Ad hoc on higher split ratio Introduction

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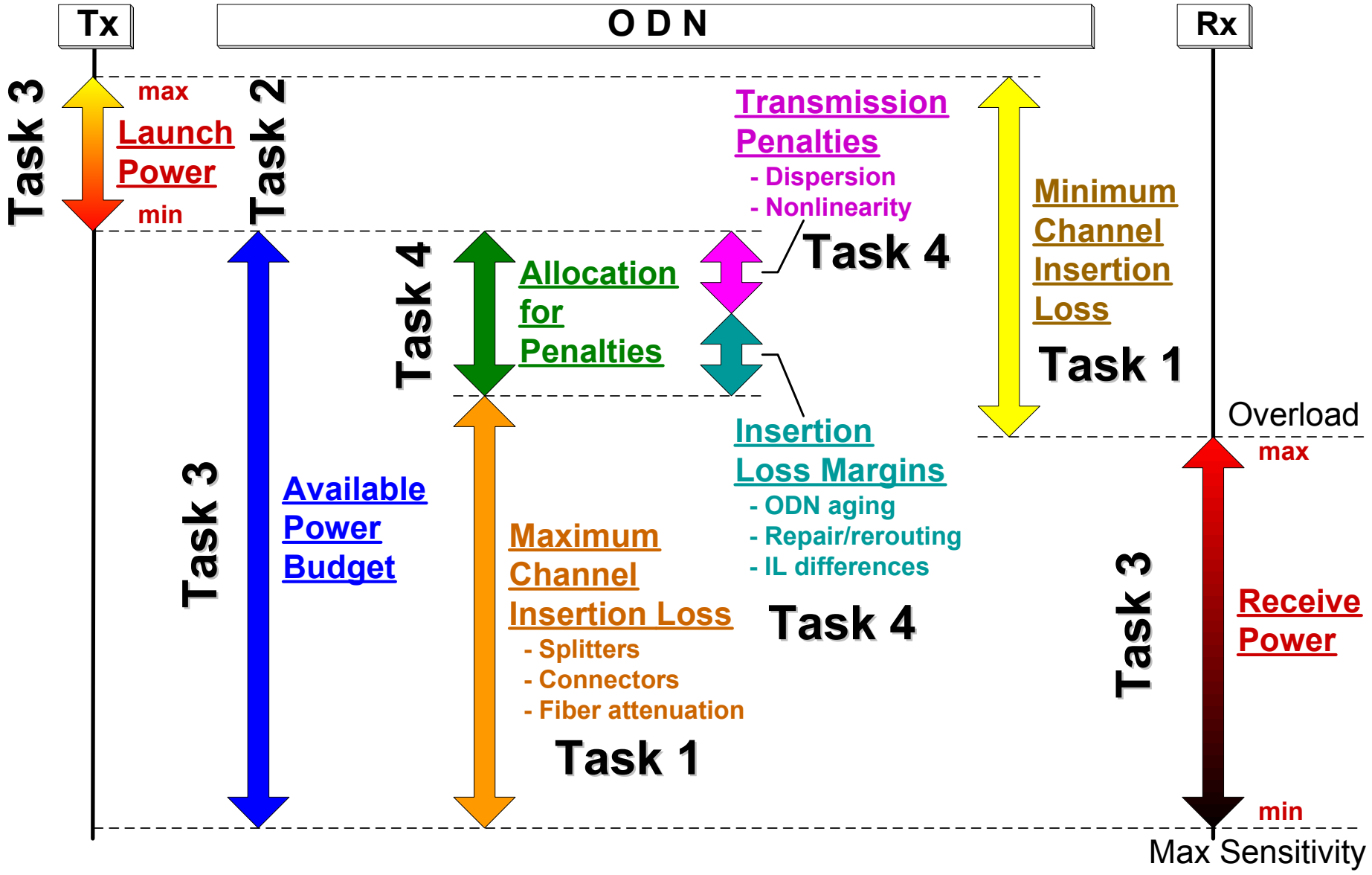
General information [1]

- Chartered tasks
  - evaluate technical feasibility of higher port count EPON systems (1x64 and 1x128 split count)
  - examine:
    - channel insertion loss in high split count EPONs
    - optical margins in 10GEPONs in general
    - available RX/TX/AMP components to reach beyond 29dB power budget with possible RF video overlay
    - fiber channel impairmentrs (non-linearities) and estimate safe launch threshold (max value)
  - provide recommendations to 10GEPON av TF on techno-economic feasibility of high split count EPON systems

