Systems Solutions for NGA

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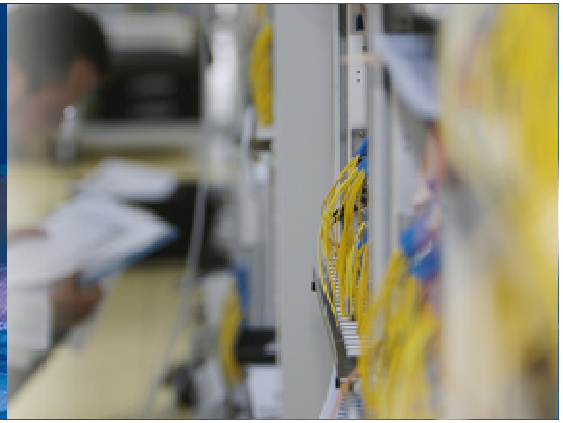
ADVA™ Optical Networking

Agenda



- NGA Requirements and Solutions
- WDM-based NGA

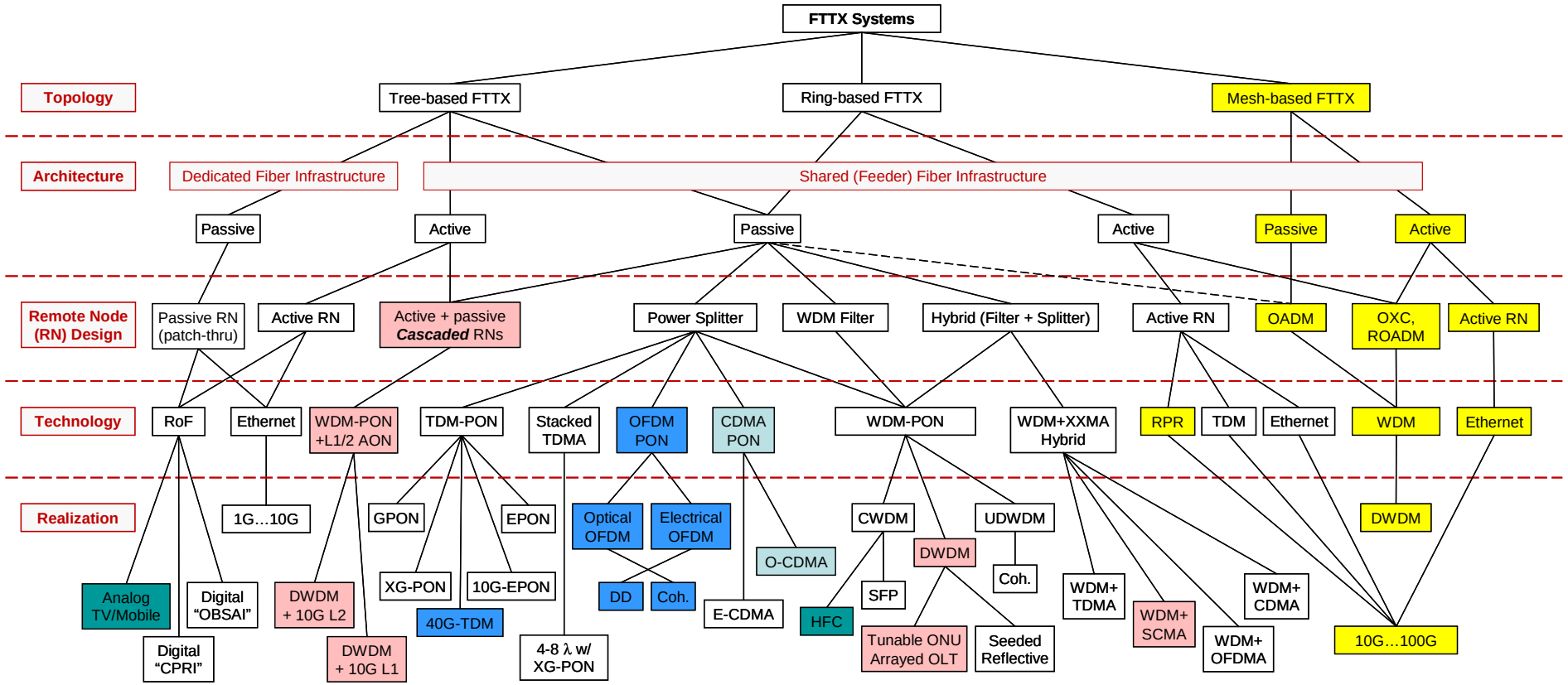
NGA Requirements and Solutions

NGA Requirements

- Maximum reach: 20…***40*** km / 60…***90*** km (without / with RE)
- Client count: ***256…1024***
- Per-residential bit rate: 500 Mb/s ***sustainable***, ≥1 Gb/s peak
- 10G for business customers, backhaul
- Traffic asymmetry better 1:2 (US/DS)
- Legacy ODN support desirable
- NGA must be ***cost-effective*** (TCO vs. CapEx)
- NGA must also be ***energy-efficient***

