Optical On-Chip Networks for High-Performance, Energy-Efficient Multi-Core Architectures

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Building Blocks

Photonic Switching Element (PSE)

• Broadband ring-resonator switch
• ON state:
  - carrier injection
  - coupling into ring
  - signal switched
• OFF state:
  - passive waveguide crossover
  - negligible power.

Network Architecture

Objective:
Co-architect high bandwidth optical switch architectures and fine grain Chip Multi-Processors to speed up high bandwidth-demand applications.

Primary Research Focus:
- Design a high bandwidth grid network implemented on a dedicated optical layer composed of very low power optical components
- Co-architect a fine-grain CMP system of low-power cores that enables learning algorithms to fully exploit high bandwidth, low power communication

- Optical data network grid
  - 2x spatial overprovisioning (i.e. two 4x4 switches per gateway per dimension)
  - Message generation occurs once and then messages are routed for free.
  - Larger networks consume the same amount of power
- Electronic control network
  - Manages photonic network
  - Path-setup packets sent in advance of data to reserve path for photonic messages
  - Distributed adaptive routing algorithms to minimize latency and power consumption

Interconnect Characteristics

4GHz, α = 1 @ 22nm

<table>
<thead>
<tr>
<th>Proposed Optical Network</th>
<th>Electrical baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup (16 bits)</td>
<td>(32 bits)</td>
</tr>
<tr>
<td>Area</td>
<td>5.38mm²</td>
</tr>
<tr>
<td></td>
<td>23.3mm²</td>
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<tr>
<td></td>
<td>25.5mm²</td>
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<tr>
<td></td>
<td>Active layer</td>
</tr>
<tr>
<td></td>
<td>11.67mm²</td>
</tr>
<tr>
<td>Power</td>
<td>28.8W</td>
</tr>
<tr>
<td>Bisection BW</td>
<td>256GB/s</td>
</tr>
<tr>
<td>Latency</td>
<td>60 cycles</td>
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</tbody>
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For equal power → 20x bandwidth improvement
→ 10x latency improvement

4GHz, α = 1 @ 22nm

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For equal bandwidth → 17.5x less power
→ 173.5x less area

Data Mining

- Mine medical, financial, communication, travel, sensor, scientific, spatial, temporal data
- Find structure, rules, associations, clusters

Algorithms:
- Clustering: K-means, k-medoids, agglomerative, divisive
- Frequent item set mining
- Graph mining
- Association rules mining

Medical & Scientific Profiling

Strategic Data Analysis

Supervised Learning

- Learn to predict target from inputs

Algorithms:
- Artificial Neural Networks
- Decision trees
- K-Nearest neighbor
- Support vector machines

Satellite Image Recognition
Speech Recognition
Moving Object Recognition
Autonomous Vehicle Control