Evolution and co–existence for extended EPON PMDs

JIDONG XU, ZHIMING FU,
ZHUANG MA, MAREK HAJDUCZENIA

ZTE Corporation

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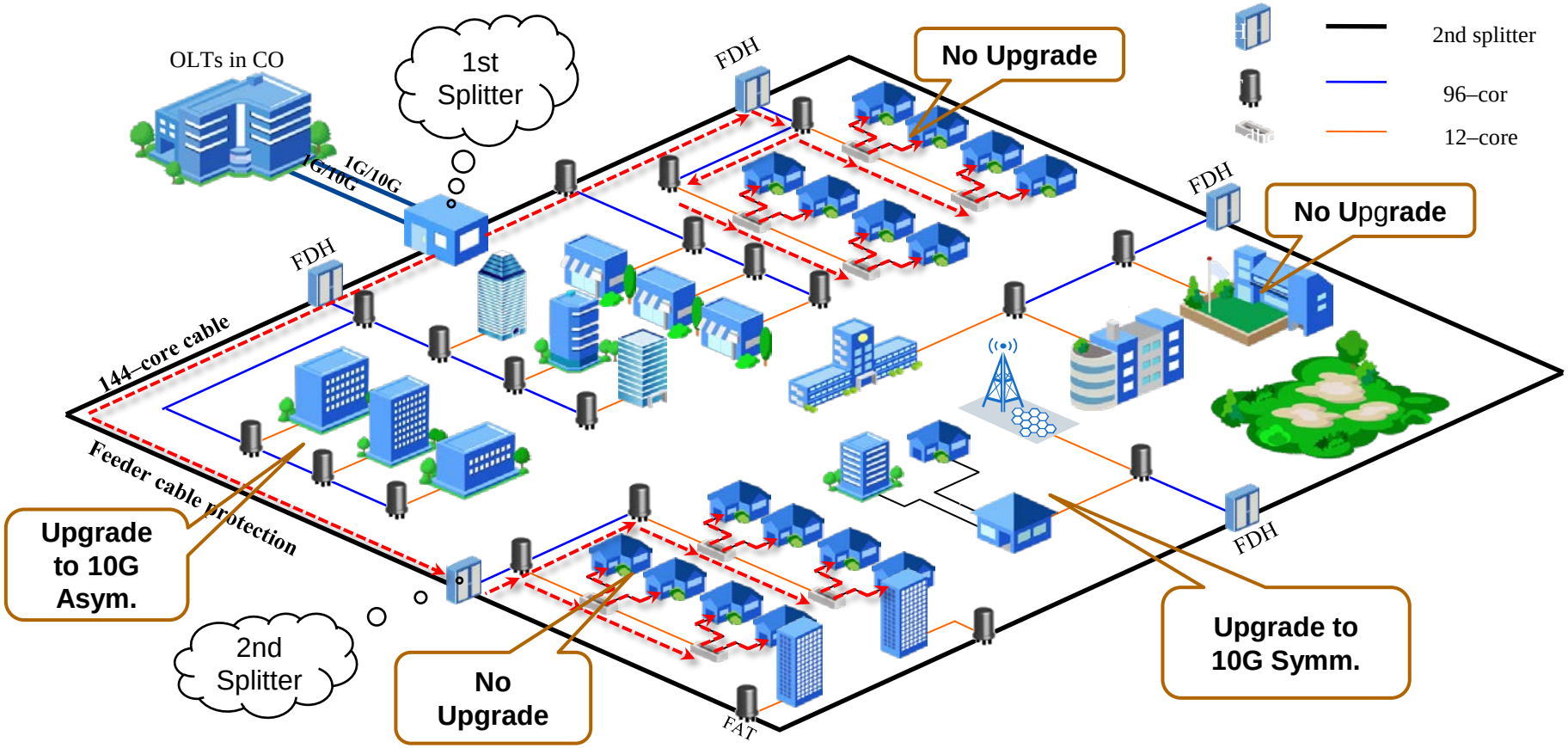
Agenda

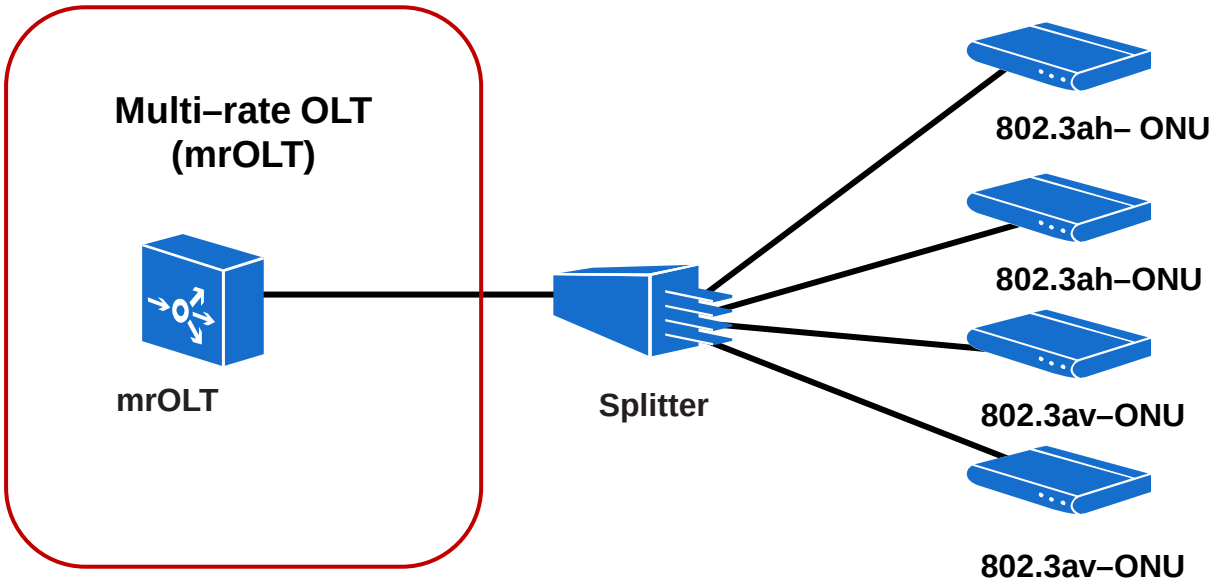
- Overview
- Assumptions for numeric calculations
- Coexistence scenarios
  - PX20 and PR(X)20 coexistence
  - PR(X)20 and PR(X)30 coexistence
  - PR(X)20, PR(X)30 and PR(X)40 coexistence
  - PX20 and PX30 coexistence
  - PX20, PX30 and PX40 coexistence