- For more requirements, refer to **WP2**

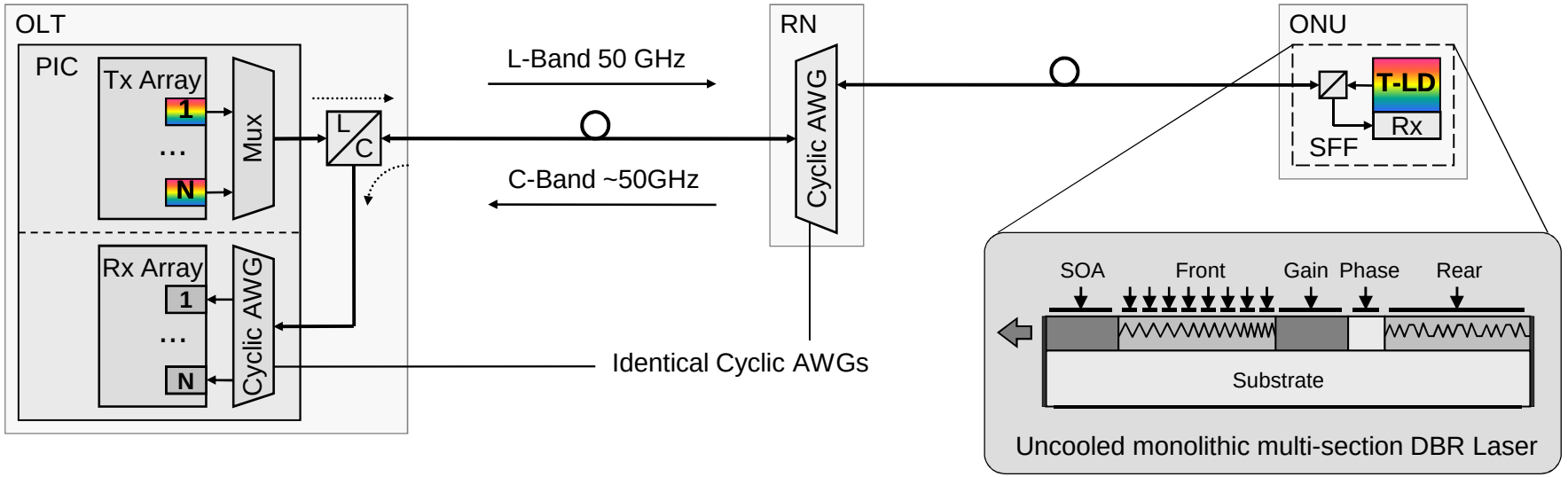
Possible Solutions



- There are many possible, potential solutions for NGA
- Not all of them fit the requirements (perfectly)

WDM-based NGA

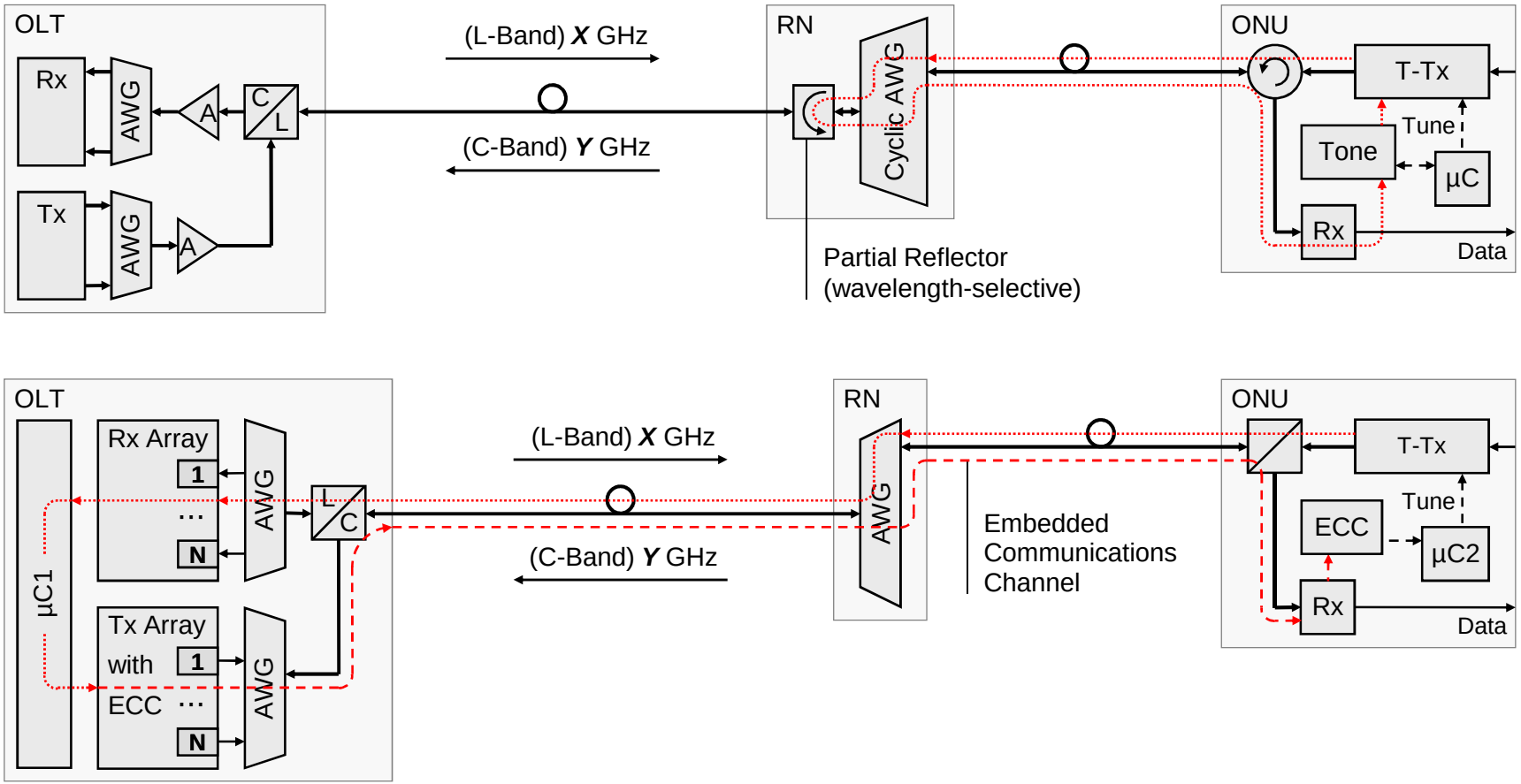
Simple WDM-PON (64…96 Ch)



