CHANNEL LINK MODEL

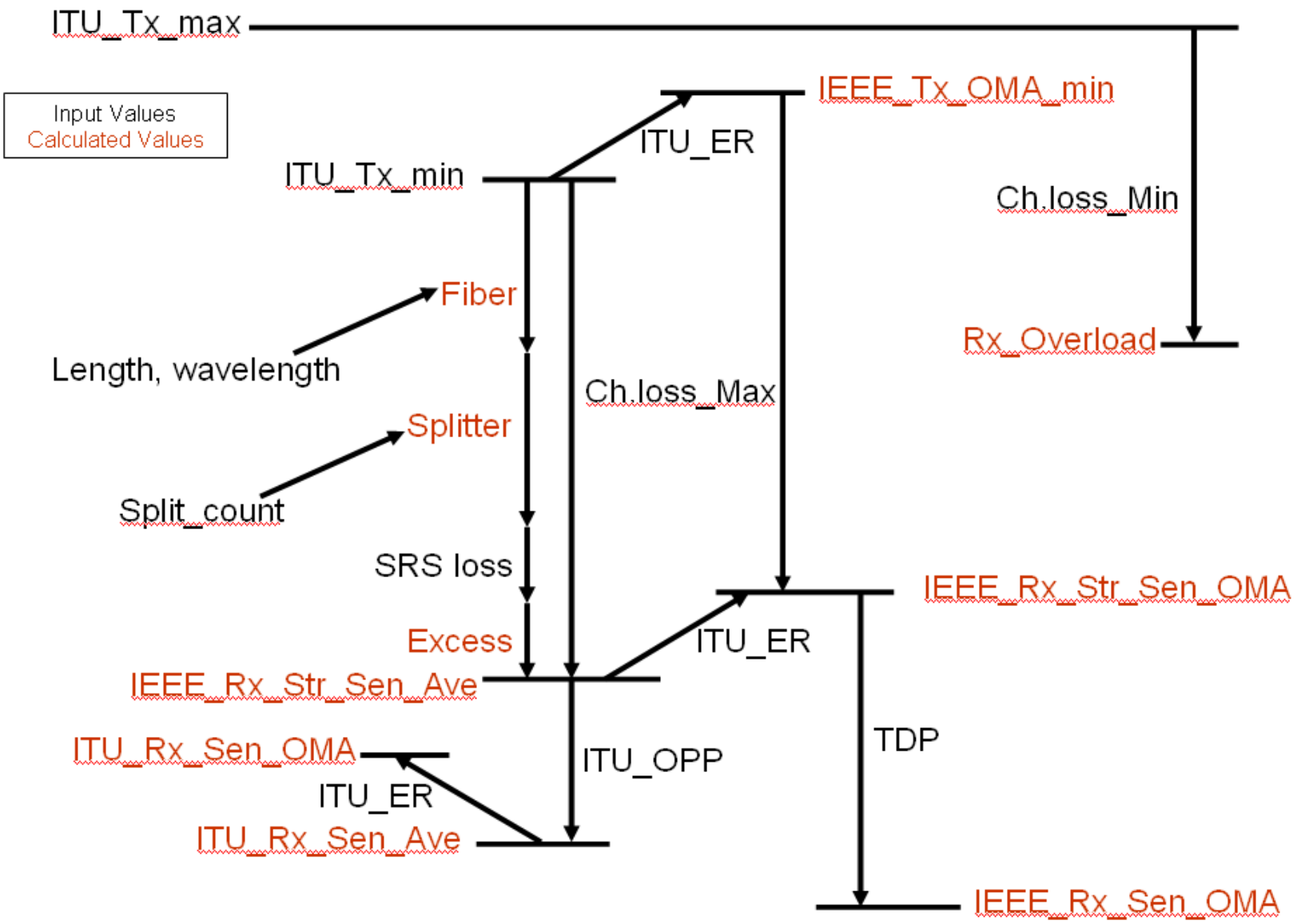
OVERVIEW + EXAMPLES

CONTACT:
MAREK HAJDUCZENIA
NETWORK ARCHITECT, PRINCIPAL ENGINEER
EMAIL: MAREK.HAJDUCZENIA@MYBRIGHTHOUSE.COM

Summary

- P802.3av (10G-EPON) developed an Excel-based link channel model, providing a set of agreed assumptions about channel loss, impairments, etc.
- NG-EPON link channel model should be used going forward for any PMD-related proposals, specifically for:
  - Wavelength allocation plans
  - Tx and Rx parameter proposals
  - Power budget discussions
- This deck provides overview of the existing tool and provides examples of 10G-EPON link definitions

EPON link model parameters



Channel loss [A]