General information [2]



General information [3]

- Participants
  - 27 participants requested participation in the ad hoc – distributed to individual tasks based on personal request
- Activities
  - 1 conference call – 11 participants: Haim Ben-Amram, Russell Davey, Glen Kramer, Marek Hajduczenia, Frank Chang, Silvia Pato, David Piehler, Shinji Tsuji, Bin Yeong Yoon, Dong Soo Lee, Wael Diab
  - 5 presentations prepared – 1 for each task + 1 general
  - 1 extended document prepared on non-linear effects in PON ODN (Silvia Pato and Sergey Y. Ten)

Task -1- general information

- Scope of the Task: "*estimation of 1x64 and 1x128 port splitter power loss value, with respect to various manufacturing technologies*"
- Subtasks:
  - estimate splitter loss for 1x128 and 1x64 devices based on commercially available devices (survey)
  - evaluate the loss variations in varied stage systems - 2,3,4 etc stage systems - cascaded splitters
- Participants: Bin Yeong Yoon, Dongsoo Lee, Glen Kramer, Marek Hajduczenia (task leader), Silvia Pato

Task -2- general information

- Scope of the Task: "*non-linear effects in PON fibre channel and their impact on the optical budget*"
- Subtasks:
  - produce an overview of non-linear effects in the fibre channel and their impact on the transmission
  - estimate the maximum launch power into fiber which can be achieved without introducing non-linear effects
  - evaluate the impact of the fibre non-linearities on RF video overlay
- Participants: David Li, Marek Hajduczenia, Ruben Luis, Sergey Y. Ten, Silvia Pato (task leader), Wael William Diab

Task -3- general information

- Scope of the Task: "*overview of RX/TX/AMP components for 10GEPON applications*"
- Subtasks:
  - overview of the critical parameters for RX/TX/AMP components based on vendor survey
  - techno-economic evaluation of various TX/RX/AMP component compbinations for high port count EPONs
- Participants: Bin Yeong Yoon (task leader), Bong Kue Kim, Dong-Soo Lee, Haim Ben-Amram, Marek Hajduczenia, Mitsunobu Kimura, Mun Sub Lee, Piers Dawe, Petre Popescu

Task -4- general information

- Scope of the Task: "*power margins in the 10GEPON systems with high port count*"
- Subtasks:
  - examine existing power budget margins in deployed EPON systems and estimation methodology
  - power budget margins for high port count 10GEPON systems
    - needs and requirements from the carrier point of view
    - estimation of minimum required power margin
- Participants: Glen Kramer, Marek Hajduczenia, Keiji Tanaka (task leader), Tsutomu Tatasuta

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Conclusions & Recommendations

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Conclusions from Task -1-

- Estimated channel insertion loss (worst case scenario):

Scenario \ PSC	Spliced	Connectors
1x64 @ 10 km	**28.6 dB**	**29.6 dB**
1x64 @ 20 km	**33.6 dB**	**34.6 dB**
1x128 @ 10 km	**31.1 dB**	**33.1 dB**
1x128 @ 20 km	**37.1 dB**	**38.1 dB**

- only 1x64 split @ 10 km fits into 29dB channel insertion loss envelope
- 1x128 split @ 20 km requires power budget in excess of 35 dB
- the figures above are informative for the channel insertion loss only and do not account for any power budget margins i.e. aging, repair etc.

Conclusions from Task -2- [1]

- SPM does not limit the 10G transmission @ 1550nm
  - no significant degradation in the systems performance
  - very high launched powers are admissible without penalties
- linear transmission in the drop sections (PSC <-> ONUs)
  - signal power level is already quite low
  - nonlinear effects may be neglected
  - drop section contribute to penalty through additional dispersion
- SBS calculations from first principles are difficult – interaction of light wave with acoustic waves is complex to model

	SBS (CW)		**SBS (10 Gbit/s NRZ)**		**SRS**
	20 km feeder	0.5 km feeder	20 km feeder	0.5 km feeder	
Threshold power	8.1 dBm	22.2 dBm	11.1 dBm	25.2 dBm	slides 11-13

Conclusions from Task -2- [2]

- SBS is the fundamental limitation
- SBS threshold enhanced G.652 fibers improve SBS threshold by >3 dB – already deployed fibre is not SBS enhanced !
- minimizing SBS related impairments with active equipment
  - increase the source linewidth
    - directly modulated source – high dispersion penalties @ 1550nm !!
  - frequency dithering to the laser source
    - directly modulating the laser with a sinusoid at a frequency significantly lower than the low-frequency cutoff of the receiver
    - the dither frequency is outside the receiver bandwidth, so it will not degrade the signal in the presence of dispersion up to a certain limit – it cannot be infinite !!!

