Rete Ottica di Accesso a Divisione di frequenza e/o di lunghezza d'onda per soluzioni Next Generation Network

Experimental Results on FDMA-PON architecture from the PRIN Project ROAD-NGN

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ROAD-NGN project in a glance

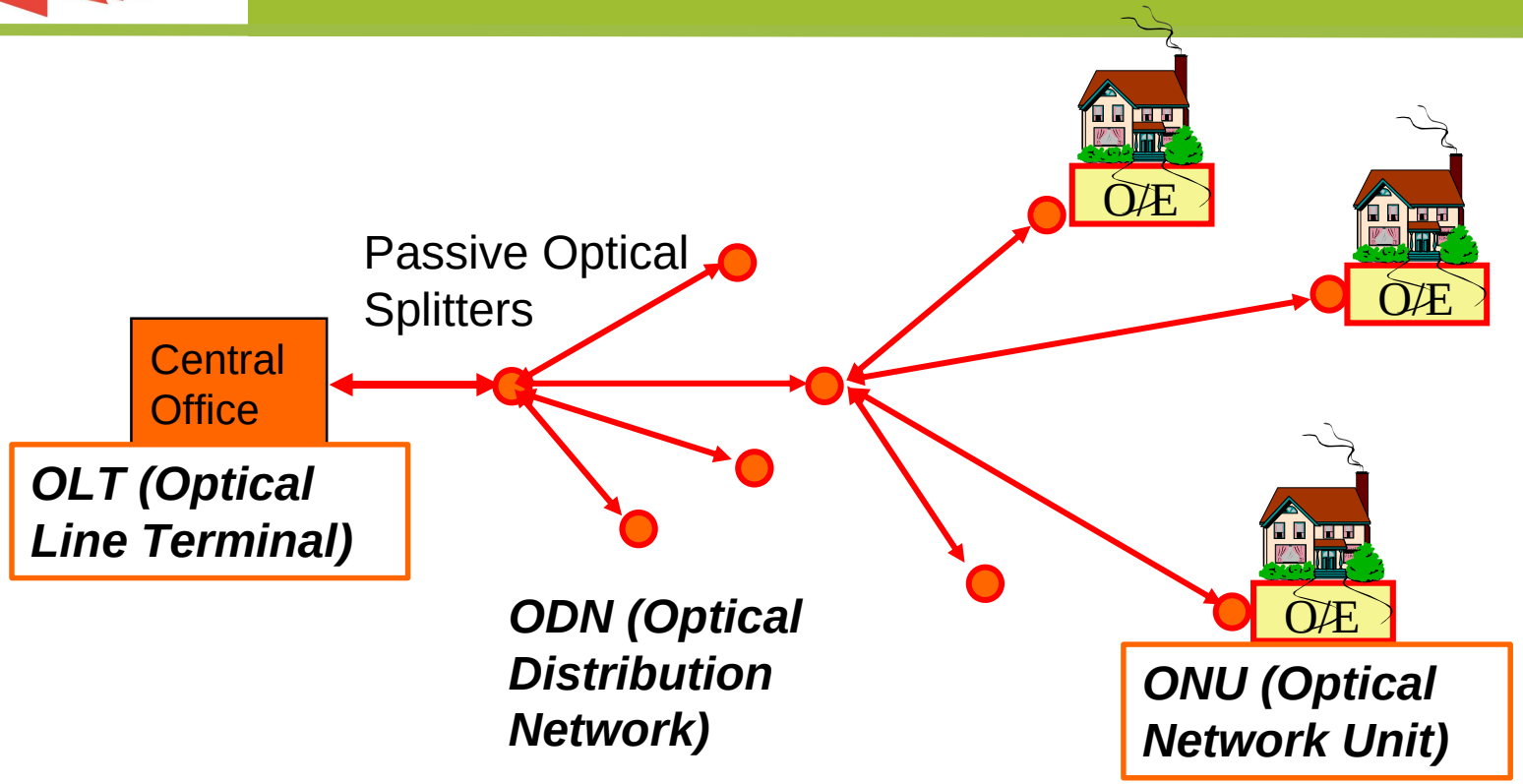
- **Scenario:** Passive Optical Networks (PON) for FTTH solutions

- **Project focus**: improvements compared to current PON standards in terms of:
  - Increase in bit rate per wavelength
  - Cost effective solutions to handle multiple wavelengths

Outline of the presentation

- The most recent ITU-T standard for PON: **NG-PON2**
- The ROAD-NGN research goals: **beyond NG-PON2**
- Proposed architectures for upstream and downstream transmission
  - Experimental results from PoliTO and PoliMI

PON architecture



Today mostly deployed standard: GPON (ITU-T G.984):

