Scalable TriDAS for the NEMO Project

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for the NEMO Collaboration
Talk overview

- Neutrino Telescope: just add water...
- all data to shore: challenging throughput
- TriDAS base concept
- From NEMO Ph.1 to the scalable km$^3$
  TriDAS architecture
Less atm. bkg. when deeper (below 3000 m usl)
Expected signal > atm. bkg. when \(E_\nu > 10\) TeV
- Telescope \(\text{Vol} > 1\) km\(^3\) for some evts/year
- Many PMTs (> 5000)
- Complex experimental setup!

NEMO location: CAPO PASSERO @ 3400 m usl

See Paolo Piattelli’s talk in plenary session today
some km$^3$ detector possible layouts:

**Hexagonal Grid**
- 90 Detection Units
- 80 PMTs / D.U.
- 7200 PMTs

**Square Grid**
- 81 Detection Units
- 80 PMTs / D.U.
- 6480 PMTs total
the Telescope is made of DETECTION UNITS

20 floors, with 4 10" PMTs each
Expected Optical Data sources

- bioluminescence (neglig. @ depth ≥ 2500 m)
- upgoing neutrinos (atm. + signal) (50 day^{-1} / km\textsuperscript{3})
- atmospheric muons (10÷100 Hz / km\textsuperscript{3})
- \textsuperscript{40}K decays (30÷40 kHz / 10” PMT @ 0.5 p.e.)

**S.P.E. HIT SIZE:**

<table>
<thead>
<tr>
<th>Hit PMT Info</th>
<th>Hit Time</th>
<th>Hit Charge</th>
<th>Hit Wave Form (samples)</th>
</tr>
</thead>
</table>

28 Bytes

**Hit samples Vs. pulse time**
on a 10” PMT with 0.5 p.e. thr. (NEMO Ph.1 data)

**S.P.E. wave form**
(~16 samples = 16 Bytes)
## Expected Data Rates

<table>
<thead>
<tr>
<th>10&quot; PMT single rate (kHz)</th>
<th>Data Rate per PMT (Mbps)</th>
<th>Data Rate per Floor* (Mbps)</th>
<th>Data Rate per D.U.** (Gbps)</th>
<th>Data Rate per km$^3$ *** (Gbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 (bare +0K)</td>
<td>8.8</td>
<td>35.2</td>
<td>0.7</td>
<td>70</td>
</tr>
<tr>
<td>80 (NEMO Ph. 1)</td>
<td>16.8</td>
<td>67.2</td>
<td>1.3</td>
<td>130</td>
</tr>
<tr>
<td>150 (present DAQ)</td>
<td>32</td>
<td>128</td>
<td>2.5</td>
<td>250</td>
</tr>
<tr>
<td>300 (expanded DAQ)</td>
<td>64</td>
<td>256</td>
<td>5.0</td>
<td>500</td>
</tr>
</tbody>
</table>

* 4 PMT/Floor  
** 20 Floor/D.U.  
*** 100 D.U.
The TrídAS reduces the data rate by filtering the data stream bunched in Time Slice (TS).

A TS contains all data from all (or part of) the detector occurred in a given time interval (~100 ÷ 200 ms).

WHAT IS SCALABLE?
The TrídAS principal elements:

- Trigger System Controller (TSC): monitors and serves the TrídAS - (1 GbE I/O)
- Hit Managers (HM): receive optical data; prepare and distribute the TS to the TCPU
- TriggerCPUs (TCPU): apply the trigger logics to the assigned TS and transfer the selected data to the EM;
- Event Manager (EM): receives the triggered data from TCPUss and build the Post-Trigger events data file

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**Atmospheric Muon Signal (@ 3000 m depth)**

- Assuming - Rate_{μ atm}: 100 Hz
- Rate_{K40}: 300 kHz
- N. PMTs: 8000
- Rec. time window: 6 μs

Post-Trigger data rate: ~ 40 MBps

Stored data /day ~ 1 TB !!!!

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**Upgoing Neutrino Signal**

- Assuming - Rate_{ν}: < 4 \times 10^{-3} Hz
- Rate_{K40}: 300 kHz
- N. PMTs: 8000
- Rec. time window: 6 μs

Post-Trigger data rate: ≲ 2 kBps

Stored data /day ≲ 150 MB !!!!
Time slice and Barrel Shift Paradigm

[refer to: M.F. Letheren, 1995 CERN School of Computing]

If a TCPU needs more time, just add one more!
TríDAS for NEMO Ph.1

The maximum throughput of the MiniTower was $\leq 512$ Mbps

One Machine, the **Master CPU**, played all the rules:
- Hit Manager,
- Trigger,
- Event Manager

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Tommaso Chiarusi

RICAP 2009
TriDAS for a first prototype Detection Unit with 16 Floors; expected throughput ≤ 2 Gbps standard 1 GbE Ethernet Networking
Possible Network infrastructure for km³ TriDAS (90 D.U.)
Number of Available Clock Cycles per CPU per TS:

\[ N_{\text{ACC}} = \frac{R_{\text{CPU}} S_{\text{Hit}}}{D_{\text{rate HM}\rightarrow \text{TCPU}}} \]

\[ D_{\text{rate HM}\rightarrow \text{TCPU}} = 10 \text{ Gbps} \]
\[ S_{\text{Hit}} = 224 \text{ b} \]
\[ R_{\text{CPU}} = 3 \text{ GHz} \]
\[ N_{\text{ACC}} \approx 70 \]

