SubOptic 2016
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OPEN CABLES AND INTEGRATION WITH TERRESTRIAL NETWORKS

Dubai
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Emerging Subsea Networks

Celebrating 30 years of SubOptic

Presenter: Georg Mohs
Company: TE SubCom

Presenter Profile

Georg has been with SubCom since 2001 starting in Transmission Testing and moving to System Design in 2008. In 2009 he took over responsibility for the experimental forward looking work at SubCom before starting to lead the System Design team in 2013. Since 2015 he also has responsibility for Product Management.

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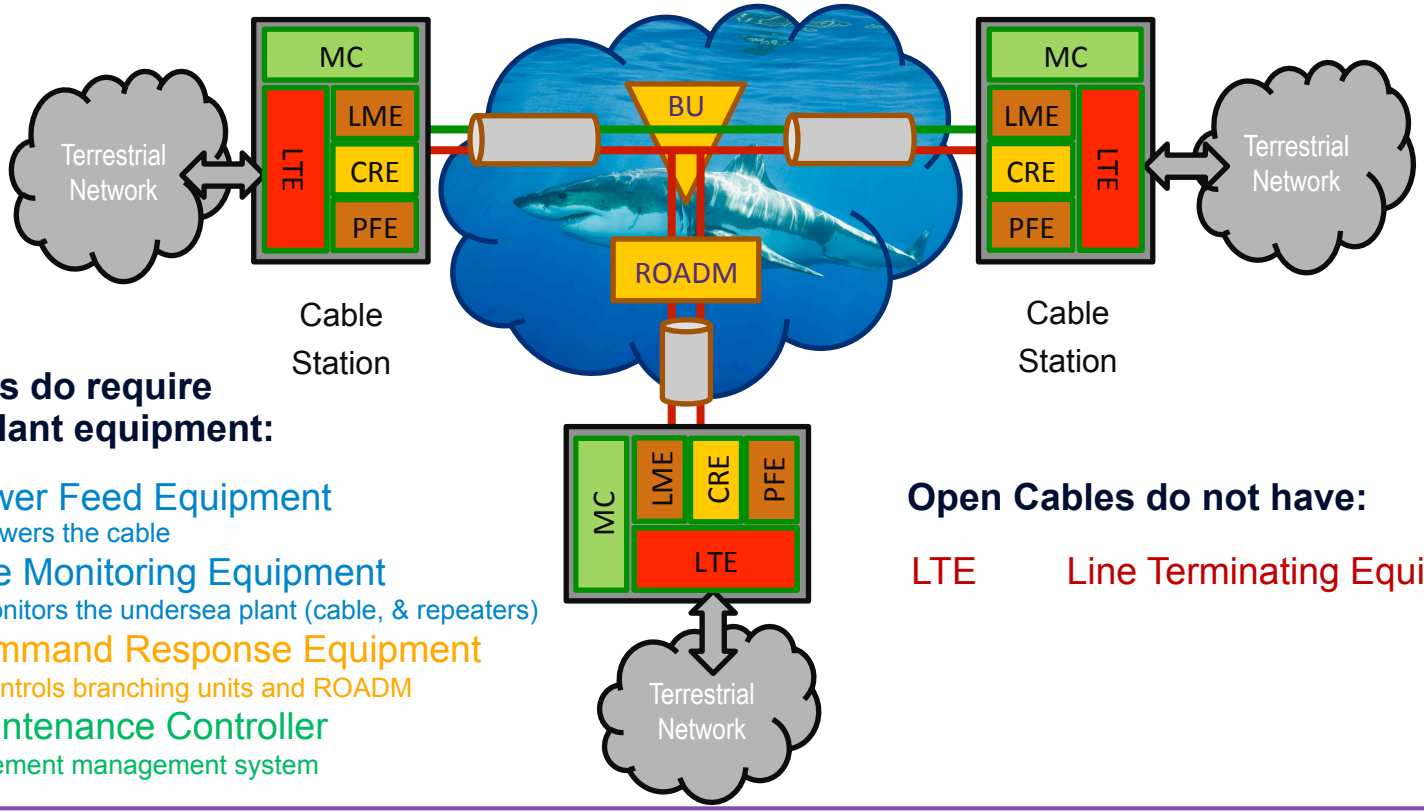
The Open Cable Concept