- Channel loss accounts for: fiber loss, splitter (PSC) loss, SRS loss, and any excess loss (connectors, splices, etc. + margin)
- Fiber loss:
  - Based on fiber attenuation curve (λ^{-4},G652AB,G652CD) [B18]
  - Includes best and worst [B19] allowed attenuation parameters, calculated for central operating wavelength [B13] and specific link length [B23]
  - **Suggestion**: use λ^{-4} curve with maximum attenuation and 0.35 dB/km loss [B20] for worst-case scenario analysis
- PSC loss:
  - Based on data collected in P802.3av (see 3av_0611_hajduczenia_1.pdf)
  - Includes best, average, and worst [B26] loss for specific PSC split count [B25]
  - Suggestion: use maximum loss curve for worst-case scenario analysis
- Excess loss
  - Calculated as difference between maximum channel insertion loss, fiber loss, PSC loss, and SRS loss [B28] (due to non-linear effects in fiber) [B29]
  - SRS calculations based on 3av_0611_ten_1.pdf and 3av_0611_pato_ten_1.pdf
  - Excess loss MUST BE greater than zero for channel to be viable

Channel loss [B]

Fiber loss parameters

Link length

PSC loss parameters

Link parameters			
Fibre_Attenuation_Curve	lambda^-4	-	Defines the type of the fibre attenuation curve which will be used for calculation of the fibre attenuation for the given operating wavelength. 3 types of curves are available i.e. lambda^-
Fibre_Attenuation_Curve_Type	max	-	Defines the variant of the fibre attenuation curve for G.652 SMF. Maximum and minimum attenuation curves are available only for G652AB and G652CD type of fibre.
Fibre_Attenuation_Base_Value	0.35	dB/km	Base wavelength for fibre attenuation estimation - only applicable to the lambda^-4 model.
Fibre_Attenuation_Base_Wavelength	1310.00	nm	Base wavelength for fibre attenuation estimation
Fibre_Attenuation_Value	0.34	dB/km	Calculated nominal attenuation of fibre in dB/km of ideal channel (no connectors, splices etc. i.e. the medium is considered to be continous)
Channel_Length_Max	20	km	The length of the fibre channel between the OLT and the most distant ONU
Fibre_Loss	6.77	dB	Calculated total attenuation of an ideal fibre channel (no connectors, splices etc. i.e. the medium
PSC_Split_count	32.00	-	The maximum number of ports on the Passive Splitter Combiner (powers of 2 are acceptable)
PSC_Loss_Curve	max	-	Defines the type of the PSC loss curve (best case [min], average [avg] and worst case [max]) for the FBT type PSC devices, based on the collected device loss data and approximated curves.
PSC_Loss	18.40	dB	The total loss of the PSC device with the particular number of ports (PSC_Split_count) for the given loss curve (PSC_Loss_Curve), accounting for the ideal and excess loss
SRS_Loss	1.00	dB	SRS induced nonlinear penalty (as resulting from the nonlinear interaction with any other transmission system e.g. 1550nm Analog video overlay operated on the PON fiber).
Excess_Loss	2.83	dB	The additional loss resulting from the non-ideal fibre channel elements i.e. connectors, splices
ITU_Optical_Path_Penalty	1.00	dB	The penalty attributable to the optical path. Given a fixed set of transmitter and receiver, the optical path penalty is equal to the link margin measured with pure attenuation less the link
Channel_Loss_Min	8.00	dB	Minimum channel insertion loss (user defined) to prevent the overload of the receiver on the
Channel_Loss_Max	29.00	dB	Maximum channel insertion loss (user defined), limited by the Tx power and Rx sensitivity
Power Budget	30.50	dB	Available power budget
Dispersion_Uo_Min	1300.00	nm	Minimum value of the zero dispersion wavelength
Dispersion_Uo_Max	1300.00	nm	Maximum value of the zero dispersion wavelength
Dispersion_So	0.09	ps/nm^2·km	Value of the dispersion curvature parameter
Dispersion_D_Max	5.22	ps/(nm·km)	Maximum calculated dispersion "D" parameter
Dispersion_D_Min	3.56	ps/(nm·km)	Minimum calculated dispersion "D" parameter
Dispersion_Penalty	0.24	dB	Dispersion penalty, calculated for the worst case transmission wavelength in the allocated window (Tx_Wavelength_Min, Tx_Wavelength_Max), based on the dispersion penalty estimation model presented
TDP	1.50	dB	Transmitter and Dispersion Penalty (maximum) is equal to the link margin, measured with an ideal Tx and pure attenuation less the link margin measured with a worst case Tx and worst case optical