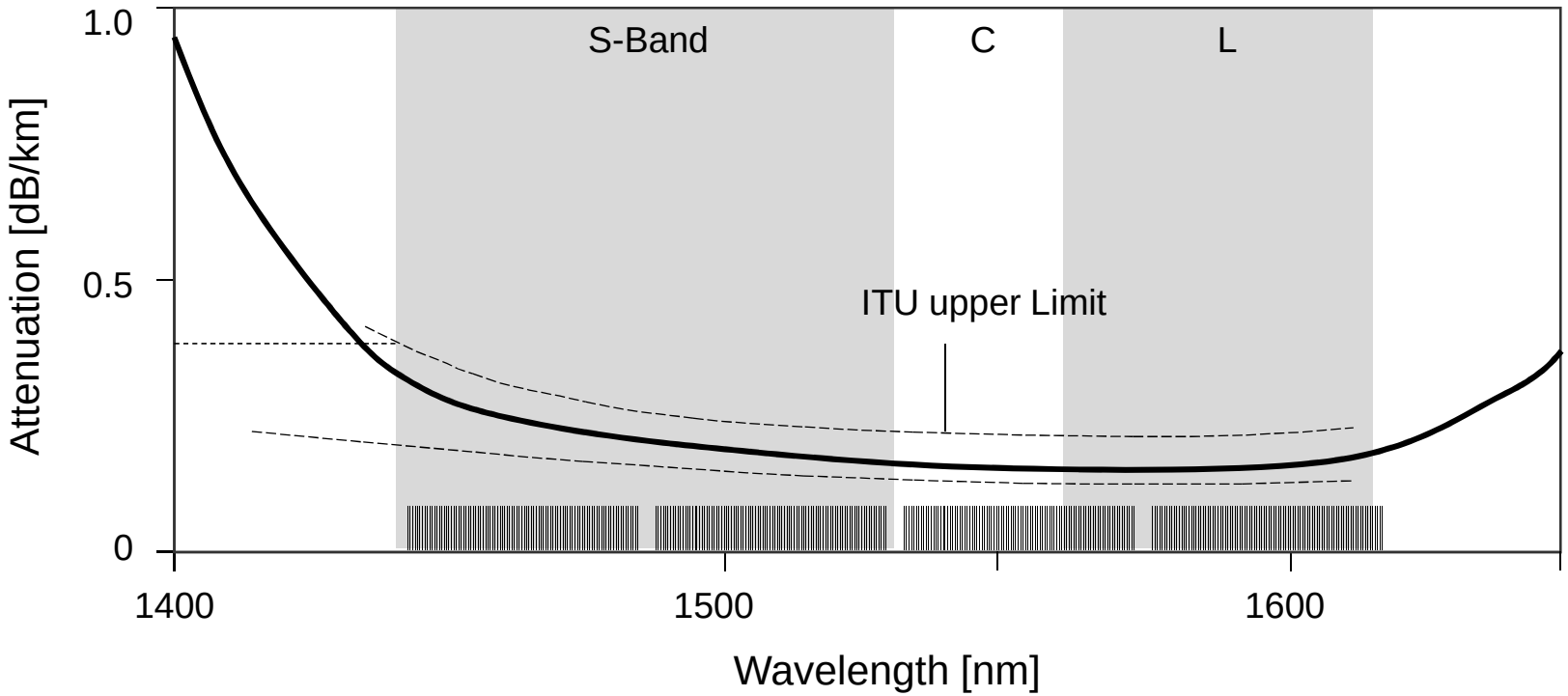
- Lowest cost for **dedicated 1G** per client
- Tunable uncooled 1Gb/s / 27dB lasers – sufficient for 50 km with low-loss AWGs
- Also enables lowest energy consumption

Cost (per client)	***150$ total***	**Energy (per client)**	***2.5 W***
AWG ports	20$	OLT array port	0.5 W
OLT array port	50$	OLT switching	1.0 W
ONU TRX	75$	ONU	1.0 W
OLT switching	5$		

Tuning the ONU Wavelength



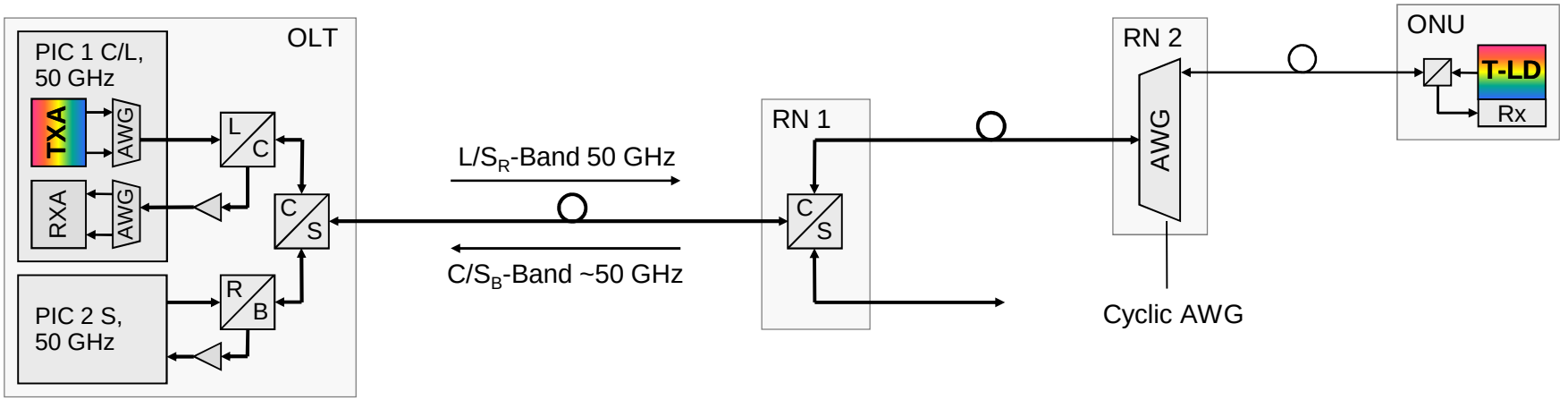
Fiber Attenuation



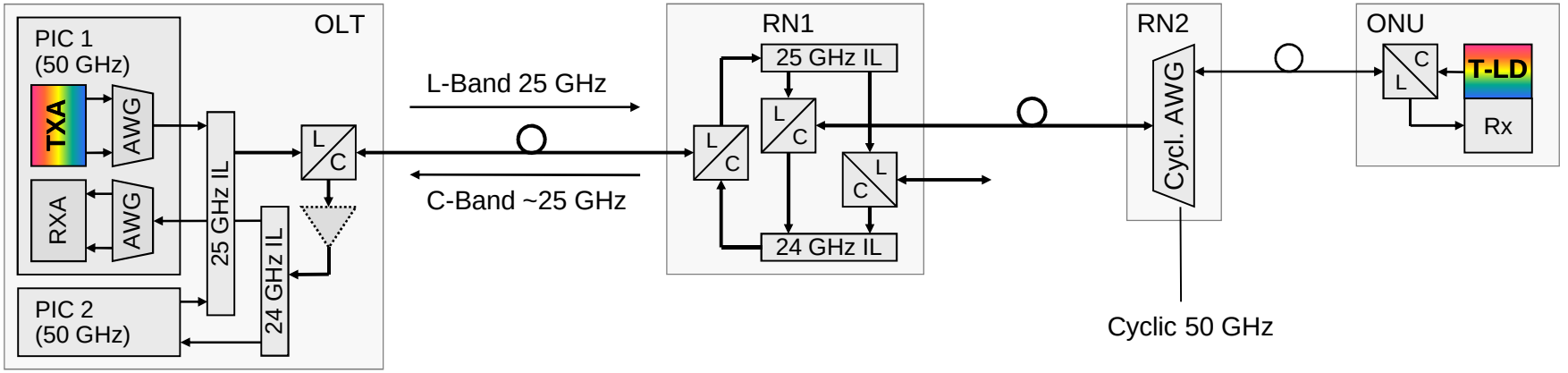
- Cyclic, athermal AWGs provide low loss in (at least) 4 bands à 96 channels
- Extension into S-band for higher capacity, broadcast, or monitoring

