An Investigation of Passive Optical Networks for India Based Neutrino Observatory

Vaibhav Pratap Singh, Nitin Chandrachoodan, Anil Prabhakar

Indian Institute of Technology Madras

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An Investigation of Passive Optical Networks for India Based Neutrino Observatory

Outline

1. India based neutrino observatory (INO)
2. Network configurations
   - Controller Area Network (CAN)
   - Optical CAN
   - Passive star optical network
3. Experimental results
4. Conclusion
India based neutrino observatory (INO)

- A project aimed at building a world class underground laboratory for neutrino research in India
- Initial objective is to design a magnetized iron calorimeter detector (ICAL) and study neutrinos produced by cosmic rays in the Earth’s atmosphere
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India based neutrino observatory (INO)

Network configurations
Controller Area Network (CAN)
Optical CAN
Passive star optical network

Experimental results

Conclusion

Resistive plate chamber (RPC)\[^1\]

- each RPC will be 1.84 m x 1.84 m
- Neutrinos generates signal on 128 metallic strips present on each RPC

Each layer on each module has 64 RPCs\textsuperscript{[2]}

- Has about 30,000 RPCs across 3 modules with 150 layers each
- At 1 Hz trigger rate each RPC will generate data at 252.25 kbps
- At 10 Hz trigger rate (worst case) it will increase to 2.52 Mbps

\textsuperscript{2}Interim Project Report, “India Based Neutrino Observatory”, Volume 1, 2005.
Network of RPCs

- A network of 30,000 RPCs (sensor nodes with a data rate of 2.52 Mbps each) is required
- Possible options are
  - Ethernet
  - Controller area network (CAN)
  - Optical CAN
  - Passive star optical network (PSON)
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Controller area network (CAN)[3]

- Is a serial, two wire, half duplex network protocol widely used in the automotive industry
- Has two ISO standards: ISO 11898- applications up to 1 Mbps & ISO 11519- applications up to 125 kbps
- Uses carrier sense multiple access/collision detection to avoid collision by arbitration on message priority

![Standard CAN frame structure](http://hem.bredband.net/stafni/developer/CAN.htm), accessed on 10.10.12.
- The round trip propagation time of a bit should be less than the transmission time of the bit.
- Network has an optical loss of about 28.81 dB.
Optical CAN

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**Optical CAN**

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![Diagram of Optical CAN network](https://via.placeholder.com/150)
Optical CAN

- The round trip propagation time of a bit should be less than the transmission time of the bit.
- Network has an optical loss of about 28.81 dB.
Collision detection in optical CAN

- ‘1’ is a dominant bit in the optical layer
- Requires a microcontroller, an optical TxRx & softcore CAN controller
Each node should transmit at $2.52 \text{ Mbps} \times 8 = 20.16 \text{ Mbps}$

In the optical layer, we have a bus length of $\frac{c}{n \times f}$ \[4\]

As each RPC is 1.84 m, this yields a bus length of $2 \times 1.84 \times 8 \approx 30 \text{ m}$ which corresponds to a data rate of 6.7 Mbps.

Can support up to 3.32 Hz average trigger rate.

\[4f = \text{effective data rate}, \quad c = 3 \times 10^8 \text{ m/s}, \quad n = 1.5 \text{ (effective refractive index of fiber)}\]
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Passive Star Optical Network (PSON)

- A 1 x 8 splitter is used
- Uses TDM in downstream and TDMA in upstream to exchange data
- Each node should transmit a worst case data rate of 2.52 Mbps x 8 = 20.16 Mbps

A diagram of the Passive Star Optical Network (PSON) is shown, with a 1 x 8 splitter and multiple sensor nodes connected through an optical bus (Bi-directional).
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**Passive Star Optical Network**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector loss</td>
<td>0.1 dB x 2 = 0.2 dB</td>
</tr>
<tr>
<td>Single mode fiber loss</td>
<td>0.35 dB/km x 16 m = 5.6 x 10^{-3} dB</td>
</tr>
<tr>
<td>1 x 8 splitter typical insertion loss</td>
<td>10.5 dB x 1 = 10.5 dB</td>
</tr>
<tr>
<td><strong>Total loss</strong></td>
<td><strong>10.7 dB</strong></td>
</tr>
</tbody>
</table>

