Transfer exact timing using a coded data communication channel
KM3NeT Timing Principle

Local Clocks are phase locked; thus isochronous. But their values have an offset.

One Reference Clock (GPS)

Loop timing

Individual Optical Channel

Broadcast

Data Receiver

Shore Station

Undersea Station

OM PMTs

PMTs

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Continuous Wave DWDM lasers (26 wavelengths)

Loop timing

Data Receiver

1 of 100 fibers

DWDM Mux

Timing (& comms)

1 of 100 Detection Units

Power splitter to feed 100 Detection Units

1500m

500m

OM PMTs

Reflective Modulator

PMTs

Optical Receiver

OM

Directional Coupler

Modulate Timing on all λ's

Modulator

λ1 + λ27

DU

Arrayed Waveguide Grating

Data

Timing

Tap

DWDM DeMuxes

1 of 100 fibers

1 of 100 fibers

Continuous Wave DWDM lasers (26 wavelengths)

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λ1 + λ27

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Arrayed Waveguide Grating

Data

Timing

Tap
Timing over 8B10B Test Setup

Tx
8B/10B
Encoded

Rx
8B/10B
Encoded

Constant Impedance
Trombone Line
0 → 2x10 cm = 0 → 700 ps
Timing over 8B10B

Tx 8B/10B Encoded

K28.5 D16.2 K23.7 K23.7 K28.5 D16.2 K28.5 D16.2 K28.5 D16.2
IDLE CharExt IDLE IDLE IDLE IDLE

Rx 8B/10B Encoded

K28.5 D16.2 K28.5 D16.2 K28.5 D16.2 K28.5 D16.2 K28.5 D16.2 K23.7 K23.7 K28.5 D16.2
IDLE IDLE IDLE IDLE IDLE CharExt IDLE

Variable propagation delay
Variable Propagation Delay...

What is happening???
At 3.125 Gbps:
Absolute timing is determined by “Start/Stop” delay
\( (\text{in 20 bit steps of 6.4 ns}) \) plus
\( \text{BitSlide fine delay (20 steps of 320 ps)} \)
Demo: “On the edge”…

Reset
(= resynchronize &
Byte Re-Align)

RxRecClk

BitSlide(4:0)

+ 320 ps

0011 1011 0000 0000 1011 0110 0010 0110 0000 0101 0110 1010 1011 0000 01

0011 = 19
0000 = 0

6.4 ns
Conclusion

• Timing information is distributed inherent over a serial data channel and can be used

• Timing resolution is equal to a Unit Interval (= bit time; at 3.125 Gbps = 320 ps)

• Receivers in Optical Modules are all phase locked (thus isochronous) to one master clock (GPS) on shore
For the skeptic…
Does this work from board to board?

Yes it does!

3.125 Gbps via Constant Impedance Trombone Line

Coarse time (6.4 ns Steps)

Fine time (320 ps Steps)

Receiver locked to Transmitter Oscillator

Transmitter Lattice LFSCM25

Transmitter Crystal Oscillator

Receiver Xilinx Virtex-5