Extended WDM-PON (128…384 Ch)

Doubling channel count through S-band addition

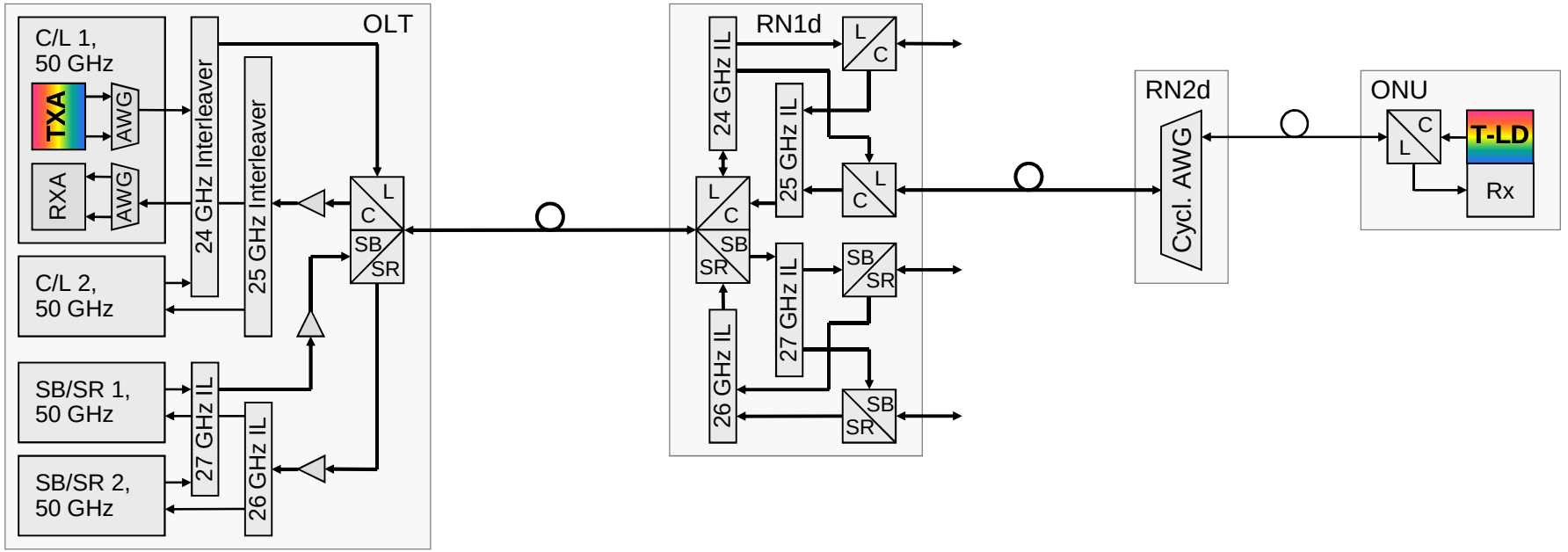


Doubling channel count through interleaving down to 25GHz grid



Combining C+L+S-band and 25GHz leads to up to 384 channels

384 Ch, 25-GHz S/C/L WDM-PON



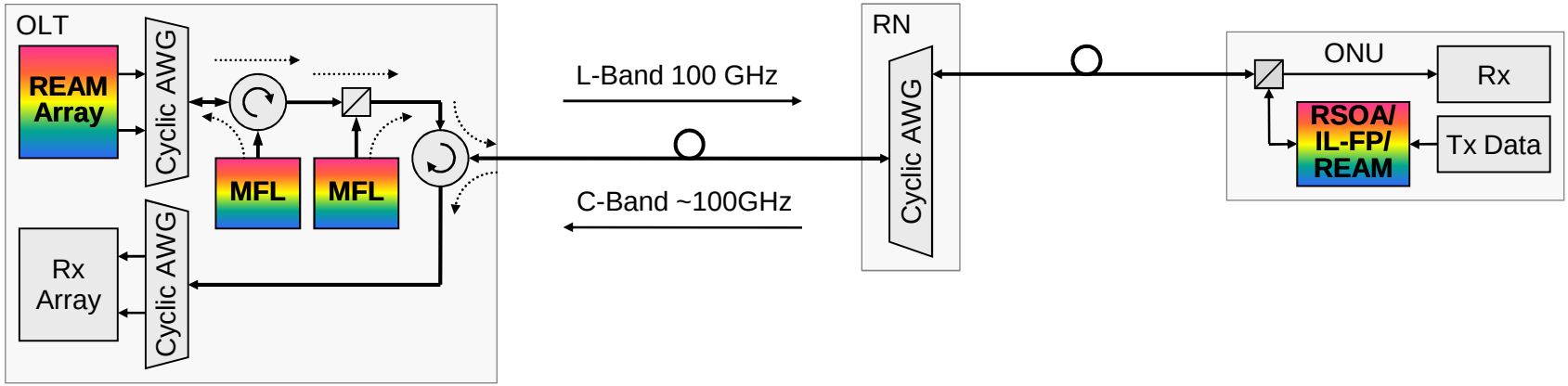
- Up to 384 clients possible with a passive system
- With 27-dB transceivers, ~5 dB (15+ km) remain for fibers
- Higher reach with ONU APD Rx, OLT Rx preamp, OLT APD Rx
- Combinations give 3 power-budget / cost classes

Fiber Power Budget Classes

	80Ch, C/L, 50 GHz	160Ch, S/C/L, 50 GHz	320Ch, S/C/L, 25 GHz
	Fiber Power Budget		
$P_{TX, MIN}$ = +4 dBm, $P_{RX, MIN}$ = -23 dBm	~15 dB	~12 dB	~7 dB
Additional APD or OLT Pre-amplifier	~23 dB	~20 dB	~15 dB
APD plus OLT Booster/Pre-amplifier	~30 dB	~27 dB	~22 dB