Open Cables do require some Dry Plant equipment:

- PFE Power Feed Equipment
  - Powers the cable
- LME Line Monitoring Equipment
  - Monitors the undersea plant (cable, & repeaters)
- CRE Command Response Equipment
  - Controls branching units and ROADM
- MC Maintenance Controller
  - Element management system

Open Cables do not have:

LTE Line Terminating Equipment

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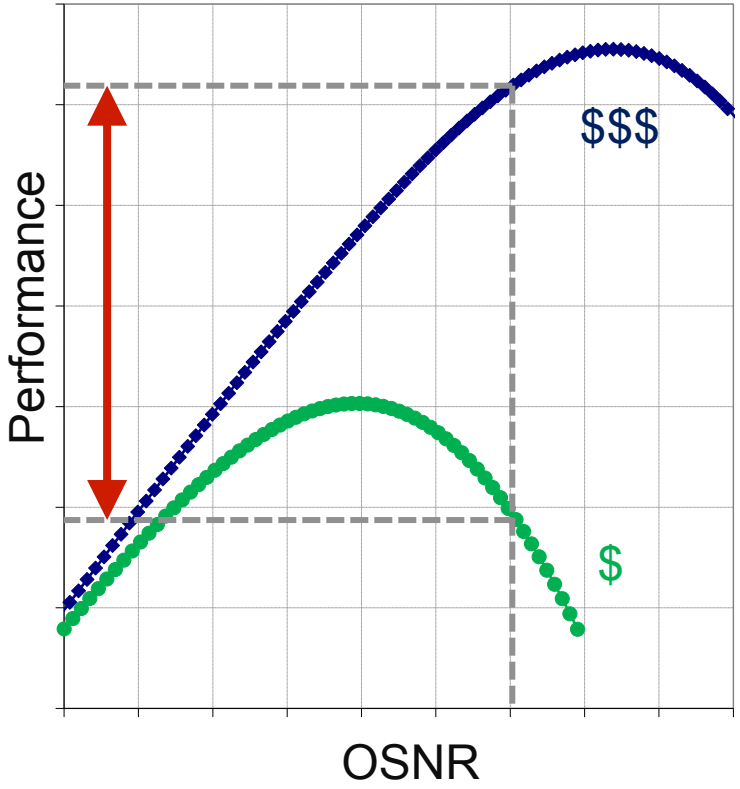
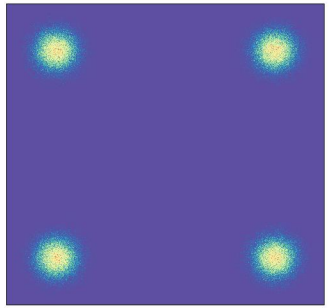
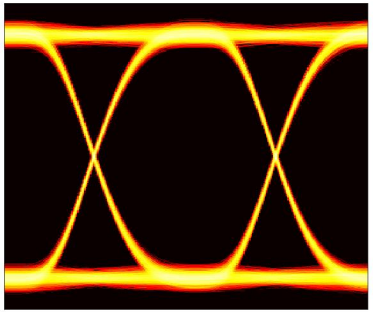
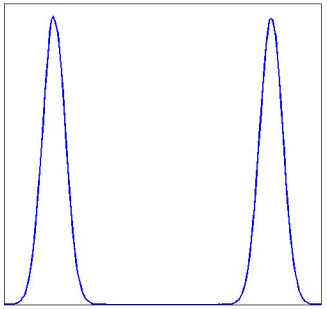
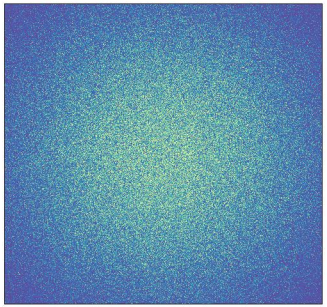
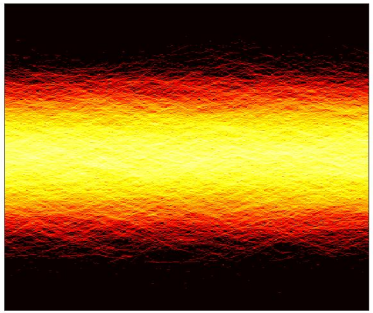
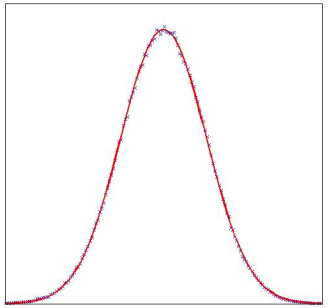
The Open Cable Challenge

Wanted: Performance guarantee of the undersea cable without SLTE.