Background of EPON evolution



- **Market Requirement**
  - Co–existence of 1G–EPON and 10G–EPON is needed in multiple mixed residential deployments
- **Standard Support**
  - IEEE Std 802.3av supports coexistence with IEEE Std 802.3ah out of the box

EPON evolution through backward compatibility and coexistence

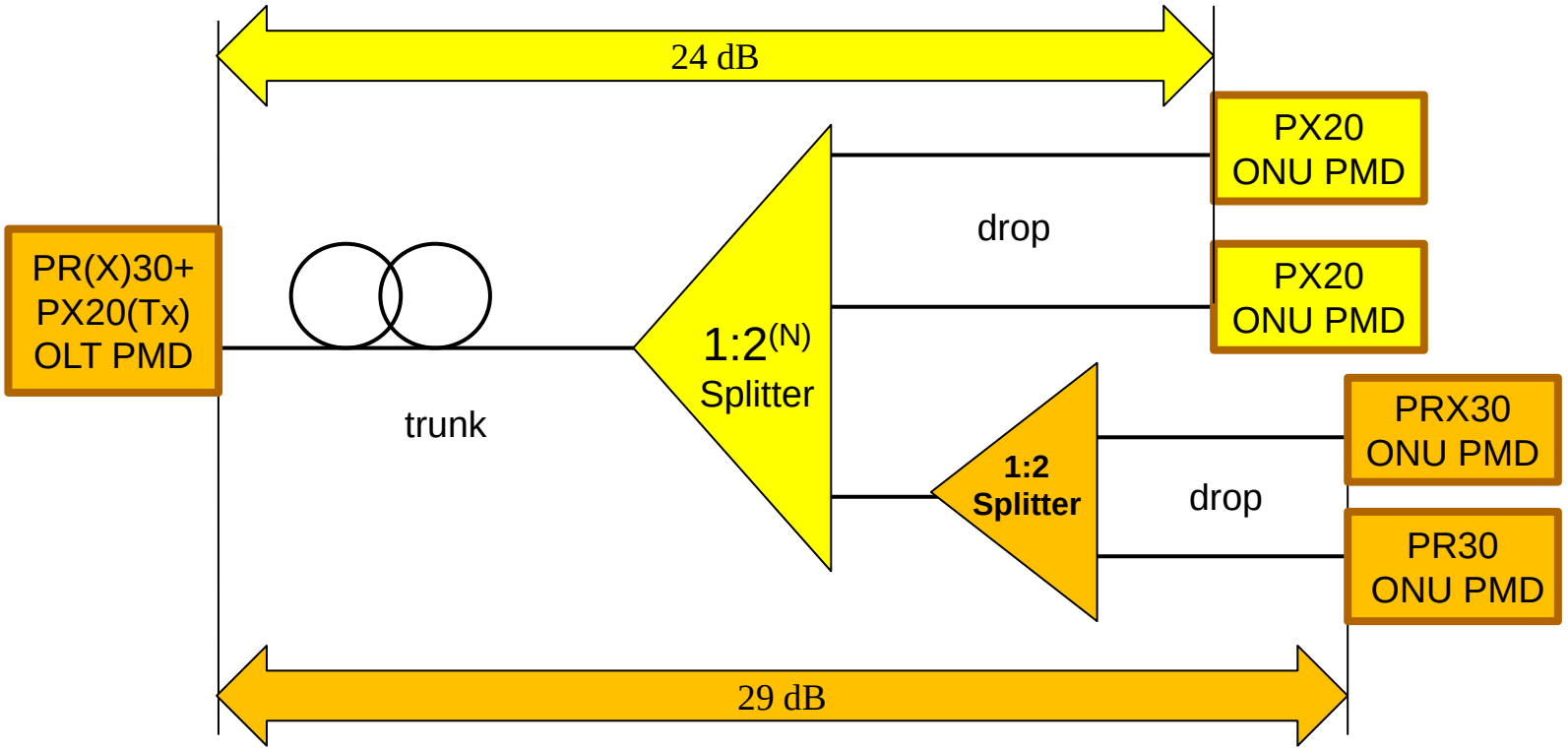


- 802.3av defined dual–rate, burst–mode operation scheme for OLT, providing coexistence option with 802.3ah devices (mrOLT)
- It allows 1G–EPON and 10G–EPON devices to coexist without the need for extra optical components (WDM1/WDM1r in XG–PON speak).
- A single OLT can control 1G–EPON and 10G–EPON devices, saving on port density, shelf space and facilitating upgrade for operators.