Conclusions from Task -3- [1]

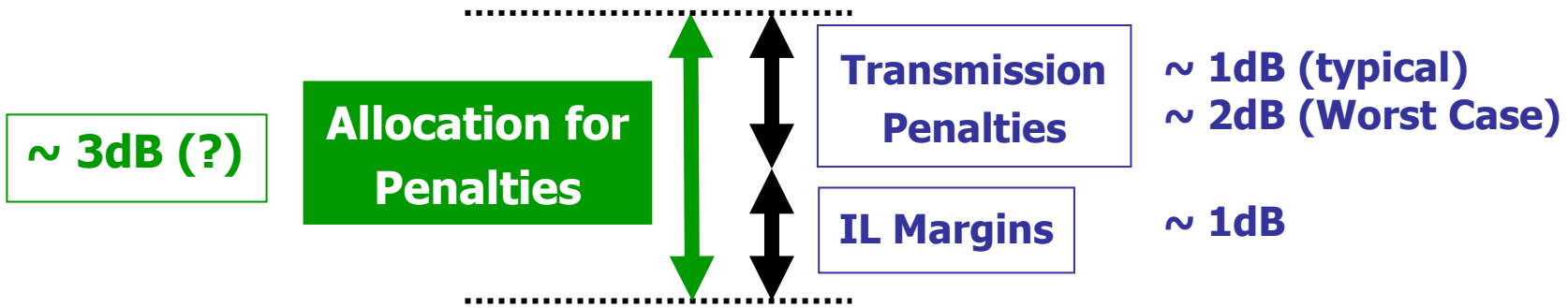
- current market availability of optical 10G devices, such as transmitters, receivers and optical amplifiers
  - 10G laser TX (TOSA module only):
    - 1550nm lasers with the minimum output power: -3 ~ +1 dBm (XMD or Butterfly package) – mainly EML
    - 1310nm lasers with the minimum output power: -5 ~ +2 dBm (both EML and DML, various packages available)
    - 1490nm lasers are currently not available on the market
  - 10G RX typical sensitivities for commercial products (ROSA only):
    - around -18 dBm for pin PD with TIA
    - around -26 dBm for APD with TIA
  - SOA amplifiers
    - available off-the-shelf components for 1550 nm and 1310 nm windows
    - typical saturation power between 11 dBm and 14 dBm (typ., max. values)
    - typical gain above 10 dB and 22 dB maximum

Conclusions from Task -3- [2]

- EDFA amplifiers
  - single channel EDFAs available only for 1550nm band
  - typical output power above 12 dBm with max. values of 27 dBm
  - typical gain above 10 dB with max. values of 30 dB
  - smallest EDFA footprint is 10 times bigger than SOA
  - other transmission bands are also covered:
    - PDFA for O band (1260 ~ 1360 nm)
    - TDFA for S band (1460 ~ 1530 nm)
  - are not widely used – higher cost when compared to SOAs

Conclusions from Task -4-

- Components of the optical budget margin related with
  - Optical transceiver: parameter degradation and fluctuation – they should be included in launch power and Rx sensitivity ranges
  - Transmission: dispersion penalty and nonlinear penalty – they should be analytically estimated, possibility based on 802.3ah/ae
  - Insertion loss of ODN: ODN degradation, repair/rerouting and IL difference/variations – the estimation of these values is difficult, because these depend on operator's policy.
- Possible estimation scheme for 10GEPON optical budget margin (example):



Conclusions & Recommendations

- Ad hoc conclusions …
  - high port EPONs system require power budget of above 32 dB (1x64 @ 10 km) or above 40 dB (1x128 @ 20km), which is still optimistic because we did not consider:
    - at least 1.5 dB SRS penalty if RF video overlay is used in the system
    - additional filter loss in the RxTx modules (separate ROSA/TOSA was considered)
    - SBS limitation of the launch power on the TX side
    - only SBS limitation can be partially overcome through dithering – other elements cannot be mitigated
- Ad hoc recommendations …
  - 1x64 and 1x128 split systems are not technically and economically justified at the moment based on current market state
  - the standard should not preclude introduction of the optical components supporting 1x64 and 1x128 split ratios in the future