- Different power-budget – and cost – classes
- High power budget at high channel count for fully passive ODN possible

Simple WDM-PON (fully reflective)

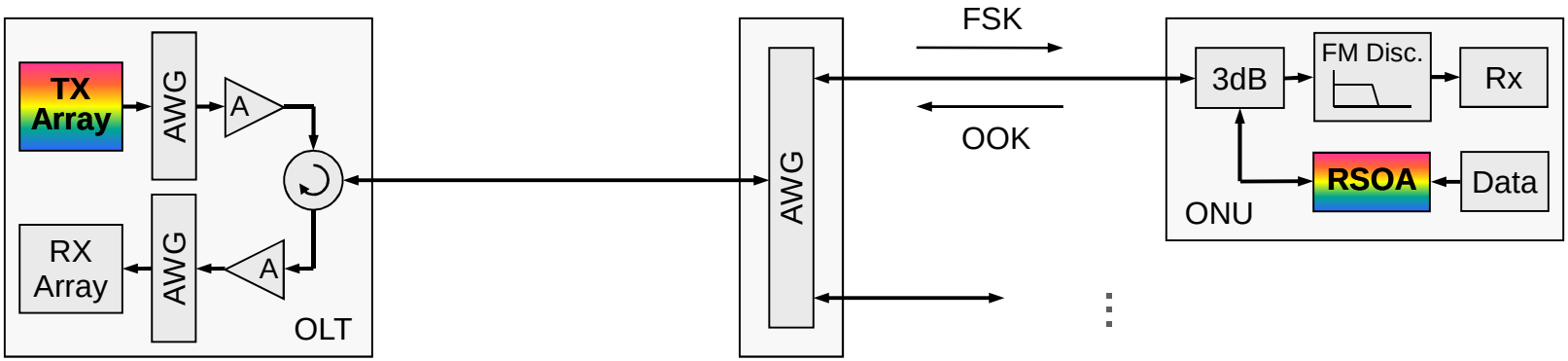


- Almost lowest cost for dedicated 1G per client (transmitters are 10G-ready)
- Sufficient for 50 km with low-loss AWGs – limited by Rayleigh scattering
- This enables both, lowest cost and lowest energy consumption!

Cost (1G Rx!)	***160$ total***	**Energy**	***2.5 W***
AWG ports	20$	OLT array port	0.5 W
OLT array port incl. MFL	60$	OLT switching	1.0 W
ONU TRX incl. MFL, circ.	75$	ONU	1.0 W
OLT switching	5$		

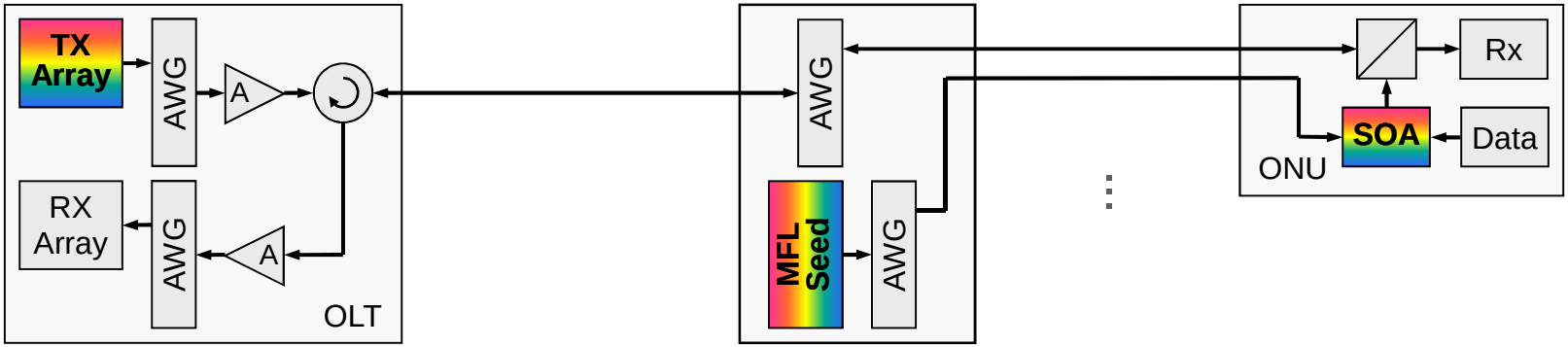
Options for seeded reflective WDM-PONs

The 1-Fiber, seeded PON has issues w/ coherent X-talk of the seed/US



\+ Re-uses seed spectrum for downstream payload

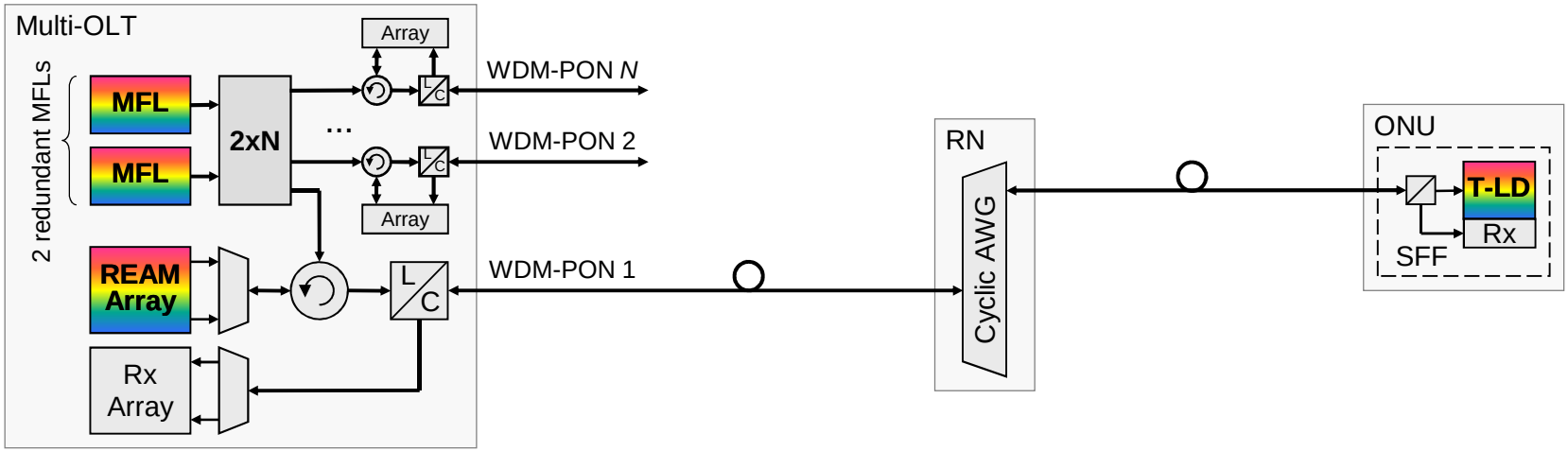
\- Now, there is coherent x-talk between modulated US/DS (payloads) signals