Assumptions for numeric calculations

- Using 802.3, Clause 60 and 802.3av PMD parameters, we show the applicability of coexistence of multiple PMD types on the same ODN.
- Main assumptions for the model are listed below.
- mrOLT uses PR(X)30–type PMD, capable of operating at 10G downstream and 10G/1G upstream
- Power budget calculations account for TDP defined per standard and use the following formula: **Tx (power) – TDP – Rx (sensitivity).** This allows for direct comparison between available power budget and ODN loss calculated as shown below
- For ODN loss calculations, the 802.3av approved spreadsheet calculator is used:
  - available at http://www.ieee802.org/3/av/public/tools/3av_0804_linkmodel_v2_3.xls
  - Average PSC loss curve was used for calculations
  - Minimum fibre loss curves were used (very pessimistic value anyway when compared with existing products)
- Positive power budget indicates that the given selected combination of PMDs can support the given ODN (fiber and splitter combination) loss budget

PX20 and PR(X)30 coexistence



- In this scenario, an operator is assumed to migrate from 24dB ODN with PX20 class devices to 29dB ODN, by locally adding 1:2 splitters in selected locations where customer demand is higher.
- This requires replacement of the OLT card to support PR(X)30 class power budget and use of PR(X)30 class ONUs for newly added branches.

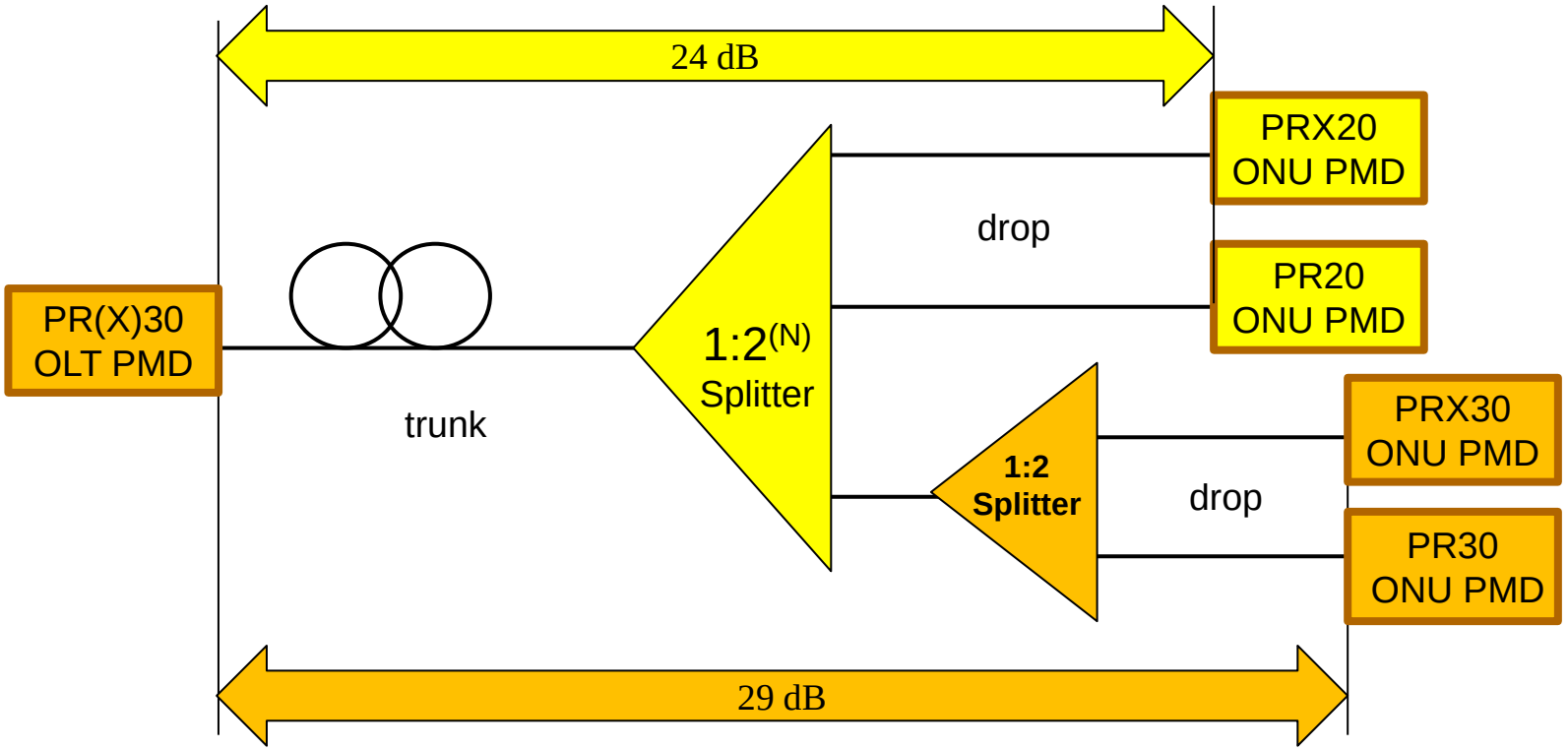
Numeric proof of coexistence (I)