![Diagram of Passive Star Optical Network](image)

*Figure not to scale*
- It has a microcontroller (M430F5438A) interfaced to an optical transceiver (SSTR3111-13-133) through UART
- It has slots for temperature, pressure and humidity sensor to provide dummy data
# Hardware specifications

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating voltage</td>
<td>3.3</td>
<td>V</td>
</tr>
<tr>
<td><strong>MSP430 (PMMCore = 2, 8 MHz)</strong>[^5]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active mode current</td>
<td>3.08</td>
<td>mA</td>
</tr>
<tr>
<td>Sleep mode (LPM3) current</td>
<td>2.3</td>
<td>µA</td>
</tr>
<tr>
<td>Optical transceiver[^6]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating wavelength</td>
<td>1310</td>
<td>nm</td>
</tr>
<tr>
<td>Average input power</td>
<td>-8 to -15</td>
<td>dBm</td>
</tr>
<tr>
<td>Maximum data rate</td>
<td>0.5</td>
<td>Mbps</td>
</tr>
<tr>
<td>Operating current</td>
<td>150</td>
<td>mA</td>
</tr>
<tr>
<td>Receiver sensitivity</td>
<td>-25</td>
<td>dBm</td>
</tr>
<tr>
<td>Single mode fiber loss</td>
<td>0.35</td>
<td>dB/km</td>
</tr>
</tbody>
</table>

[^5]: "MSP430F543xA, MSP430F541xA data sheet", Texas Instruments, October 2010.
[^6]: "SSTR3111-1*-13*(-P) product data sheet", Star Opto, Ver 0.1, 06.08.11.
Optical loop back test

Eye diagrams

Data rate = 454.4 kbps and Tx power = -15 dBm.
## Comparison

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Optical CAN</th>
<th>PSOn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware in the network</td>
<td>eight nodes, eight $2 \times 2$ couplers</td>
<td>eight nodes, one $1 \times 8$ splitter</td>
</tr>
<tr>
<td>Data rate</td>
<td>supports the typical trigger rate of 1 Hz, with a data rate of 252 kbps.</td>
<td>can support much higher trigger rates. limited by the speed of the optical TxRx and microcontroller</td>
</tr>
<tr>
<td>Collision avoidance</td>
<td>arbitration on message priority</td>
<td>TDM</td>
</tr>
<tr>
<td>Optical power loss</td>
<td>more ($\approx 29$ dB)</td>
<td>Less ($\approx 10.7$ dB)</td>
</tr>
<tr>
<td>Cost</td>
<td>high (uses 8 couplers)</td>
<td>Low (uses only one splitter)</td>
</tr>
<tr>
<td>Application</td>
<td>easy (patch cord between two couplers)</td>
<td>Tough (drawing of fiber out at each node)</td>
</tr>
</tbody>
</table>
Conclusion

- The proposed PSON is a possible passive optical network that can be implemented at INO to get the full network of about 30,000 RPCs.
- The optoelectronic board designed meets the optical power requirement of the network as well.
The authors are thankful to

- members of the INO consortium for sharing details of the INO electronics
- Dr. B. Satyanarayana for detailed discussions on data rates
- Texas Instruments for assistance with the MSP430 microcontroller
- Mr. Arun for designing the optoelectronic board
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Passive star optical network

Experimental results

Conclusion

Thank you
### Power budget of optical CAN

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value of one unit</th>
<th>Total number of unit</th>
<th>Total loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector loss</td>
<td>0.1 dB</td>
<td>16</td>
<td>1.6 dB</td>
</tr>
<tr>
<td>Single mode fiber loss</td>
<td>0.35 dB/km</td>
<td>32 m</td>
<td>11.2 \times 10^{-3} dB</td>
</tr>
<tr>
<td>2 x 2 50:50 coupler typical insertion loss</td>
<td>3.4 dB</td>
<td>8</td>
<td>27.2 dB</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>28.81 dB</td>
</tr>
</tbody>
</table>