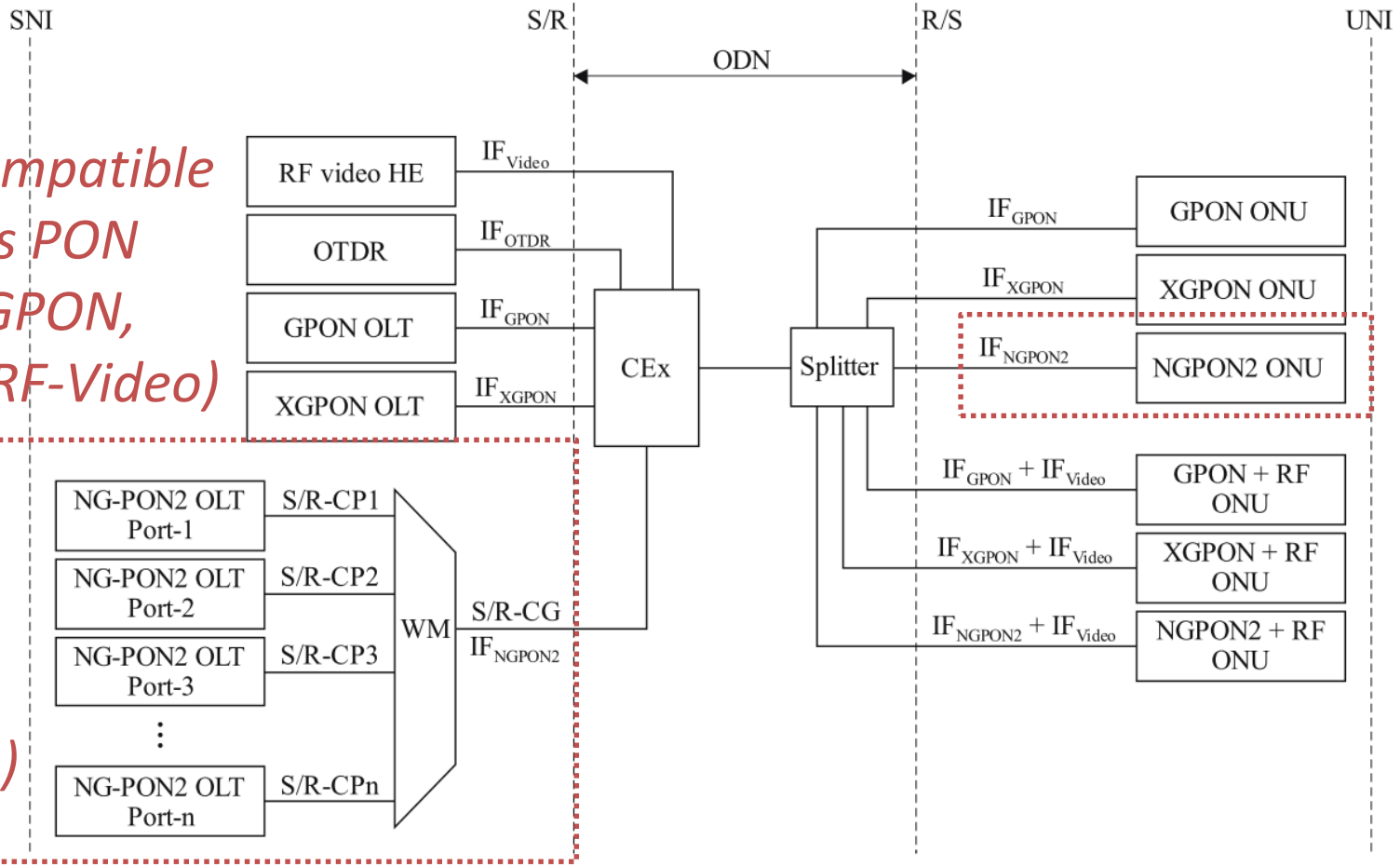
- Number of user per PON tree: up to 64
- Multiplexing technique:
  - TDM in downstream at 2.5 Gbps, TDMA in upstream at 1.25 Gbps

ITU-T most recent standard: NG-PON2 (TWDM-PON)

- Defined by FSAN and ITU-T in the Recommendation G.989.1 **"40-Gigabit-capable passive optical networks (NG-PON2)"**
- **TWDM-PON:** time and wavelength division multiplexed PON

Backward compatible with previous PON standards (GPON, XGPON and RF-Video)

NG-PON2: 4 new wavelengths (per direction)



NG-PON2 features

- **4 wavelengths** per direction, 100 GHz spacing
  Upgradeable to 8 wavelengths (50 GHz)
- **TDMA** on each of the 4 wavelengths
  Each wavelength is treated as an independent **XG-PON**
  - Downstream: 10 Gbps
  - Upstream: 2.5 Gbps
- Traditional Splitter-based PON
  Backward compatibility with **ODN loss classes**

	Nominal 1 (N1 class)	Nominal 2 (N2 class)	Extended 1 (E1 class)	Extended 2 (E2 class)
Minimum loss	14 dB	16 dB	18 dB	20 dB
Maximum loss	29 dB	31 dB	33 dB	35 dB

ROAD-NGN targets

- **Target #1: Increase the bit rate per wavelength** in both directions
  - toward 30-40 Gbps in both directions (as symmetrically as possible)