- **PX20 class ONUs with PR(X)30 class OLT**
  - **Downstream (1G)**
    - **Power budget: +2 – 2.3 – (–24) = 23.7 dB**
    - **ODN loss: 5.52+14= 19.52 dB**
    - **Power budget margin: +4.18 dB**
    - **Conclusions: PX20 ONU receive optical signal within sensitivity limit of their Rx**
  - **Upstream (1G)**
    - **Power budget: +1 – 1.8 – (– 29.78) = 28.98 dB**
    - **ODN loss: 8.36+14 = 22.36 dB**
    - **Maximum power level at OLT Rx: +4 – 1.8 – 22.36 = – 20.16 dBm**
    - **Power budget margin: +6.62 dB**
    - **Damage threshold of OLT Rx: –5dBm >> –20.16 dBm (observed max)**
    - **Conclusions: PRX30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold**

Numeric proof of coexistence (II)

- **PR30 and PRX30 class ONUs with PR(X)30 class OLT**
  - **Downstream (10G)**
    - Power budget: +2 – 1.5 – (–28.5) = 29 dB
    - ODN loss: 5.52+17.41= 22.93 dB
    - Power budget margin: +6.07 dB
    - Conclusions: both ONUs receive optical signal within sensitivity limit of their Rx
  - **Upstream (1G)**
    - Power budget: +0.62 – 1.4 – (– 29.78) = 29 dB
    - ODN loss: 8.36+17.41= 25.77 dB
    - Maximum power level at OLT Rx: +5.62 – 1.4 – 25.77 = -21.55 dBm
    - Power budget margin: +3.23 dB
    - Damage threshold of OLT Rx: –5dBm >> –21.55 dBm (observed max)??
    - Conclusions: PRX30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold
  - **Upstream (10G)**
    - Power budget: 4 – 3 – (– 28.0) = 29 dB
    - ODN loss: 8.36+17.41= 25.77 dB
    - Maximum power level at OLT Rx: +9 – 3 – 25.77 = -19.77 dBm
    - Power budget margin: +3.23 dB
    - Damage threshold of OLT Rx: –5dBm >> – 19.77 dBm (observed max)
    - Conclusions: PR30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold

PR(X)20 and PR(X)30 coexistence



- In this scenario, an operator is assumed to migrate from 24dB ODN with PR(X)20 class devices to 29dB ODN, by locally adding 1:2 splitters in selected locations where customer demand is higher.
- This requires replacement of the OLT card to support PR(X)30 class power budget and use of PR(X)30 class ONUs for newly added branches.

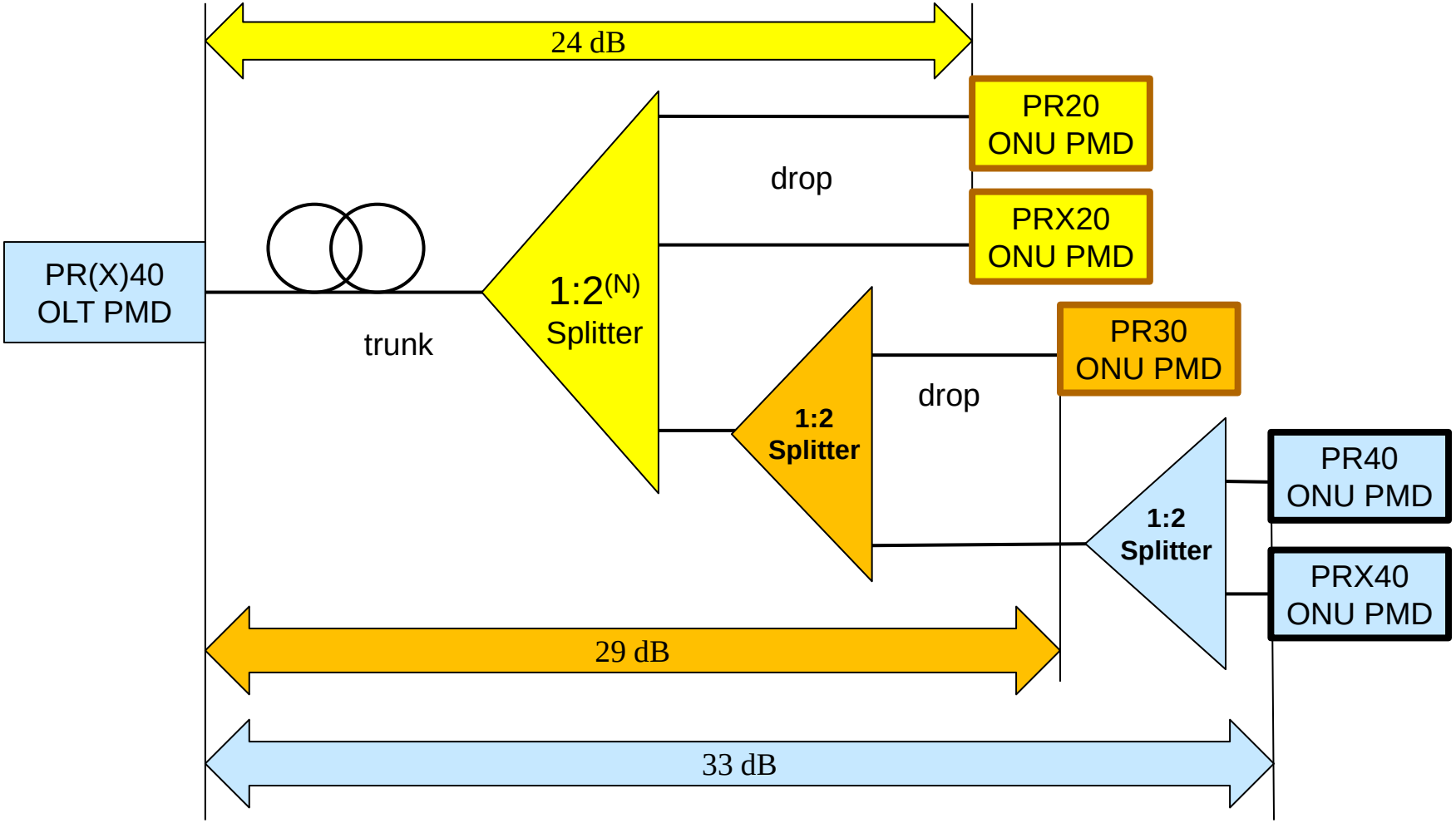
Numeric proof of coexistence (I)