Estimated number of necessary TCPU:

\[ N_{\text{TCPU}} = \frac{V_{K} N_{C} N_{\text{PMT}}}{R_{\text{CPU}}} \]

If the req. \( N_{C} > N_{\text{ACC}} \)
(i.e. trigger algo. is slow)
ADD TCPU!
Monitoring

Via ControlHost: a Tag Controlled Data Dispatching

## Multi purpose on-line Visualizer (with D. Bonfigli - UniBo)

<table>
<thead>
<tr>
<th>tag</th>
<th>dispatcher</th>
<th>gruppo</th>
<th>stato</th>
<th>allarme</th>
<th>soglia allarme</th>
<th>valore istantaneo</th>
<th>media</th>
<th>media dall'inizio</th>
<th>descrizione</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>lxantares 3.boi...</td>
<td>HM</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>73.31 MB/s</td>
<td>70.84 MB/s</td>
<td>71.22 MB/s</td>
<td>HM 3 out</td>
</tr>
<tr>
<td>2</td>
<td>lxantares 3.boi...</td>
<td>EM</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>19.26 MB/s</td>
<td>29.14 MB/s</td>
<td>29.97 MB/s</td>
<td>EM in</td>
</tr>
<tr>
<td>3</td>
<td>lxantares 3.boi...</td>
<td>MCPU</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>73.86 MB/s</td>
<td>70.69 MB/s</td>
<td>71.08 MB/s</td>
<td>MCPU 1 in</td>
</tr>
<tr>
<td>4</td>
<td>lxantares 3.boi...</td>
<td>MCPU</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>73.54 MB/S</td>
<td>70.94 MB/S</td>
<td>71.08 MB/S</td>
<td>MCPU 0 in</td>
</tr>
<tr>
<td>5</td>
<td>lxantares 3.boi...</td>
<td>HM</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>73.96 MB/s</td>
<td>70.65 MB/s</td>
<td>71.02 MB/s</td>
<td>HM 2 out</td>
</tr>
<tr>
<td>6</td>
<td>lxantares 3.boi...</td>
<td>HM</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>73.01 MB/s</td>
<td>48.66 MB/s</td>
<td>71.02 MB/s</td>
<td>HM 1 out</td>
</tr>
<tr>
<td>7</td>
<td>lxantares 3.boi...</td>
<td>HM</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>73.00 MB/s</td>
<td>70.65 MB/s</td>
<td>71.02 MB/s</td>
<td>HM 0 out</td>
</tr>
<tr>
<td>8</td>
<td>lxantares 3.boi...</td>
<td>MCPU</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>73.79 MB/S</td>
<td>3.09 MB/S</td>
<td>71.07 MB/S</td>
<td>MCPU 2 in</td>
</tr>
<tr>
<td>9</td>
<td>lxantares 3.boi...</td>
<td>MCPU</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>829.17 kBa/s</td>
<td>7.43 MB/S</td>
<td>8.13 MB/S</td>
<td>MCPU 3 out</td>
</tr>
<tr>
<td>10</td>
<td>lxantares 3.boi...</td>
<td>MCPU</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>73.66 MB/s</td>
<td>70.91 MB/s</td>
<td>71.07 MB/S</td>
<td>MCPU 3 in</td>
</tr>
<tr>
<td>11</td>
<td>lxantares 3.boi...</td>
<td>TSO</td>
<td>connesso</td>
<td>disattivato</td>
<td>20</td>
<td>8.64 kBa/S</td>
<td>10.02 kBa/S</td>
<td>11.47 kBa/S</td>
<td>TSO out</td>
</tr>
</tbody>
</table>

### Grafici temporali
- colore: 1
- right: 1

### soggiunta grafici temporali
- line stra: 1
- pad: 1

### Grafici sinottici
- selezionati: SElezionat
- mostra: mostra

### Allarmi
- selezionati: SElezionat
- attiva: attiva
- disattiva: disattiva

### azzera dati
- azzera media
- azzera media dall'inizio

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**Notes:**
- The data in the table represents various data points over time, with columns for tag, dispatcher, gruppo, stato, allarme, soglia allarme, valore istantaneo, media, media dall'inizio, and descrizione.
- The graphs show various trends and data visualizations, likely related to network or system performance metrics.
- Additional controls and options are available for interacting with the data and graphs.
On(Off)-line Event Display (with A. Riccardo - UniBo)
Conclusions

- “all data to shore” is a challenging BUT feasible strategy for km$^3$ underwater V-telescope;
- scalable TriDAS architecture supplying high data-stream (up to 500 Gbps) is possible and affordable with the present technology;
- The NEMO Collaboration is completing a scaled TriDAS for the prototype Detection Unit.
Fig. 2. Scatter plots of density of bioluminescent sources as a function of depth in the Eastern and Western Mediterranean Sea. Upper row (a)–(e), Western Mediterranean, Ligurian Sea ANTARES locations. Lower row (f)–(j) Eastern Mediterranean, Ionian Sea NESTOR locations. Note the difference in the density scale (m$^{-3}$) between the upper and lower rows. Each point corresponds to a count of flashes detected by the profiler converted to number m$^{-3}$. (a) and (b) January 2004. (c)–(e) May 2004. Keys to stations are as in Table 1. Superimposed are fitted curves derived from GAMS, solid line—predicted value. Dashed lines—upper and lower 95% confidence limits.