Efficient Approach towards Energy Minimized Optical Network

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Outline

- Introduction Needs, Scenario & Approaches
- Our Focus
- Targets & Achievement
- Further Improvement
- Conclusion
Growing Issues on Environment: Simultaneous threat against the global environment and resources

- Threat against the existence of human race due to weather disasters and ecological destruction
- Economic loss predicated if energy mass consumption system continues: 5~20% of annual world GDP ('06, Stern Review)
- Shortage of energy resources and increase in price
- Caused by economic development of new developing countries and continuous growth in world population

**Summer Period**
- : Jun.3~Sep.21 (1920s)
- -> May 24~Sep.27 (1990s)
- : 16 days increase

**Winter Period**
- : Nov. 21 ~ Mar. 18 (1920s)
- -> Nov. 29 ~ Mar. 8 (1990s)
- : 19 days decrease

Source: METRI Korea, 2006
In past no any concern with the power consumption on the optical network

Power issue is also being taken as a resource and more focus drawn towards its efficient use

Energy Saving Optical Technologies Tendency
- All-optical technology as the solution of electronic bottleneck.
- Current trends of developing the electronics devices: compact size higher speed
- As concerned more about power and development of electronics high speed devices the trends moves to the hybrid

Finding the ways to improve power efficient networks
- Component level design (Improve electronic technology for the hybrid system)
- Power aware protocol design (low energy states)
- Power aware network design (New architecture i.e. bypassing)
Multi-disciplinary approach Tendency towards Future Green Internet

Power forecast based on current technologies
- Power consumption based on vendor specs
- Telco network architectures
- Projected services take up

Power forecast based on new technologies
- New optical technologies
- New router architectures
- New mix of electro & opto
- New protocols
- New network architectures

Strategies to minimise power consumption
- New paradigm for power minimisation

source: MERIT, Australia
Reasons for moving to Hybrid Technology:

- Current trends of developing the electronics devices: compact size higher speed
- Not necessarily introduce system benefits on the all optical systems due to transparency

Power Aware Protocol Designing

- Nearly 70% by BW. Allow generic long packets
- Nearly 70% of switching times Switching by flow bursts

source: Thompson, Miller, Wilder 1997
Dominance of Access Network in IP Related Processing


Efficient Approach towards Energy Minimized Optical Network @ITU-T workshop at Shanghai Expo 2010
Present scenario of Power Consumption in Optical Network

![Graph showing power consumption vs. peak access rate]

- **Power (W/user)** vs. **Peak Access Rate (Mb/s)**
  - **Today’s Internet** (~ 2.5 Mb/s)
  - **Core**
  - **Access**
  - **Metro**
  - **SDH/WDM Links**

10 router hops

Source: R. Tucker, OFC 2007

Source: [ITU-T workshop at Shanghai Expo 2010](#)
Our Focus: Present Scenario

Still need of the OEO wavelength converter in our proposed hybrid PSMB

Power consumption by various components in optical network

So further approach should be taken on the minimizing of wavelength converter
Set-UP: Modification from the Past System PSMB

- On approach to the hybrid technology we used the shared electronics buffer
- Change all optical wavelength converter to the OEO wavelength converter
- Change the Node architecture

Very low power consumption

Performance of PSMB with different sharing ratio

source: J. Kevin Lee, KAIST ICC workshop 2010

Hybrid optical packet node architecture (PSMB)

Shared Electrical memory buffers
Wavelength Converters

OOO wavelength converter (using SOA)

<table>
<thead>
<tr>
<th>Item</th>
<th>Power (W)</th>
<th>Relative cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooled laser diode</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Cooled tunable laser diode</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Adjustable optical delay</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>4 cooled SOAs</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Rx CDR</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>PIN-TIA</td>
<td>0.13</td>
<td>0.30</td>
</tr>
<tr>
<td>Total</td>
<td>3.13</td>
<td>4.5</td>
</tr>
</tbody>
</table>