- **PR20 and PRX20 class ONUs with PR(X)30 class OLT**
  - **Downstream (10G)**
    - Power budget: +2 – 1.5 – (–20.5) = 21 dB
    - ODN loss: 5.52+14= 19.52 dB
    - Power budget margin: +1.48 dB
    - Conclusions: both ONUs receive optical signal within sensitivity limit of their Rx
  - **Upstream (1G)**
    - Power budget: +1 – 1.8 – (– 29.78) = 28.98 dB
    - ODN loss: 8.36+14 = 22.36 dB
    - Maximum power level at OLT Rx: +4 – 1.8 – 22.36 = – 20.16 dBm
    - Power budget margin: +6.62 dB
    - Damage threshold of OLT Rx: –5dBm >> –20.16 dBm (observed max)
    - Conclusions: PRX30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold
  - **Upstream (10G)**
    - Power budget: – 1 – 3 – (– 28.0) = 24 dB
    - ODN loss: 8.36+14 = 22.36 dB
    - Maximum power level at OLT Rx: +4 – 3 – 22.36 = – 21.36 dBm
    - Power budget margin: +1.64 dB
    - Damage threshold of OLT Rx: –5dBm >> – 21.36 dBm (observed max)
    - Conclusions: PR30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold

Numeric proof of coexistence (II)

- **PR30 and PRX30 class ONUs with PR(X)30 class OLT**
  - **Downstream (10G)**
    - Power budget: +2 – 1.5 – (–28.5) = 29 dB
    - ODN loss: 5.52+17.41= 22.93 dB
    - Power budget margin: +6.07 dB
    - Conclusions: both ONUs receive optical signal within sensitivity limit of their Rx
  - **Upstream (1G)**
    - Power budget: +0.62 – 1.4 – (– 29.78) = 29 dB
    - ODN loss: 8.36+17.41= 25.77 dB
    - Maximum power level at OLT Rx: +5.62 – 1.4 – 25.77 = -21.55 dBm
    - Power budget margin: +3.23 dB
    - Damage threshold of OLT Rx: –5dBm >> –21.55 dBm (observed max)
    - Conclusions: PRX30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold
  - **Upstream (10G)**
    - Power budget: 4 – 3 – (– 28.0) = 29 dB
    - ODN loss: 8.36+17.41= 25.77 dB
    - Maximum power level at OLT Rx: +9 – 3 – 25.77 = -19.77 dBm
    - Power budget margin: +3.23 dB
    - Damage threshold of OLT Rx: –5dBm >> – 19.77 dBm (observed max)
    - Conclusions: PR30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold

PR(X)20, PR(X)30 and PR(X)40 coexistence



- PR(X)40 OLT and ONU PMDs use parameters proposed in http://www.ieee802.org/3/EXTND_EPON/public/1201/ExEPON_1201_li_2.pdf

Numeric proof of coexistence (I)

- **PR20 and PRX20 class ONUs with PR(X)40 class OLT**
  - **Downstream (10G)**
    - Power budget: +5 – 1.5 – (–20.5) = 24 dB
    - ODN loss: 5.52 + 14 = 19.52 dB
    - Power budget margin: +4.48 dB
    - Conclusions: both ONUs receive optical signal within sensitivity limit of their Rx
  - **Upstream (1G)**
    - Power budget: –1 – 1.8 – (– 32) = 29.2 dB
    - ODN loss: 8.36 + 14 = 22.36 dB
    - Maximum power level at OLT Rx: +4 – 1.8 – 22.36 = – 20.16 dBm
    - Power budget margin: +6.84 dB
    - Damage threshold of OLT Rx: –5dBm >> –20.16 dBm (observed max)
    - Conclusions: PRX40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold
  - **Upstream (10G)**
    - Power budget: – 1 – 3 – (– 29.0) = 26 dB
    - ODN loss 8.36 + 14 = 22.36 dB
    - Maximum power level at OLT Rx: +4 – 3 – 22.36 = – 21.36 dBm
    - Power budget margin: +3.64 dB
    - Damage threshold of OLT Rx: –5dBm >> – 21.36 dBm (observed max)
    - Conclusions: PR40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold

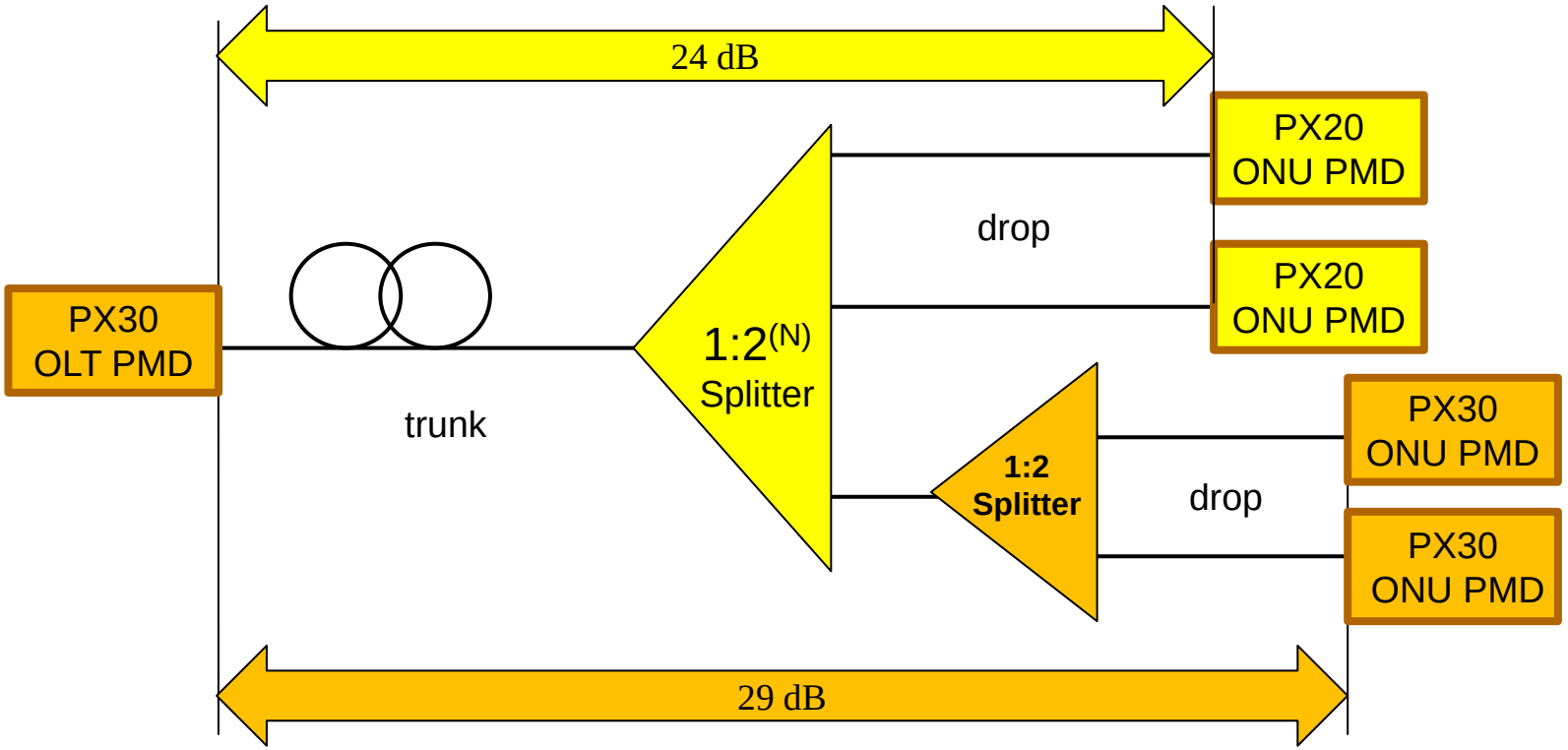
Numeric proof of coexistence (II)

- **PR30 and PRX30 class ONUs with PR(X)40 class OLT**
  - **Downstream (10G)**
    - Power budget: +5 – 1.5 – (–28.5) = 32 dB
    - ODN loss: 5.52+17.41 = 22.93 dB
    - Power budget margin: +9.07 dB
    - Conclusions: both ONUs receive optical signal within sensitivity limit of their Rx
  - **Upstream (1G)**
    - Power budget: +0.62 – 1.4 – (– 32) = 31.22 dB
    - ODN loss: 8.36+17.41 = 25.77 dB
    - Maximum power level at OLT Rx: +5.62 – 1.4 – 25.77 = – 21.55 dBm
    - Power budget margin: +5.45 dB
    - Damage threshold of OLT Rx: –5dBm >> –21.55 dBm (observed max)
    - Conclusions: PRX40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold
  - **Upstream (10G)**
    - Power budget: 4 – 3 – (– 29.0) = 30 dB
    - ODN loss: 8.36+17.41 = 25.77 dB
    - Maximum power level at OLT Rx: +9 – 3 – 25.77 = – 19.77 dBm
    - Power budget margin: +4.23 dB
    - Damage threshold of OLT Rx: –5dBm >> – 19.77 dBm (observed max)
    - Conclusions: PR40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold

Numeric proof of coexistence (III)