- **Target #2: Simplify wavelength handling** for the upstream, trying to solve one of the most critical issues to be solved in TWDM-PON

The recipes to achieve ROAD-NGN targets

- **Target #1: higher bit rate per wavelength**

Introduce more sophisticated modulation formats and multiplexing techniques

- Frequency division multiplexing (FDMA)
  - → in both directions (US and DS)
  - → implemented at the electrical level on top of each λ
- complex modulation formats (such as QPSK and M-QAM) on each electrical subcarrier in the FDMA comb

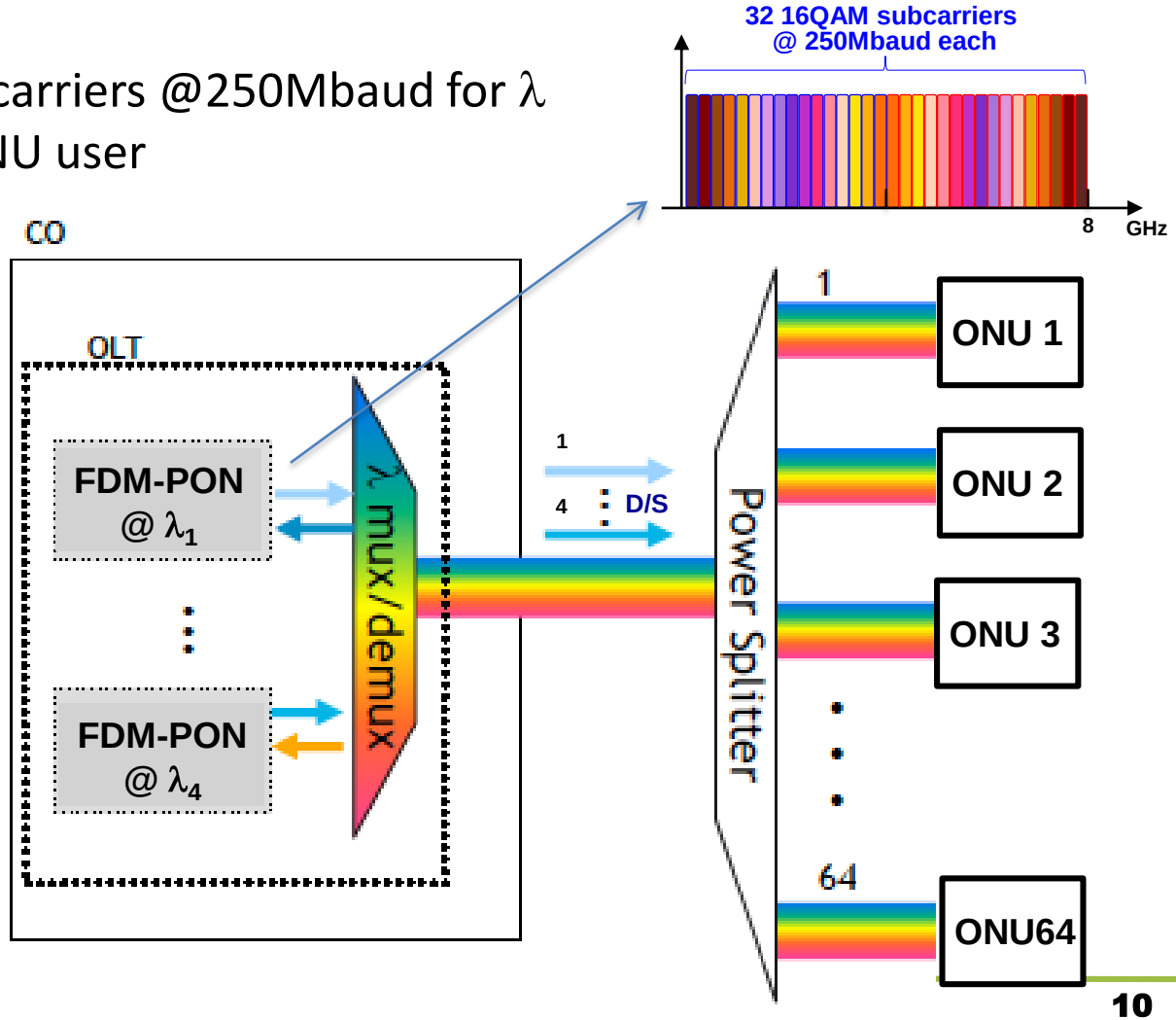
As a result: digital signal processing (DSP) required at both the ONU and OLT

- Constraint: low DSP rate at the ONU to keep cost and power consumption at reasonable levels