Insertion loss (min/max)
Current link budget

SRS loss
(calculated externally)

Example of EPON power budget

PX30-D

Transmitter parameters	
ITU_ERnom	6.00
ITU_Tx_Ave_Min	3.00
ITU_Tx_Ave_Max	7.00
IEEE_Tx_OMA_Min	3.78
IEEE_Tx_OMA_Min	2.39
IEEE_Tx_OMA_Max	7.78
IEEE_Tx_OMA_Max	6.00
Tx_Wavelength_Min	1480.00
Tx_Wavelength_Max	1500.00
Tx_Wavelength_Uc	1490.00
Tx_Chirp_Parameter_Max	-2.00
Tx_Data_Rate	1250.00

Link parameters	
Fibre_Attenuation_Curve	lambda^-4
Fibre_Attenuation_Curve_Type	min
Fibre_Attenuation_Base_Value	0.36
Fibre_Attenuation_Base_Wavelength	1550.00
Fibre_Attenuation_Value	0.36
Channel_Length_Max	20
Fibre_Loss	7.21
PSC_Split_count	32.00
PSC_Loss_Curve	max
PSC_Loss	18.40
SRS_Loss	1.00
Excess_Loss	2.39
ITU_Optical_Path_Penalty	1.00
Channel_Loss_Min	15.00
Channel_Loss_Max	29.00
Power_Budget	30.00
Dispersion_Uo_Min	1300.00
Dispersion_Uo_Max	1300.00
Dispersion_So	0.09
Dispersion_D_Max	15.20
Dispersion_D_Min	13.93
Dispersion_Penalty	0.04
TDP	1.00

Receiver parameters	
ITU_Rx_Sensitivity_Ave	-27.00
ITU_Rx_Sensitivity_Ave_OMA	-26.22
ITU_Rx_Sensitivity_Ave_OMA	2.39
IEEE_Rx_Stressed_Sensitivity_Ave	-26.00
IEEE_Rx_Stressed_Sensitivity_OMA	-25.22
IEEE_Rx_Stressed_Sensitivity_OMA	3.01
IEEE_Rx_Sen_Ave	-27.00
IEEE_Rx_Sen_Ave	2.00
IEEE_Rx_Sen_OMA	-26.22
IEEE_Rx_Sen_OMA	2.39
Rx_Overload	-8.00

+

PX30-U

Transmitter parameters	
ITU_ERnom	6.00
ITU_Tx_Ave_Min	0.62
ITU_Tx_Ave_Max	5.62
IEEE_Tx_OMA_Min	1.40
IEEE_Tx_OMA_Min	1.38
IEEE_Tx_OMA_Max	6.40
IEEE_Tx_OMA_Max	4.37
Tx_Wavelength_Min	1260.00
Tx_Wavelength_Max	1360.00
Tx_Wavelength_Uc	1310.00
Tx_Chirp_Parameter_Max	-2.00
Tx_Data_Rate	1250.00

Link parameters	
Fibre_Attenuation_Curve	lambda^-4
Fibre_Attenuation_Curve_Type	min
Fibre_Attenuation_Base_Value	0.35
Fibre_Attenuation_Base_Wavelength	1310.00
Fibre_Attenuation_Value	0.35
Channel_Length_Max	20
Fibre_Loss	7.00
PSC_Split_count	32.00
PSC_Loss_Curve	max
PSC_Loss	18.40
SRS_Loss	1.00
Excess_Loss	2.60
ITU_Optical_Path_Penalty	1.00
Channel_Loss_Min	15.00
Channel_Loss_Max	29.00
Power_Budget	30.40
Dispersion_Uo_Min	1300.00
Dispersion_Uo_Max	1324.00
Dispersion_So	0.09
Dispersion_D_Max	5.22
Dispersion_D_Min	-6.42
Dispersion_Penalty	-0.01
TDP	1.40

Receiver parameters	
ITU_Rx_Sensitivity_Ave	-29.38
ITU_Rx_Sensitivity_Ave_OMA	-28.60
ITU_Rx_Sensitivity_Ave_OMA	1.38
IEEE_Rx_Stressed_Sensitivity_Ave	-28.38
IEEE_Rx_Stressed_Sensitivity_OMA	-27.60
IEEE_Rx_Stressed_Sensitivity_OMA	1.74
IEEE_Rx_Sen_Ave	-29.78
IEEE_Rx_Sen_Ave	1.05
IEEE_Rx_Sen_OMA	-29.00
IEEE_Rx_Sen_OMA	1.26
Rx_Overload	-9.38