\+ No x-talk, US/DS are separated, e.g., C/L-band split via cyclic AWG

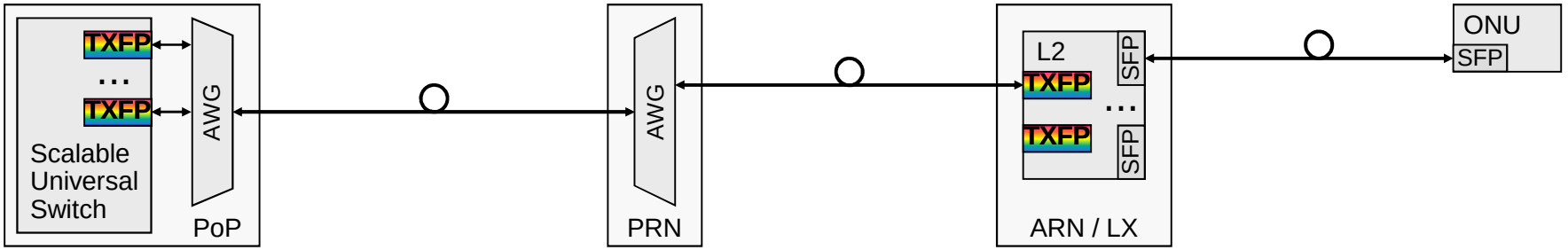
\- 2 fibers!

Sharing the Seed MFL



- The seed MFL can be shared between several OLT-seeded WDM-PONs
- Reduces cost of one of the main components
- Needs to be protected to reduce failure impact

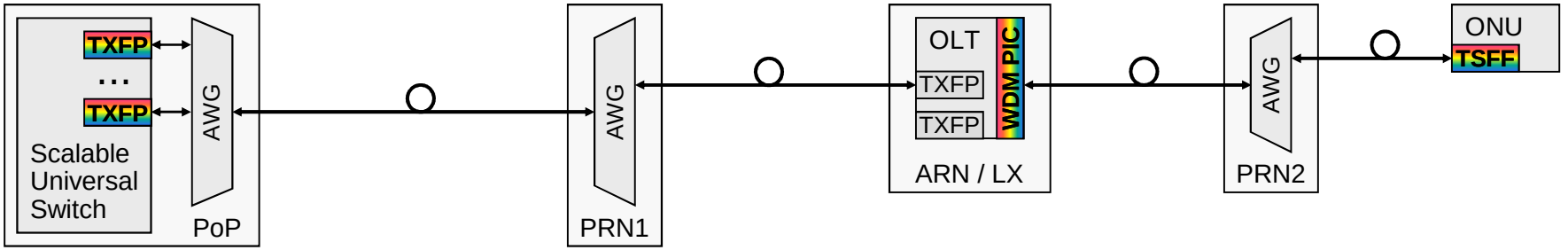
Hybrid WDM-PON/AON



- Lowest cost for high fan-out, but requires active access sites
- Also very low energy consumption for high fan-out
- Easily achieves 50 + 10 km
- Example: 40 x 10G, each carrying 24 clients (960 clients, ~400 Mb/s guaranteed)

Cost (per client)	***147$ total***	**Energy (per client)**	***3.3 W***
AWG ports	2$	PoP switching	1.0 W
10G TRX	100$ (!)	LX switching	1.0 W
Switch (PoP)	5$	LX TRX (2 x TXFP)	0.3 W
Switch (LX)	10$	CPE TRX (2 x grey SFP)	1.0 W
CPE TRX (2 x grey SFP)	30$		

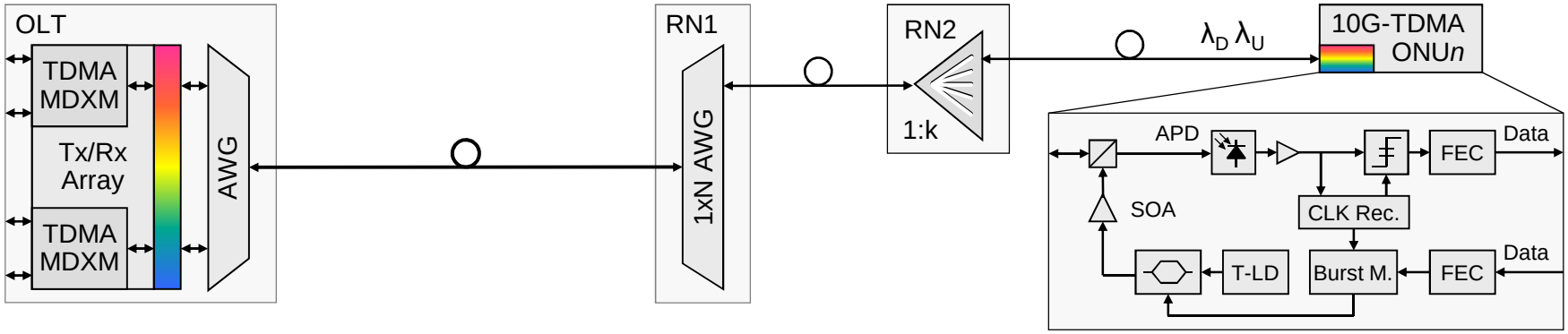
Hybrid active PON-in-PON



- Fairly low cost for high fan-out, but still active sites required (but less fibers than P2P AON)
- Still comparatively low energy consumption
- Easily achieves 50 + 50 km
- Example: 40 x 10G, each pair carrying 40 clients (800 clients, ~500 Mb/s guaranteed)