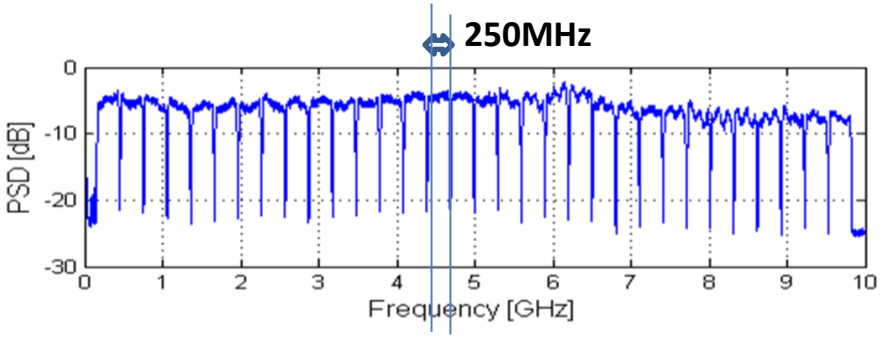
ROAD-NGN proposal: FDM in downstream

- ROAD-NGN proposes to use **32–subcarrier FDM,** each subcarrier 16-QAM modulated and carrying **1-Gbps data rate**

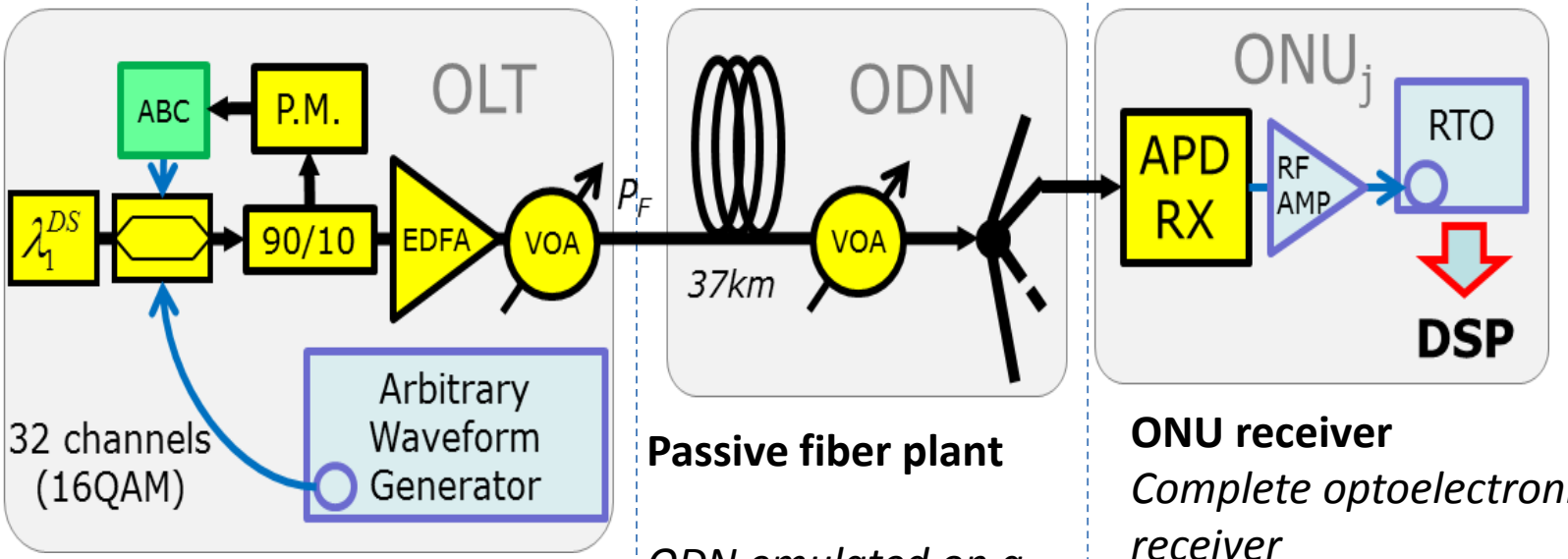
- FDM modulation at OLT
- 32 16QAM-modulated subcarriers @250Mbaud for λ
- at least 1 subcarrier per ONU user
- 32 Gbps per wavelength
- 4x32-Gbps total capacity



Experimentation



The proposed FDM spectrum totally fills the available downstream electrical bandwidth over a typical direct-detection optical link (8-GHz 3dB bandwidth)