- Optical Signal to Noise Ratio (OSNR)
  - Easy
  - Universally accepted
  - Not sufficient! Does not include nonlinear performance impairments!
- Nonlinear performance impairment
  - Included in a Q measurement
  - Nonlinear modelling
    - Needs Key System Parameters
    - How do we specify the Manufacturing Margin?

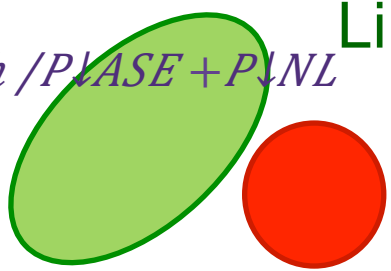


Modern Coherent Transmission

	Constellation	Eye Diagram (Real)	Histogram
Transmit (No Dispersion)			
Receive (100,000 ps/nm)			

Wet Plant Figure of Merit: SNR_e

$$SNR_e = P_{ch} / P_{ASE} + P_{NL}$$



Linear Noise Performance - OSNR

Nonlinear Interference Noise

See for example: P. Poggiolini, JLT, Vol. 30, No. 24, 2012, pp. 3857.

A coherent receiver cannot distinguish between linear noise P_{ASE} and nonlinear interference noise P_{NL} (ignoring nonlinearity compensation)

A system Q-factor measurement with that line card then determines the total system SNR_e at that wavelength including nonlinear impairments

A back-to-back measurement (where $P_{NL} = 0$) uniquely determines the relationship between Q-factor and SNR for any line card

Knowledge of SNR_e allows performance prediction of any other line card with known back-to-back performance

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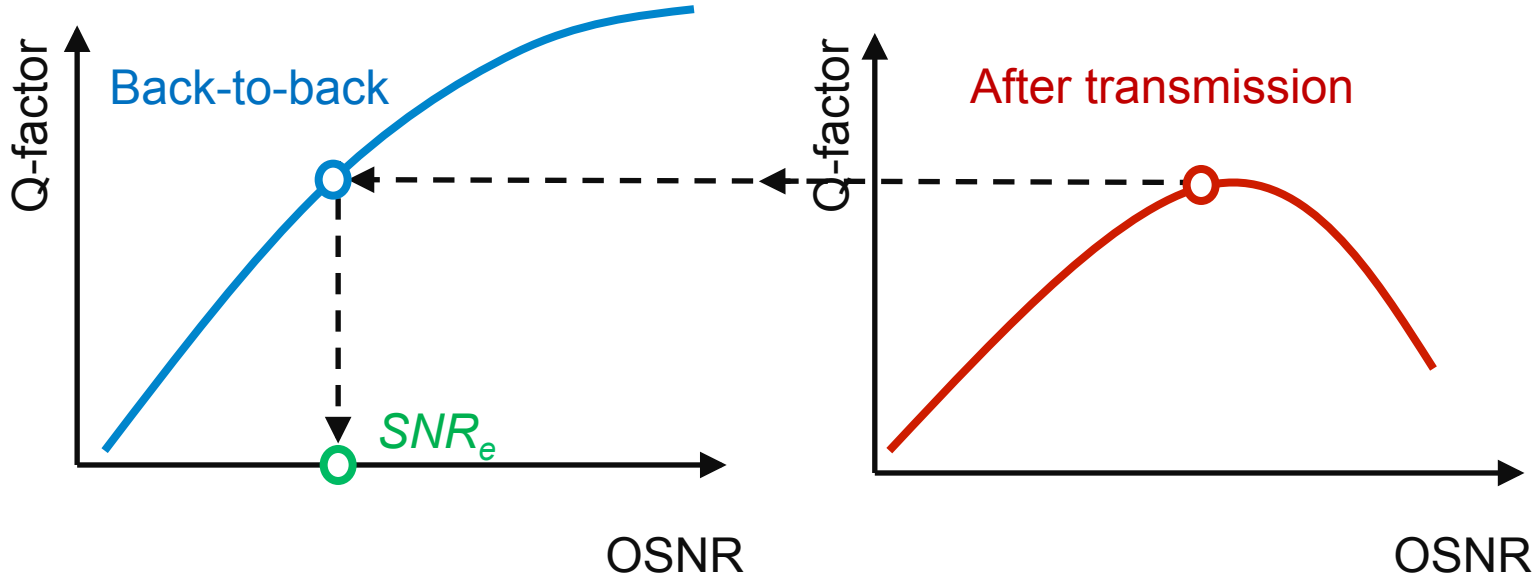
Using SNRe to Predict System Performance