Cost	***262$ total***	**Energy**	***3.6 W***
AWG ports	12$	PoP switching	1.0 W
10G TRX	120$	LX TRX (2 x TXFP)	0.35 W
Switch (PoP)	5$	OLT Array port	0.5 W
WDM-PON OLT port (LX)	50$	ONU TRX	1.0 W
CPE TRX (2 x grey SFP)	75$	OLT Switching	0.75 W

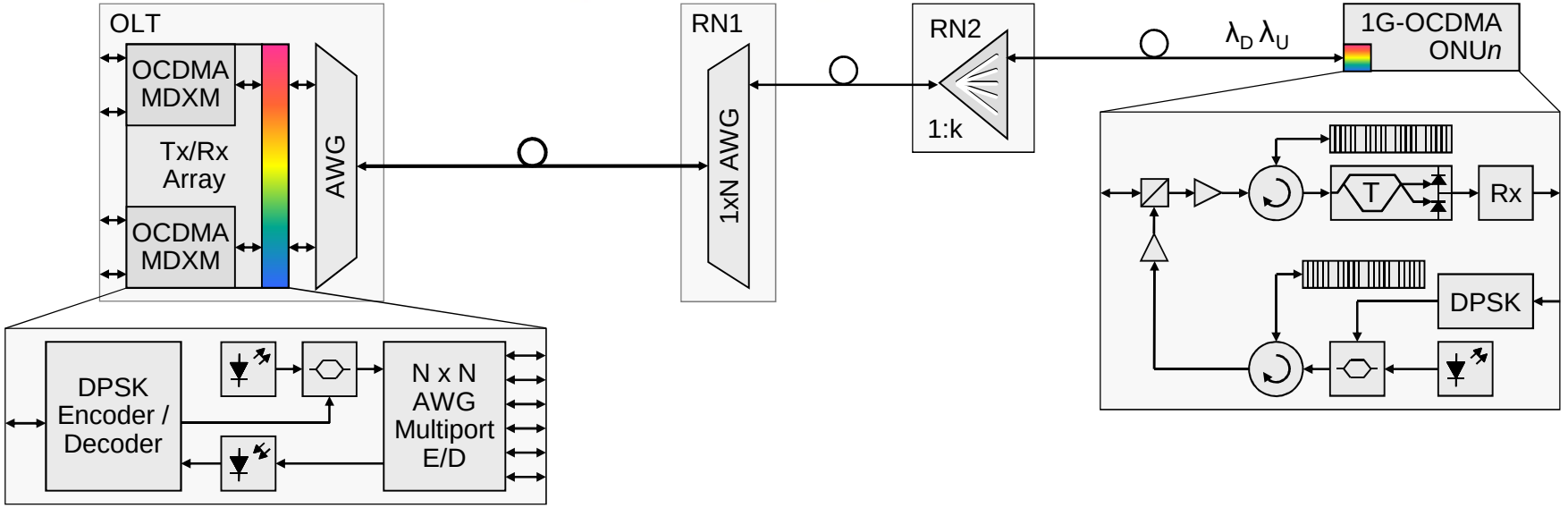
Hybrid WDM/TDMA-PON



- Cheapest passive hybrid PON for high client count
- Requires 10G 35dB burst-mode transceivers for 50 km
- Still comparatively low energy consumption
- Example: 40 wavelengths à 10 Gb/s, passively split 1:16 (640 clients, ~600 Mb/s)

Cost	***217$ total***	**Energy**	***3.8 W***
AWG/splitter ports	12$	OLT port	0.25 W
OLT port	22$	OLT switching	1.0 W
OLT amplifiers	3$	OLT amplifiers	0.05 W
ONU TRX	175$	ONU	2.5 W
OLT switching	5$		

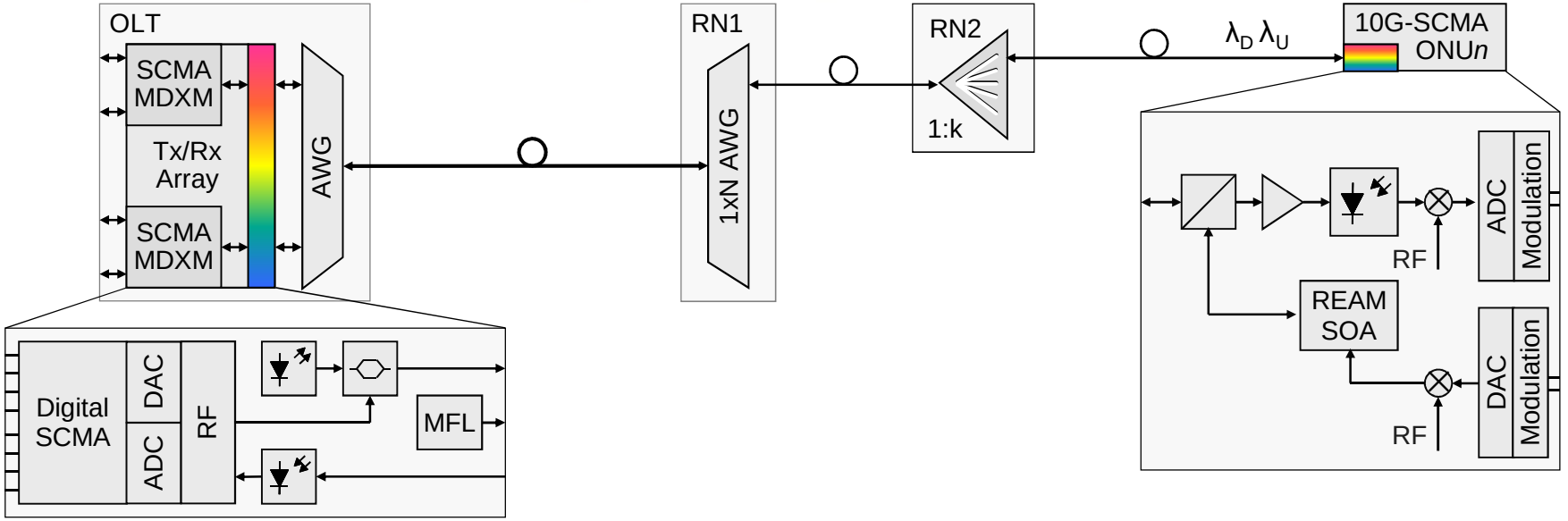
Hybrid WDM/OCDMA-PON



- Low fan-out (up to a max. of 16 OCs per wavelength, few wavelengths)
- Chips are generated with passive optics - leads to very low energy consumption!