OLT transmitter

DSP emulation through a Tektronix 20 Gsample/s arbitrary waveform generator

Passive fiber plant

ODN emulated on a real metropolitan fiber testbed

Realistic ODN losses as requested by ITU-T

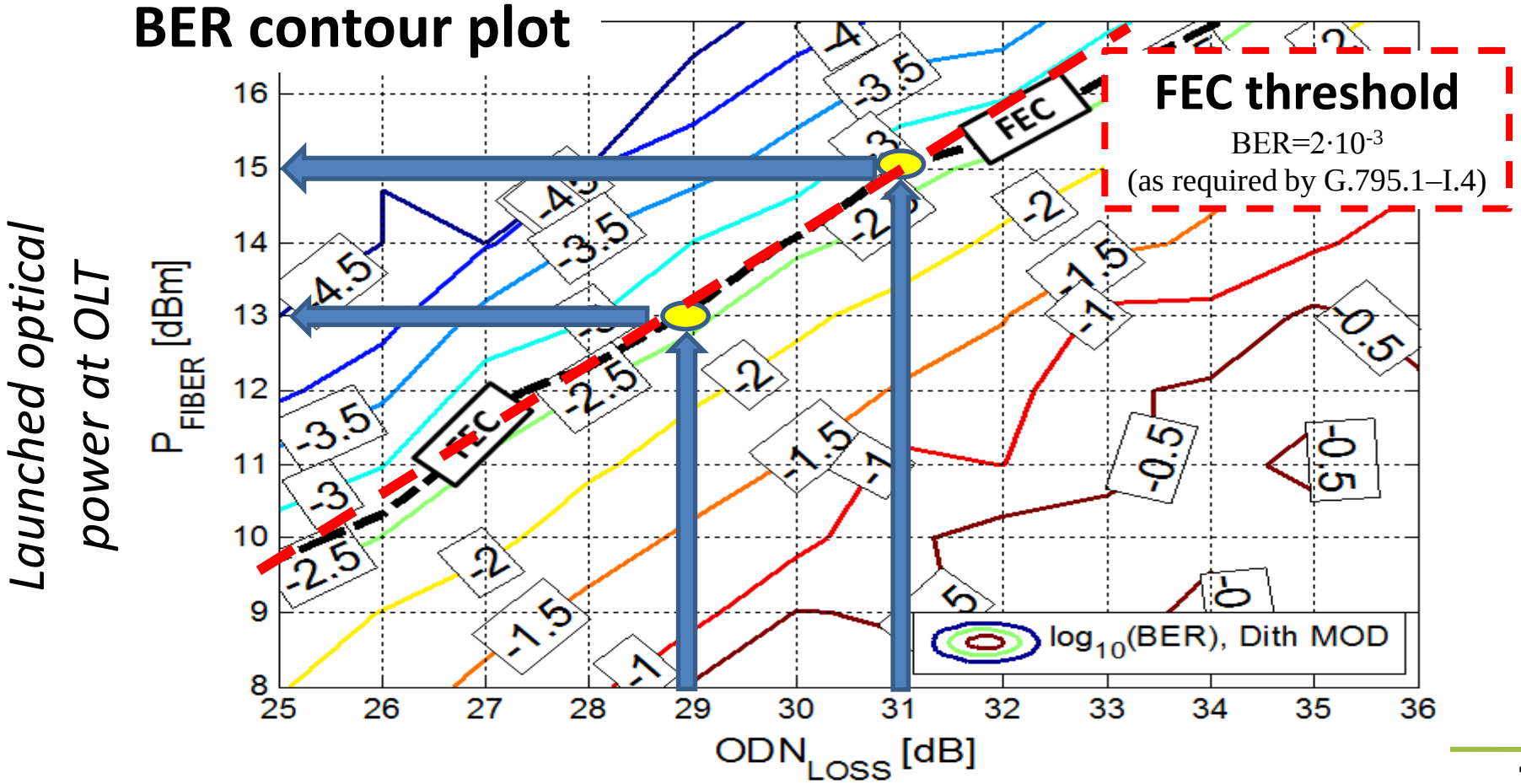
ONU receiver

Complete optoelectronic receiver

Offline DSP emulation in Matlab after ADC using a 50 Gsample/s real time oscilloscope

Experimentation

- After a careful optimization of many system parameters *PoliTO* obtained 32 Gbps downstream at FEC threshold for the required ODN losses



DSP complexity at OLT

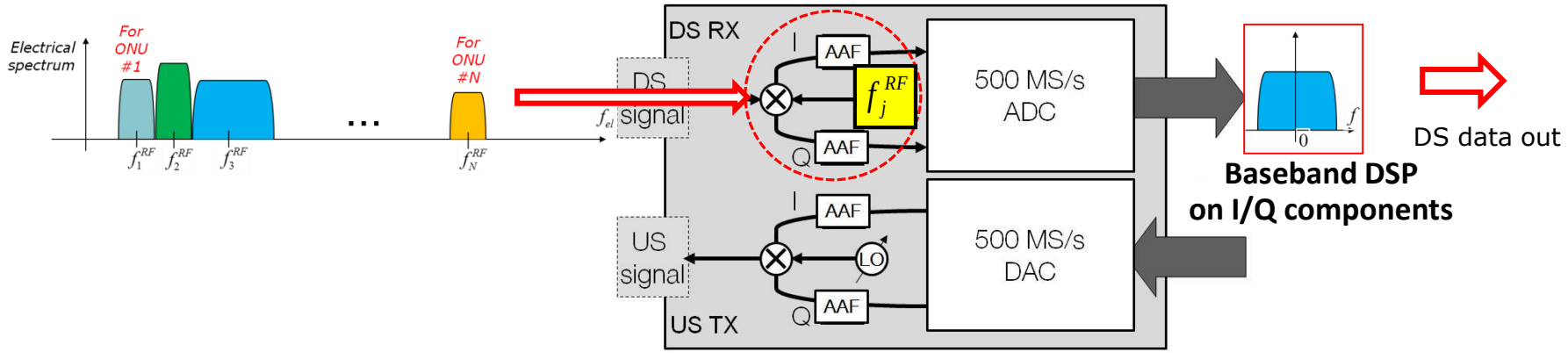
- The DSP required at the central office is for sure significantly more complex than the current NG-PON2 (TWDM-PON)
  - Mostly because it must run at about 20 Gsample/s (and thus also requires extremely fast DAC)