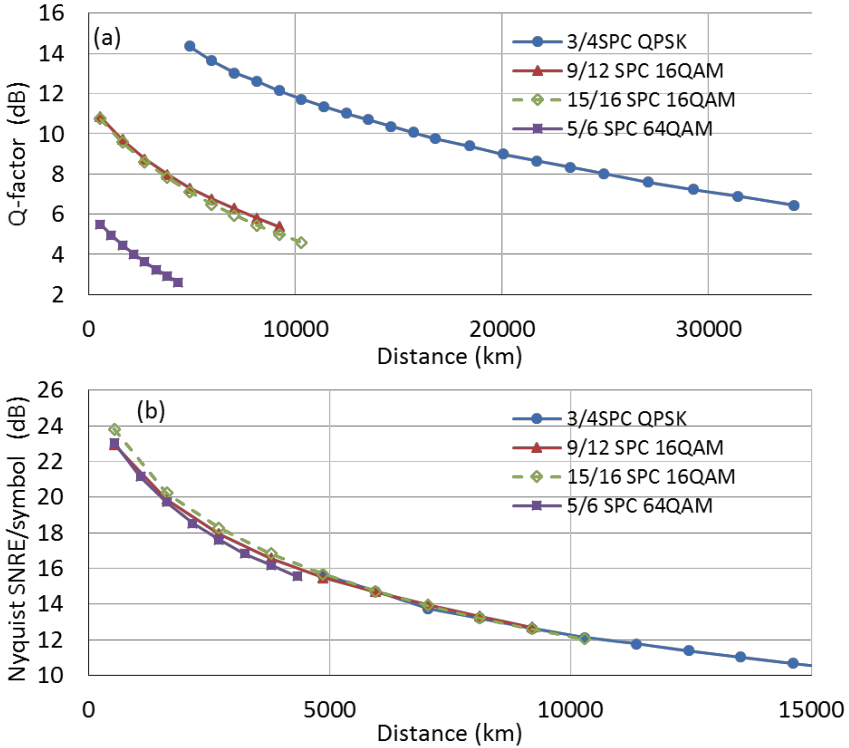
Q measurement includes both linear and nonlinear performance impairments

SLTE impact can be removed through b2b measurement

SNR_e fully describes wet system performance

In the Lab

Cable Performance for Various Transmission Formats



- Different Q-factors translate to similar SNR_e for several modulation formats from QPSK to 64QAM
- SNR_e describes wet plant performance!

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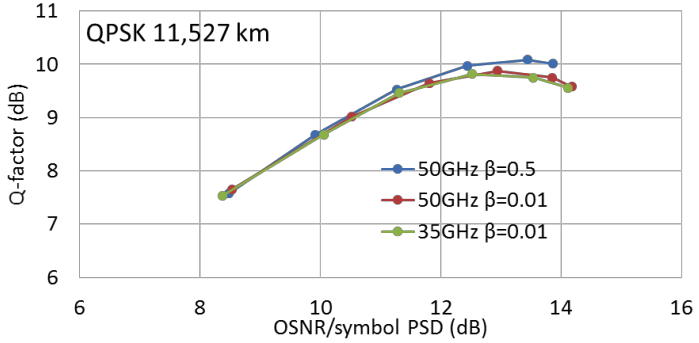
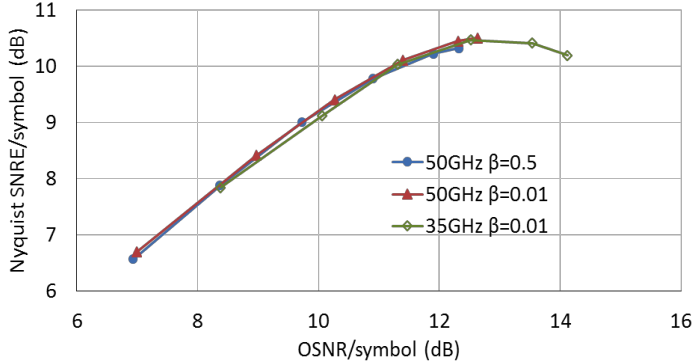
Calibrating Non-Nyquist Condition





