Experience. Outcomes.

Machine Learning Datasets from Optical Systems

Network as a Sensor

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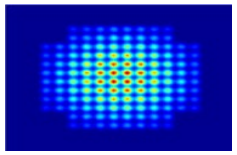
Opportunities for Neural Nets with Machine Learning using Coherent Modem Data

- Modern DWDM systems can now produce vast amounts of data
- Coherent modems by their very nature can generate a number of different optical parameters which historically were difficult to measure in real-time
- Combining traditional system parameters like power levels, loss, distance with coherent modem parameters like CD, PMD, SOP, SNR, etc yields a rich area for analysis

Higher Baud/Higher order modulation



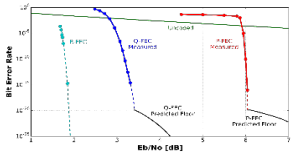
- Selectable baud- up to 95 Gbaud
- Optimize capacity for a given photonic layer

Link Monitoring Enhancements

$$SNR_{ASE}^{XPM} = \frac{S(\Delta f)}{N(\Delta f)}_{SPM}$$

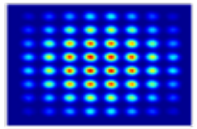
- Link monitoring derived from machine learning
- Ability to optimize network designs

Enhanced coding gain



- Longer distance
- More capacity/wave
- Higher spectral efficiency

Probabilistic Constellation Shaping



- Granular capacity increments, from 200G-800G to optimize capacity to avail. margin

Non-Linear Compensation

- Improved reach for a given capacity and vice versa

In this session we will review the set of observables that are currently available from an example coherent modem, identify some initial use cases and discuss what other kinds of analysis might be interesting. We will also discuss if there is other information not already available that might be interesting to extract.

Some Current Focus Areas for Neural Networks / ML in Optical Systems

- Predictive Assessment of Network Equipment
- Predictive and Analytic Assessment of Fiber Health
- Estimation of Network Performance at Different Operating Points

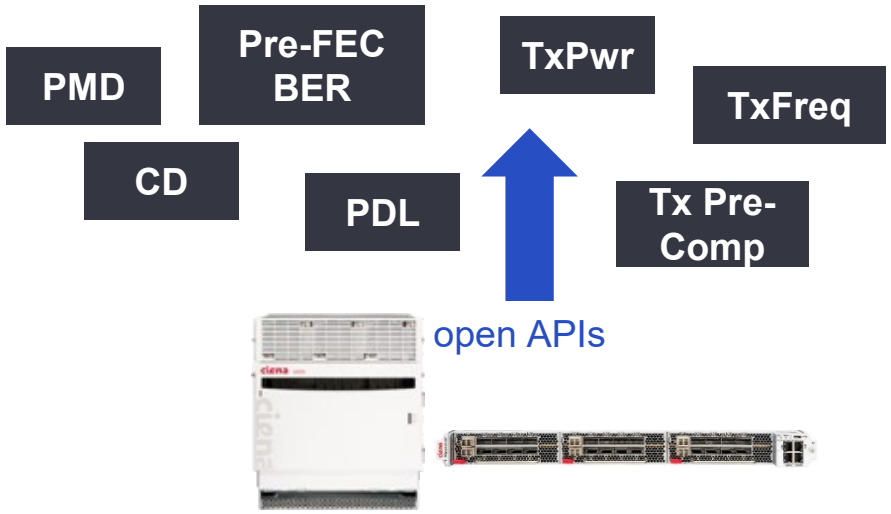
- What other problem sets can we address?

- A key problem is how to select the set of data to export from the modem as we have practical limitations in what can be send over a internal comm link.

Real-time access to unprecedented levels of network performance data

Using Coherent Modem as a Sensor

Access real-time link parameters through streaming telemetry



Future Parameters

ESNR

- Effective Signal-to-Noise Ratio
- Total noise experienced by Rx: internal, linear and nonlinear noise

OSNR

- Optical Signal-to-Noise Ratio
- Optical linear noise derived using machine learning
- (Also available from Ciena line system)

TNLE

- Total Non-Linear Noise Estimate
- Measure of total NL noise: i4WM, XPM, SPM
- Transduction derived at Rx, converted to SNR using machine learning

SPM

- Self-Phase Modulation
- Intra-channel noise derived using machine learning

Visibility into real-time link parameters allows for optimal link engineering and diagnostics and Provides a rich data set in which otherwise hard to measure and compute parameters can be estimated using Neural Nets tuned with ML

Coherent Modems

Real-time link monitoring … complete list of parameters collected

Line facility Link performance parameters

- Estimated Instance of DGD
- Maximum Instance of DGD
- Estimated fiber length
- Total Rx Link Dispersion
- Total Tx Link Dispersion
- Estimated Unidirectional Latency

Line PMs Link performance parameters

- DGD-AVG and DGD-MAX
- Pre-FEC BER
- Q
- Error count
- Tx Power level
- Rx Total power
- Rx Channel power

Link Data Collection (LDC) feature Link performance parameters

Link Data Collection parameter name	Description
Time and Date	Collection time stamp
Elapsed Time ms	Collection time stamp since tool started in milliseconds
Total Pwr mdBm	Rx total optical power
Chan Pwr mdBm	Rx channel power
FE Tx CD Pre-Comp ps/nm	Tx CD pre-compensation
Rx CD Comp ps/nm	Rx CD post-compensation
BER	PreFEC BER
Fast BER	PreFEC BER estimated every millisecond
FER	Integrated Frame Error Rate. Collection start point is when “PMtick” counter=0.
Uncorrected Blocks	Cumulative Un-corrected FEC blocks
Cycle slip	Accumulated cycle slips
PM Tick Count	Collection time stamp
PMD ps	PMD
PDL db	Polarization dependent loss estimate
SOPs1	SOP S1
SOPs2	SOP S2
SOPs3	SOP S3
FreqOffset MHz	Frequency offset of the laser - how far from setpoint
ESNRx dB	Electrical SNR
ESNRy dB	Electrical SNR
SPM dB	Self Phase Modulation (NEW IN R12.3)
TNLE dB	Total nonlinearity noise estimate (NEW IN R12.3)

Network as a Sensor

- **With a rich set of real-time (50-500ms period) optical parameters available in our latest modems it is now possible to gain a better window into the health of the network.**
  - Fiber Length and Latency estimates can be used to verify that traffic path is un-changed
  - Chromatic dispersion and PMD can be used to determine if fiber type or characteristics have changed
  - SPM, TLNE, OSNR can be used to determine if signal has been degraded by interference.
  - Q, Pre-FEC BER, and RX power level can determine if data link is healthy
  - Using Pinpoint data can detect bends, pinches, breaks, and other fiber defects.
- **Applying analytics to the data to trend and look for anomalies can result in even greater insights**

- *What other network insights can we get using ML on this large and quasi real-time data set ?*

Thank You