- But the achieved capacity per wavelength is 3 times bigger than NG-PON2

- Moreover, in most optical transmission sectors it is today widely recognized that DSP is required to beat the “10 Gbps per wavelength” barrier

DSP complexity at ONU

- At the ONU RX after photo detection, electrical RF down-conversion is applied so that DSP can be at baseband and only on the spectral slice dedicated to each specific ONU



- The required baseband processing can be done using DAC and ADC working in the 500 Msample/s range
- Low-cost chipsets are already available today to implement this electronic architecture
  - UWB chipsets (for instance from Alereon)

The recipes to achieve ROAD-NGN targets

- **Target #2: simplify wavelength handling for upstream**

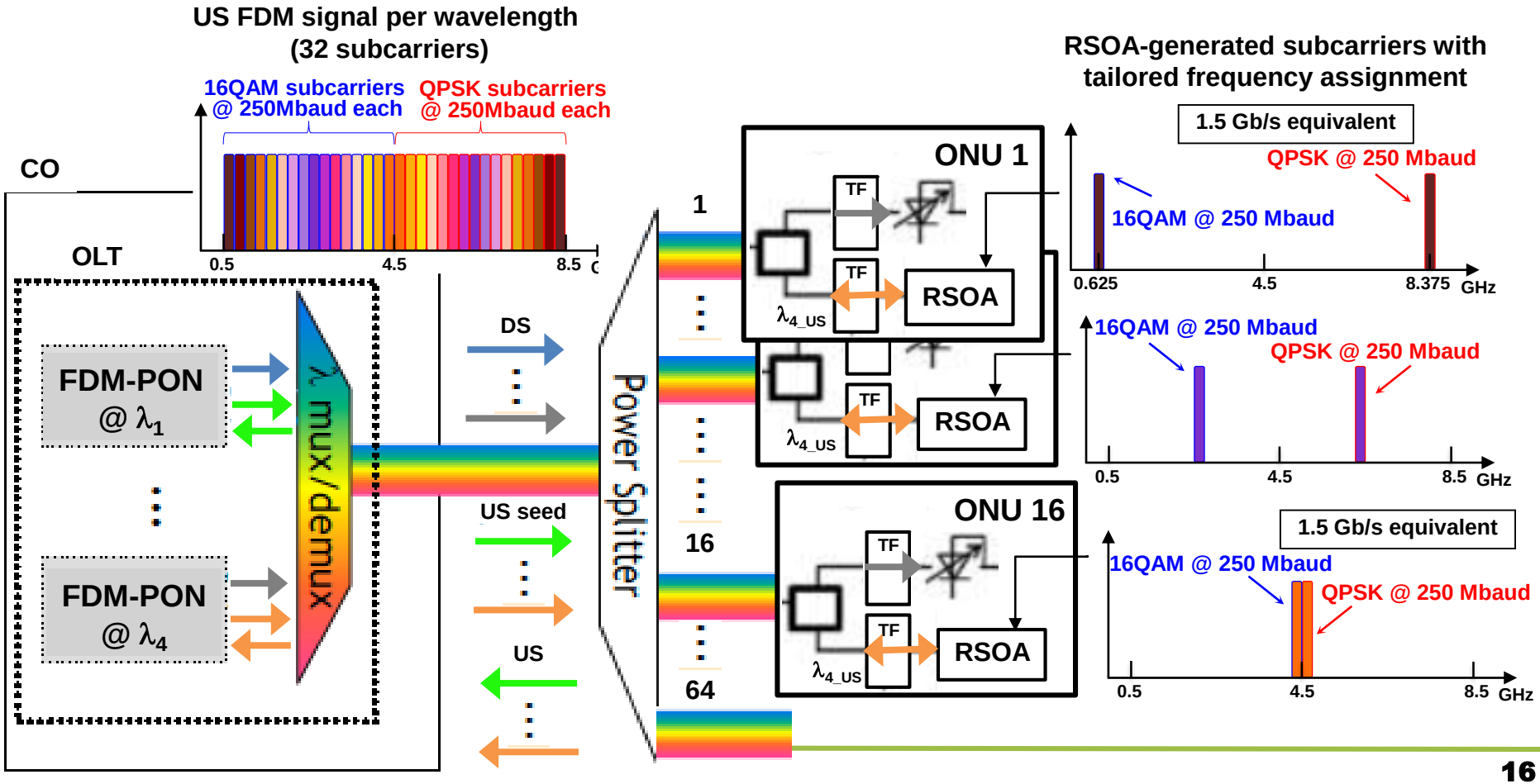
In the ITU-T NG-PON2 standards each ONU should generate its upstream wavelength with very high accuracy (100 GHz grid) by a tunable laser