- **PR40 and PRX40 class ONUs with PR(X)40 class OLT**
  - **Downstream (10G)**
    - Power budget: +5 – 1.5 – (–29.5) = 33 dB
    - ODN loss: 5.52+20.81= 26.33 dB
    - Power budget margin: +6.67 dB
    - Conclusions: both ONUs receive optical signal within sensitivity limit of their Rx
  - **Upstream (1G)**
    - Power budget: +2 – 1 – (– 32) = 33 dB
    - ODN loss: 8.36+20.81 = 29.17 dB
    - Maximum power level at OLT Rx: +7 – 1 – 29.17 = – 23.17 dBm
    - Power budget margin: +3.83 dB
    - Damage threshold of OLT Rx: –5dBm >> –23.17 dBm (observed max)
    - Conclusions: PRX40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold
  - **Upstream (10G)**
    - Power budget: 6 – 2 – (– 29.0) = 33 dB
    - ODN loss: 8.36+20.81 = 29.17 dB
    - Maximum power level at OLT Rx: +10 – 2 – 29.17 = – 21.17 dBm
    - Power budget margin: +3.83 dB
    - Damage threshold of OLT Rx: –5dBm >> – 21.17 dBm (observed max)
    - Conclusions: PR40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold

PX20 and PX30 coexistence



- In this scenario, we examine the coexistence between PX20 and PX30 ONUs on the same ODN, representing a migration and evolution scenario for operators that have already deployed PX20 compatible ODN.
- PX30 OLT and ONU PMDs use parameters proposed in http://www.ieee802.org/3/EXTND_EPON/public/1201/ExEPON_1201_li_2.pdf

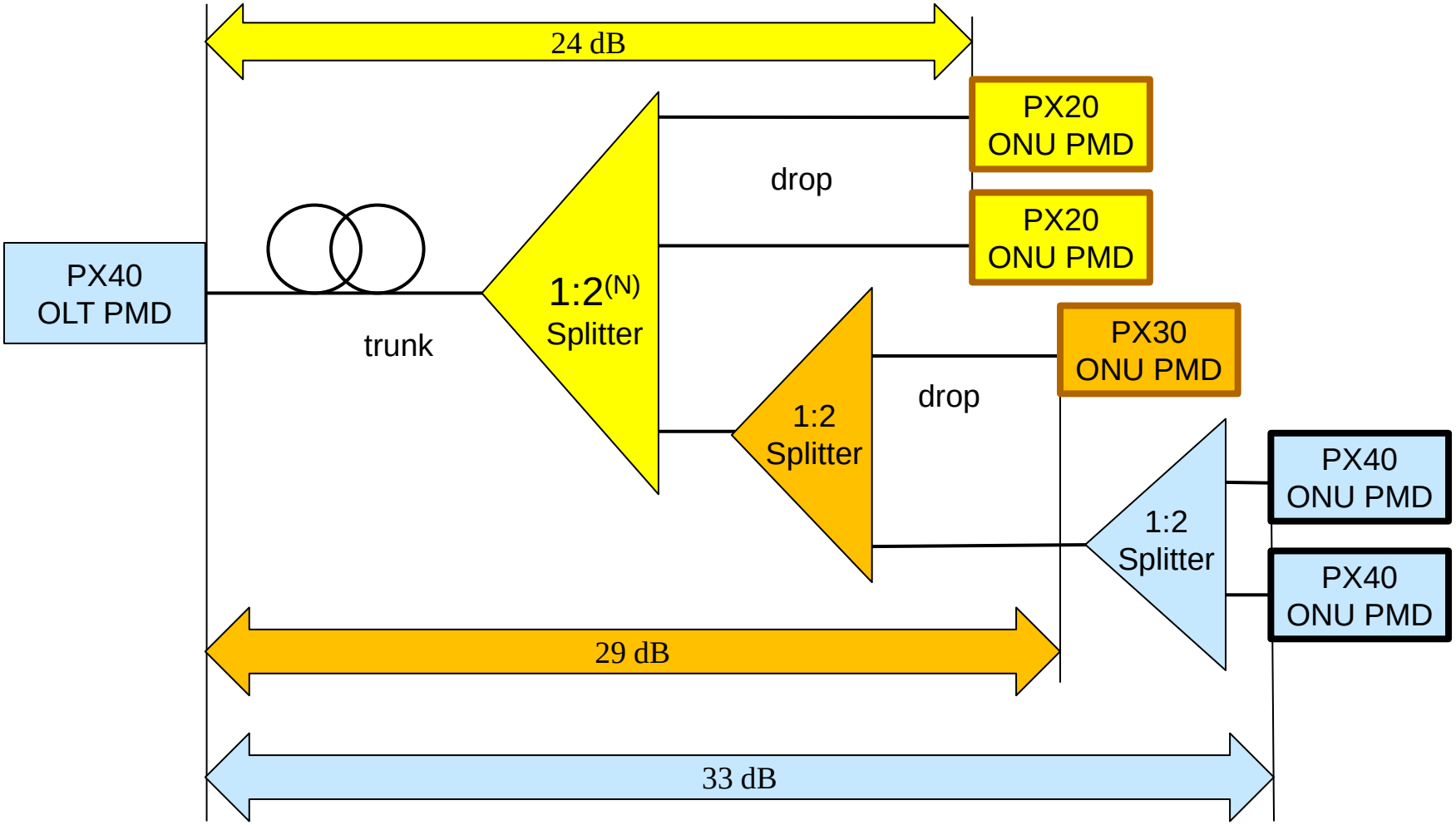
Numeric proof of coexistence (I)