- Example on right shows PX30-D and PX30-U links, as defined in IEEE Std 802.3bk-2013
- NG-EPON link budget proposals can be submitted as D (downstream) or U (upstream) link
  - D = OLT Tx + ONU Rx
  - U = ONU Tx + OLT Rx
  - Take note of operating wavelength change for D and U links

Tx parameters

- Transmitter is described using data rate [B15], wavelength range [B11-12], min/max average launch power [B5-6] and extinction ratio [B4] (defaulted to 9dB)
  - Data rate is expressed in MBd (currently set to 25GBd)
  - Wavelength range defines min and max values – central wavelength is calculated as the center or target range
  - Average launch power is expressed in dBm using ITU definition
  - IEEE Tx launch values are calculated in reference to OMA (Optical Modulation Amplitude) [B7-10] – these are values that end up in draft
  - Chirp parameter to be added if needed (worst case)

Transmitter parameters			
ITU_ERnom	9.00	dB	Nominal Extinction Ratio used to convert average power values to OMA values - for a test procedure, see 802.3, clause 52.9.5; for relation between OMA, ER and average power, see 802.3, clause 58.7.6
ITU_Tx_Ave_Min	6.00	dBm	Average Tx launch power (minimum) equal to the minimum OMA at the maximum ER
ITU_Tx_Ave_Max	8.00	dBm	Average Tx launch power (maximum) equal to the maximum OMA at the nominal ER
IEEE_Tx_OMA_Min	7.91	dBm	Minimum OMA Tx launch power
IEEE_Tx_OMA_Min	6.18	mW	Minimum OMA Tx launch power
IEEE_Tx_OMA_Max	9.91	dBm	Maximum OMA Tx launch power
IEEE_Tx_OMA_Max	9.80	mW	Maximum OMA Tx launch power
Tx_Wavelength_Min	1340.00	nm	Transmitter wavelength (min)
Tx_Wavelength_Max	1360.00	nm	Transmitter wavelength (max)
Tx_Wavelength_Uc	1350.00	nm	Transmitter wavelength (central wavelength), calculated based on Tx_Wavelength_Min and
Tx_Chirp_Parameter_Max	0.00	-	The maximum (worst case) value of Chirp parameter used in the calculation of the dispersion
Tx_Data_Rate	25000.00	MBd	The effective data rate at the PMD level after encoding, scrambling i.e. fed to the PMA interface

Rx parameters

- Receiver is described using average sensitivity in ITU-style [B43-45], IEEE average (stressed) sensitivity [B46-52], and Rx overload [B53]
  - All parameter are calculated based on Tx parameters and channel model
  - To achieve specific Rx parameters, user can modify channel parameters and/or Tx parameters
  - IEEE average stressed receiver sensitivity (also in OMA), receiver sensitivity (also in OMA) and Rx overload value end up in the draft. Other parameters are only used for reference, to simplify calculation between ITU-T and IEEE specifications

Receiver parameters			
ITU_Rx_Sensitivity_Ave	-24.00	dBm	Average Rx sensitivity in ITU formalism, calculated as the difference between the minimum, average Tx launch power (ITU_Tx_Ave_Min) and the total power budget (Channel_Loss_Max +
ITU_Rx_Sensitivity_Ave_OMA	-22.09	dBm	Average Rx sensitivity (ITU_Rx_Sensitivity_Ave) in OMA, for the given nominal ER (ITU_Ernom) @ BER
ITU_Rx_Sensitivity_Ave_OMA	6.18	uW	Average Rx sensitivity (ITU_Rx_Sensitivity_Ave) in OMA, for the given nominal ER (ITU_Ernom) @ BER
IEEE_Rx_Stressed_Sensitivity_Ave	-23.00	dBm	Stressed Rx sensitivity in average power form @ BER 1e-3
IEEE_Rx_Stressed_Sensitivity_OMA	-21.09	dBm	OMA stressed Rx sensitivity in average power form @ BER 1e-3
IEEE_Rx_Stressed_Sensitivity_OMA	7.78	uW	OMA stressed Rx sensitivity in average power form @ BER 1e-3
IEEE_Rx_Sen_Ave	-24.50	dBm	Ideal Rx sensitivity in IEEE formalism in average power taking the TDP into account.
IEEE_Rx_Sen_Ave	3.55	uW	Ideal Rx sensitivity in IEEE formalism in average power taking the TDP into account.
IEEE_Rx_Sen_OMA	-22.59	dBm	Ideal Rx sensitivity in IEEE formalism in OMA taking the TDP into account.
IEEE_Rx_Sen_OMA	5.51	uW	Ideal Rx sensitivity in IEEE formalism in OMA taking the TDP into account.
Rx_Overload	0.00	dBm	The Rx overload value for the given link

THANK YOU!