- This is the key technological obstacle to be solved today
- No tunable lasers exist today with a price compatible with ONU

ROAD-NGN proposes to adopt a **reflective approach** based on **RSOAs fed by a remote seed** coming from the OLT.
Colourless ONU transmitters can be achieved.
PoliMI developed high-performance RSOAs operating in C-band (4-GHz 3dB bandwidth)

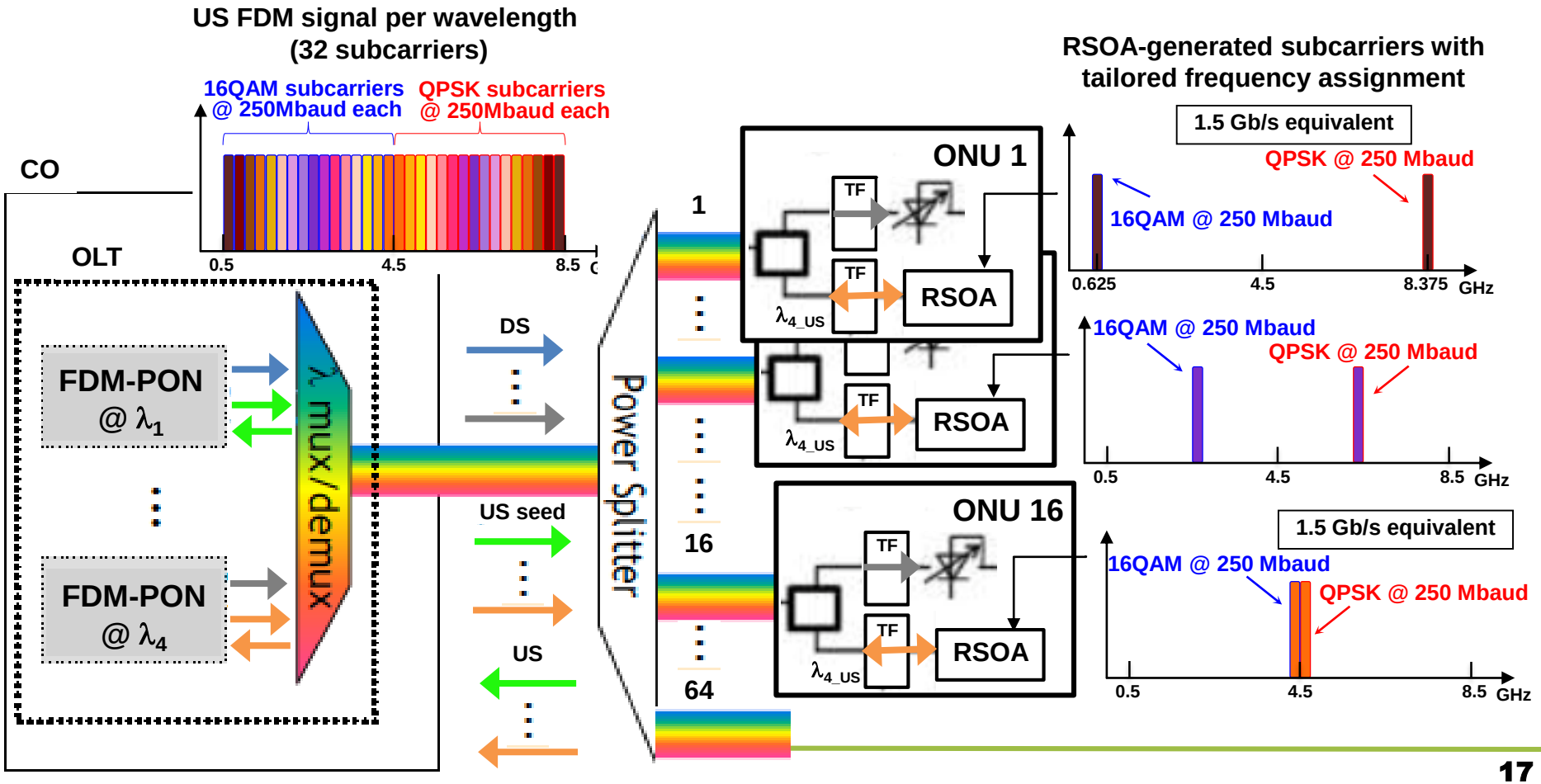
ROAD-NGN proposal: FDMA in upstream

- ROAD-NGN proposes to use **32-subcarrier FDMA** with subcarrier assignmnent and modulation optimized to effectively exploit the limited-bandwidth RSOAs, achieving at least **1.5-Gbps data rate per user**