Cost	***394$ total***	**Energy**	***2.75 W***
AWG/splitter ports	13$	OLT port	0.55 W
OLT port incl. E/D	***60$***	OLT switching	1.0 W
OLT amplifiers	16$	OLT amplifiers	0.2 W
ONU TRX incl. E/D	***300$*** (Circulators!)	ONU (DPSK)	1.0 W
OLT switching	5$		

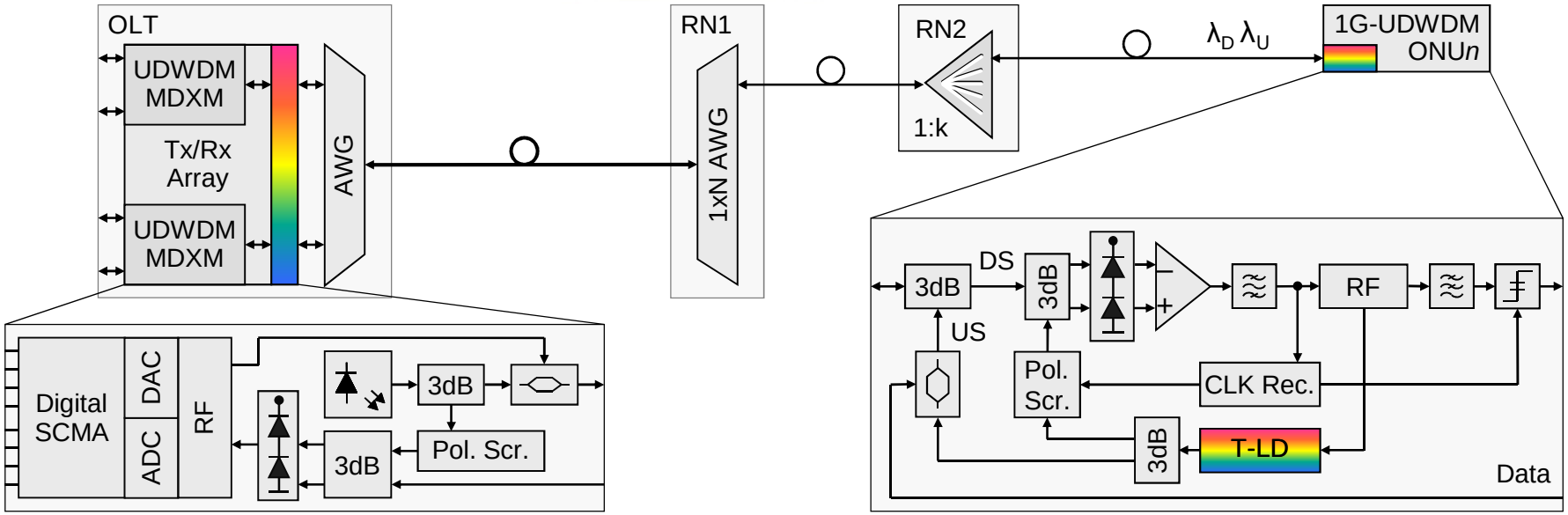
Hybrid WDM/SCMA-PON



- Simpler / cheaper but than OFDMA, UDWDM
- Example: 40 wavelengths à 10 GHz, followed by passive 1:16 split

Cost	***235$ total***	**Energy**	***4.8 W***
AWG/splitter ports	12$	OLT port incl. Digital Tx	0.75 W
OLT port	20$	OLT switching	1.0 W
OLT amplifiers	3$	OLT amplifiers	0.05 W
ONU TRX	175$	ONU	3.0 W
ASICs + switching	25$		

Ultra-Dense WDM



- Medium cost, medium power consumption
- Either very high reach or very high client count
- Example: 40-h/100-GHz AWG, each 100-GHz slot accommodates 16 UDWDM channels

Cost	***312$ total***	**Energy**	***4.5 W***
AWG/splitter ports	12$	OLT port incl. digital Tx	1.5 W
OLT port	100$	OLT switching	1.0 W
ONU TRX	175$	ONU	2.0 W
OLT switching + ASICs	25$		

Conclusions

- Many NGA solutions have been proposed
- WDM has advantages regarding scalability, cost, power consumption
- Simple WDM can be complemented
  - S-band, 25 GHz grid
  - AON, PON-in-PON
  - Hybrid – TDMA, SCMA, CDMA
  - UDWDM (coherent)
- Simple WDM is cheapest for high dedicated bit rates, and has lowest power consumption

Thank you

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PON Analysis - Parameters

ONU housing, OLT shelves, PSUs, controllers etc. are not considered here (cost, power con.) because they are common to all approaches

Component	Energy Con.	Cost
10G base TRX (SFF, coolerless, w/o Locker, 22 dB, not used hereinafter)	1.25 W	100
10G TXFP (TEC, Locker, 25 dB)	3.5 W	***1200***
10G Burst-mode TRX, 35 dB (SFF, APD, SOA, FEC, coolerless, w/o Locker)	2.5 W	175
30GHz TRX (coherent, TEC, Locker, 16 Channels à 1G / 3 GHz)	8 W	1600
30GHz TRX (32 dB, coolerless, w/o Locker, single channel)	2.5 W	175
10G REAM-SOA, incl. Fraction of MFL, 1G 26 dB Rx (!)	1 W	75
10G REAM-SOA, incl. Fraction of MFL, 10G 35 dB Rx (!)	2 W	175
1G coherent ONU TRX, pol.-diverse or w/ Pol. Scrambler	2 W	175
1G tunable ONU TRX	1 W	75
40x1G Laser/Rx Array	20 W	2000
40x1G REAM/Rx Array plus MFL and Circulators	20 W	2400
1G grey SFP, 10 dB	0.5 W	15
ASIC 1G SCMA ONU	1 W	10
ASIC 10G OFDM ONU	4 W	40
ASIC 10G OFDM / SCMA OLT 16Ch	8 W	160
ASIC 50G UDWDMA OLT 16Ch	16 W	320
ASIC CDMA OLT 8Ch	4 W	120
OLT EDFA Booster/Preamp Combo	25 W	2000
Circulator	--	100
AWG Port / Power Splitter/Combiner Port	--	20 / 10
OLT / PoP Switch per 1G	1 W	5
Baseline cost per client (CPE, OLT shelf, motherboards)	***5 W***	***100***