OEO wavelength converter

<table>
<thead>
<tr>
<th>Item</th>
<th>Power (W)</th>
<th>Relative cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>DML diode</td>
<td>0</td>
<td>0.35</td>
</tr>
<tr>
<td>DML driver</td>
<td>0.42</td>
<td>0.20</td>
</tr>
<tr>
<td>EML diode with TEC</td>
<td>1.00</td>
<td>0.7</td>
</tr>
<tr>
<td>EML driver</td>
<td>0.60</td>
<td>0.8</td>
</tr>
<tr>
<td>Tx-Rx Mux and CDR</td>
<td>0.25</td>
<td>1.50</td>
</tr>
<tr>
<td>PIN-TIA</td>
<td>0.13</td>
<td>0.30</td>
</tr>
<tr>
<td>Total</td>
<td>0.80</td>
<td>3.40</td>
</tr>
</tbody>
</table>

Table: Power & cost comparison of WCs using OEO & SOA

Efficient Approach towards Energy Minimized Optical Network @ITU-T workshop at Shanghai Expo 2010
**Power & Cost Comparison of PSMB & Exiting Architecture**

<table>
<thead>
<tr>
<th>Major Component</th>
<th>OEXC</th>
<th>PSMB</th>
<th>ASDB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunable WC</td>
<td>$2W (N+B)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FDL</td>
<td>$\left[ WB/ W_{FDL} \right]$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOA</td>
<td>$W (N-B)$</td>
<td>$WB$</td>
<td></td>
</tr>
<tr>
<td>Electro-optic switch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2x2)</td>
<td>$WN (\log_2 N+1)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronic switch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2x2 at 10 or 40G)</td>
<td>$WN (\log_2 WN - \frac{1}{2})$</td>
<td>$WB (\log_2 WB - \frac{1}{2})$</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(E/SR &amp; SR/E)</td>
<td>$WN$</td>
<td>$WB$</td>
<td></td>
</tr>
<tr>
<td>TRx</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(SR/E/O &amp; O/E/SR)</td>
<td>$WN$</td>
<td>$WB$</td>
<td></td>
</tr>
</tbody>
</table>

Table: Major components counts in Node Models
Target & Achievement

<table>
<thead>
<tr>
<th>Target</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving towards the Hybrid technology</td>
<td>Obtained by using shared electronics buffer and Optical switch fabric</td>
</tr>
<tr>
<td>Reduce Power consumed</td>
<td>About 50% reduction is achieved using the proposed Node Architecture</td>
</tr>
<tr>
<td>Reduce on total cost</td>
<td>About 1/3 cost reduction achieved</td>
</tr>
<tr>
<td>Changing the Wavelength converter Technology</td>
<td>From OOO to OEO wavelength converter</td>
</tr>
<tr>
<td>Modifying the Present Node Architecture (ASDB)</td>
<td>Proposed a new Node architecture (PSMB)</td>
</tr>
</tbody>
</table>
Further Approaches To be Taken

- Modifying in the electronics switch part

- Buffer the input data on the basis of lambda so if needed then use the wavelength converter and if not needed of the conversion bypass it.

- This features not only reduce the number of wavelength converter but also reduces the number of locking of different wavelength

- As each locking process will have some amount of more power consumption it can reduce the power as it is reducing the number of converting different frequency

- Finally obtain the power reduction up to 75% and cost reduction to the 30% than that of traditional node architecture
Traffic grooming modification for reducing number of WCs

Source : N8
Destination : N9
Paths : \{8,1,3,2,9\}
\{8,4,3,2,9\}
\{8,4,5,7,9\}
\{8,4,6,7,9\}

Groomed paths:
\{8,4,5,7,9\}
\{8,4,6,7,9\}

Reduced 1 wavelength converter

Representation of a physical route from source to destination
(a) Wavelength layered model (b) lambda run model (c) lambda run graph
Conclusion

- Only photonics solution seem not to help so approach should be towards Hybrid Technology
- Shows the significant power and cost saving with proposed PSMB Switching Node
- Usage of shared Buffer and Wavelength converter can minimize the power
- Modifying the WCs from OOO to OEO WCs
- Further improvement can be made by reducing number of wavelength converter and minimizing the transition of converted wavelength