- **PX20 class ONUs with PX30 class OLT**
  - **Downstream (1G)**
    - **Power budget: +3 – 1.0 – (–24) = 26 dB**
    - **ODN loss: 5.52+14 =19.52 dB**
    - **Power budget margin: +6.48 dB**
    - **Conclusions: PX20 ONU receive optical signal within sensitivity limit of their Rx**
  - **Upstream (1G)**
    - **Power budget: +1 – 1.8 – (– 30) = 29.2 dB**
    - **ODN loss: 8.36+14= 22.36 dB**
    - **Maximum power level at OLT Rx: +4 – 1.8 – 22.36 = – 20.16 dBm**
    - **Power budget margin: +6.84 dB**
    - **Damage threshold of OLT Rx: –3dBm >> –20.16 dBm (observed max)**
    - **Conclusions: PX30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold**

Numeric proof of coexistence (II)

- **PX30 class ONUs with PX30 class OLT**
  - **Downstream (1G)**
    - **Power budget: +3 – 1.0 – (–27) = 29 dB**
    - **ODN loss: 5.52+17.41 =22.93 dB**
    - **Power budget margin: +6.07 dB**
    - **Conclusions: PX30 ONU receive optical signal within sensitivity limit of their Rx**
  - **Upstream (1G)**
    - **Power budget: +1 – 2 – (– 30) = 29 dB**
    - **ODN loss: 8.36+17.41 =25.77**
    - **Maximum power level at OLT Rx: +4 – 2 – 25.77 = – 23.77 dBm**
    - **Power budget margin: +3.23 dB**
    - **Damage threshold of OLT Rx: –5dBm >> –23.77 dBm (observed max)**
    - **Conclusions: PX30 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold**

PX20, PX30 and PX40 coexistence under ExEPON



- PX40 and PX30 OLT and ONU PMDs use parameters proposed in http://www.ieee802.org/3/EXTND_EPON/public/1201/ExEPON_1201_li_2.pdf

Numeric proof of coexistence (I)

- **PX20 class ONUs with PX40 class OLT**
  - **Downstream (1G)**
    - **Power budget: +4 – 1.0 – (–24) = 27 dB**
    - **ODN loss: 5.52+14 = 19.52 dB**
    - **Power budget margin: +7.48 dB**
    - **Conclusions: PX20 ONU receive optical signal within sensitivity limit of their Rx**
  - **Upstream (1G)**
    - **Power budget: +1 – 1.8 – (– 32) = 31.2 dB**
    - **ODN loss: 8.36+14 = 22.37 dB**
    - **Maximum power level at OLT Rx: +4 – 1.8 – 22.37 = – 20.17 dBm**
    - **Power budget margin: +8.83 dB**
    - **Damage threshold of OLT Rx: –3dBm >> –20.17 dBm (observed max)**
    - **Conclusions: PX40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold**

Numeric proof of coexistence (II)

- **PX30 class ONUs with PX40 class OLT**
  - **Downstream (1G)**
    - **Power budget: +4 – 1.0 – (–27) = 30 dB**
    - **ODN loss: 5.52+17.41 = 22.93 dB**
    - **Power budget margin: +7.07 dB**
    - **Conclusions: PX30 ONU receive optical signal within sensitivity limit of their Rx**
  - **Upstream (1G)**
    - **Power budget: +1 – 2 – (– 32) = 31 dB**
    - **ODN loss: 8.36+17.41 = 25.77 dB**
    - **Maximum power level at OLT Rx: +4 – 2 – 25.77 = – 23.77 dBm**
    - **Power budget margin: 5.23 dB**
    - **Damage threshold of OLT Rx: –3dBm >> –23.77 dBm (observed max)**
    - **Conclusions: PX40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold**

Numeric proof of coexistence (III)

- **PX40 class ONUs with PX40 class OLT**
  - **Downstream (1G)**
    - **Power budget: +4 – 1.0 – (–30) = 33 dB**
    - **ODN loss: 5.5.2+20.81= 26.33 dB**
    - **Power budget margin: +6.67 dB**
    - **Conclusions: PX40 ONU receive optical signal within sensitivity limit of their Rx**
  - **Upstream (1G)**
    - **Power budget: +2 – 1 – (– 32) = 33 dB**
    - **ODN loss: 8.36+20.81 = 29.17 dB**
    - **Maximum power level at OLT Rx: +7 – 1 – 29.17 = – 23.17 dBm**
    - **Power budget margin: 3.83 dB**
    - **Damage threshold of OLT Rx: –3dBm >> –23.17 dBm (observed max)**
    - **Conclusions: PX40 OLT PMD receives optical signal within sensitivity limit of its Rx; Rx operates with large safety margin from damage threshold**

Conclusions

- Multiple combinations of PMDs (existing and proposed) can coexist on the same OLT port, as long as the OLT port is upgraded to support the highest power budget available.
- Through simple numeric calculations we show that there are no problems with overload on the ONU and OLT receivers and they operate within their optimum sensitivity range.
- The examined scenarios of coexistence between different PMD classes allow operators to use the grow-as-needed approach, in which they start from lower-loss ODN and then gradually expand selected drop sections, adding 1:2 or 1:4 splitters to add more ONUs to the network.
- Addition of PX30, PX40, PR40 and PRX40 power budgets will further enable operators to extend the coverage of already deployed networks, adding 1:2 extra split where needed, or build new networks with longer reach / higher split support.

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