$$k = \frac{P_{NL}^{eff}}{P_{NL,Nyq}^{eff}}$$

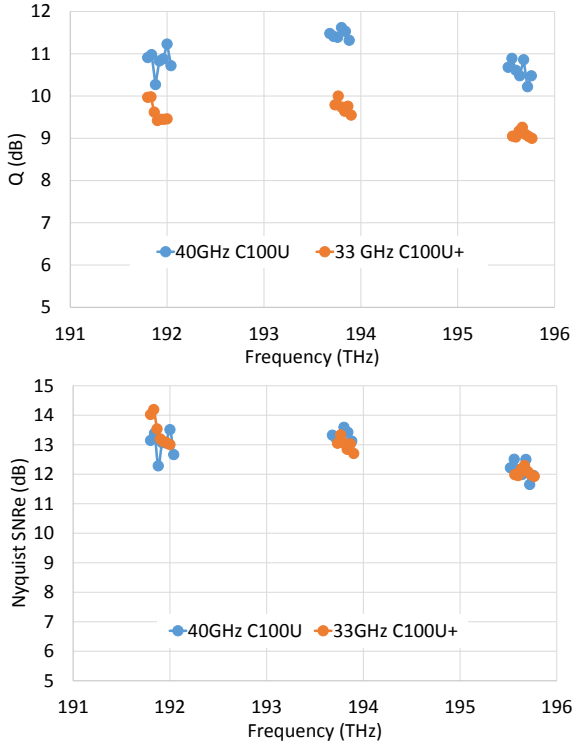
$$\frac{1}{SNRE} = \frac{1}{OSNR} + k\left(\frac{1}{SNRE_{Nyq}} - \frac{1}{OSNR}\right)$$

- Ratio k describes departure from Nyquist condition
- Calculate ratio k using basic system parameters
- Close to 1 for practical conditions

In the Field

C100U and C100U+ over 4,600km

- Two generations of DSP
  - C100U: Differential Coding
  - C100U+: Abs. Phase Detection
- Two channel spacings
  - C100U: 40 GHz
  - C100U+: 33 GHz
- Two full loading capacities
  - C100U: 100x100G
  - C100U+: 121x100G
- Measurement across the band
  - Different Q
  - Same SNRe!



Draft Wet Plant Budget

Item	Description	dB/0.1nm	Comment
1.1	Nominal Average BOL Wet Plant OSNR		
1.2	Nominal Average EOL Wet Plant OSNR		
2	Supplier's Impairments		
2.1	Non-Ideal Gain		
2.2	Manufacturing Impairments		
2.3	Other OSNR Impairments		
3.1	Average BOL Segment OSNR		Equalized
3.2	Average EOL Segment OSNR		Equalized
4	**Nyquist Loading SNRe**	**dB**	
4.1	OSNR to SNR Conversion Factor		Conversion from 0.1nm to carrier spacing
4.2	Propagation Impairment		Worst channel; includes manufacturing margin
5.1	BOL Segment SNRe		Worst channel
5.2	EOL Segment SNRe		Worst channel