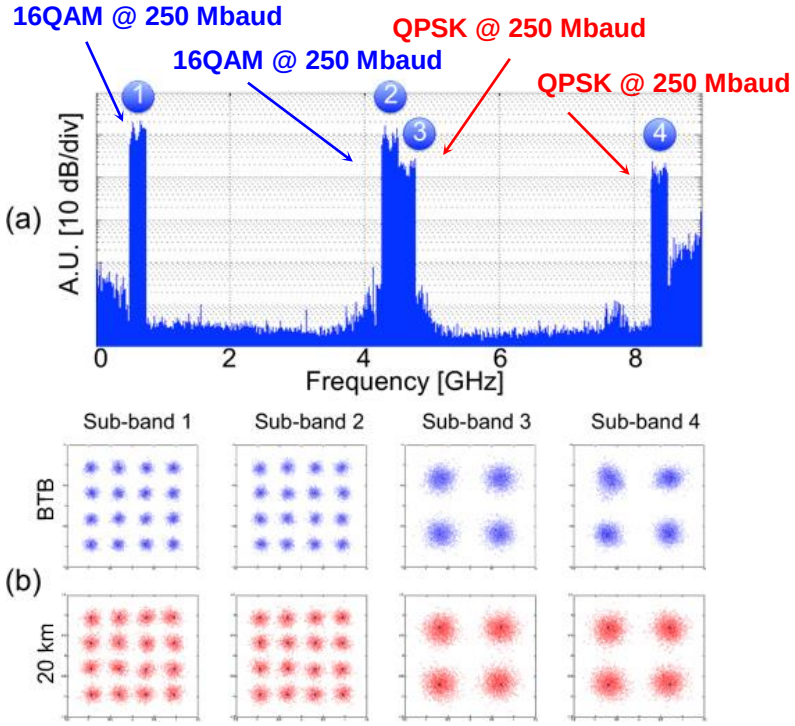
ROAD-NGN proposal: FDMA in upstream

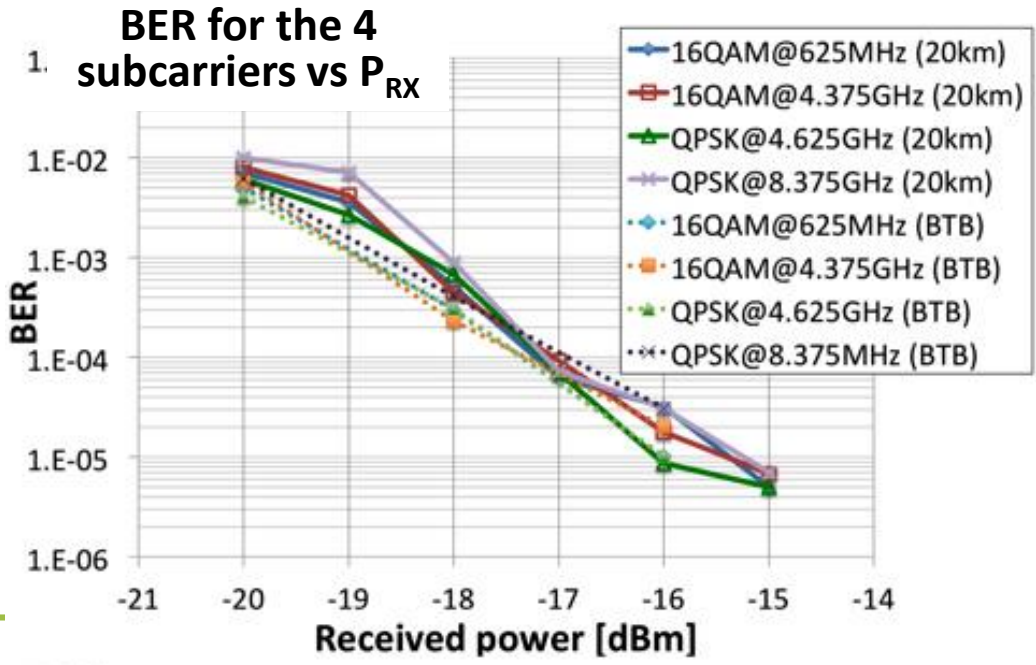
- 32 subcarriers modulated @250Mbaud per λ
- at least 1.5-Gbps US rate per ONU user
- 24 Gbps per wavelength
- 4x24-Gbps total capacity



Experimentation

- *PoliMI* confirmed the operation of the proposed US scheme over 20-km reach and 64 independent ONUs exploiting 4 ONU wavelengths. Proof-of-principle experimentation with two ONUs sharing the same wavelength demonstrated 1.5-Gbps US transmission per user.





Conclusions

- In ROAD-NGN Project we have demonstrated solutions that can be of interest for the next generation of ITU-T PON standards
  - NG-PON3 ?

- Will all this capacity be required in fixed access?
  - A candidate application: using NG-PON3 to support front-hauling in Cloud Radio Access Networks (C-RAN) for 5G mobile networks

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visit http://www.roadngn.uniroma3.it/

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