estimated \( B'_w \) and the non-overlapping blocks \( B_i \))

Fig. 2 System diagram

Guarantee in-vehicle video transmission and help drivers make quick response
Application Delivery Platform for Multi-Cloud and IoT-Based Applications like Healthcare Monitoring and Delivery
Application Delivery Platform for Multi-Cloud and IoT Based Healthcare Monitoring and Delivery

- The $2.9 trillion U.S. healthcare economy – gearing up for a fundamental change
- Distributed virtual infrastructure with multiple clouds (Micro-clouds on towers, several public local and regional clouds and hospitals’ private clouds)
- OpenADN is a multi-cloud application management platform that allows CIOs to automate the creation/allocation/lifecycle management of application workflows
- IoT chipsets used in devices and clouds need to incorporate software like OpenADN
- Optimized OpenADN is critical for efficient healthcare delivery
Thank You