Connection to G.977 Budget

Item	Description	dB/0.1nm	Comment
A	Average BOL Segment OSNR Including SLTE		Corresponds to Wet Plant Line 3.1 plus SLTE OSNR; SLTE OSNR from Key Parameters Table
B	Average EOL Segment OSNR Including SLTE		Corresponds to Wet Plant Line 3.2 plus SLTE OSNR; SLTE OSNR from Key Parameters Table
Item	**Description**	**Q (dB)**	
1	Back-to-Back Q at BOL OSNR (Line A)		
2	Propagation Impairment		Worst channel; includes wet plant manufacturing margin
	Expected BOL Q w/o TTE impairments		Wet Plant Line 5.1 + SLTE converted to Q
	Expected EOL Q w/o TTE impairments		Wet Plant Line 5.2 + SLTE converted to Q
3	Supplier's Q Impairments		
3.1	Implementation Penalty (CD, Laser Linewidth)		
3.2	Wavelength Tolerance Impairment		
3.3	Supervisory Impairment		
3.4	Mean Penalty Due to Polarization-Dependent Effects		
3.5	Other Q Impairments		
4	Margin for Q-Time Variations (5σ)		
5	BOL Segment Q (Commissioning Limit)		
6	Ageing and Repairs		
6.1	TTE Ageing		
6.2	Cable Ageing and Repairs		Nonlinear propagation impairment change; linear change already included on Line B
7	EOL Segment Q		
8	FEC Limit		
9	Customer Segment EOL Margin		

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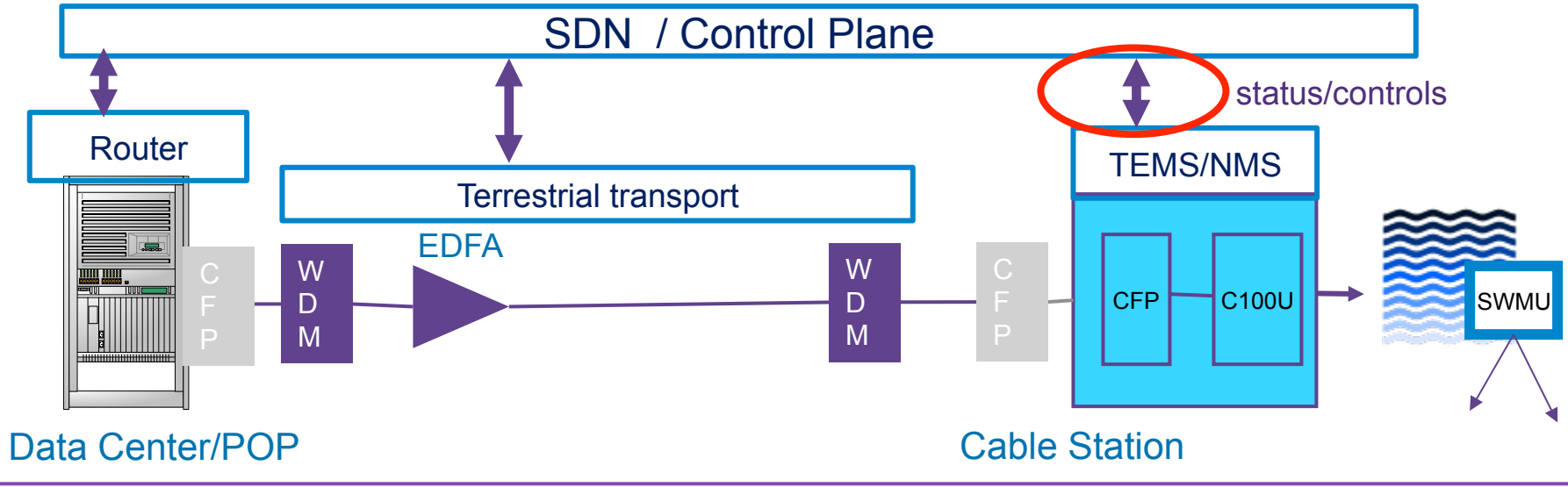
Integration with Terrestrial Networks

Now: Latency, link up/down and capacity information
New need: Cable performance data via NBI

- SNR_e
- Status of other wet plant elements and branch alarms

Initial applications is submarine link status awareness. Control is long term.



Summary

- SNRe uniquely characterizes Open Cable System Performance
- Consistent wet plant performance over a wide variety of transmission formats (in the lab)
- Consistent wet plant performance with two generations of DSP in the field with line cards
- Wet plant performance budgets
- Report to network controller

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