Survey on Solutions for NG-PON2

A joint contribution from EU FP7 “OASE” consortium members in FSAN:
Ericsson and ADVA

FSAN NG-PON2 Workshop, Tokyo, Jan. 25, 2011

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Introduction

- "*The OASE Integrated Project will examine Fibre-to-the-Home (FTTH) within a multi-disciplinary study to provide a self-consistent and coherent set of technological solutions*" *

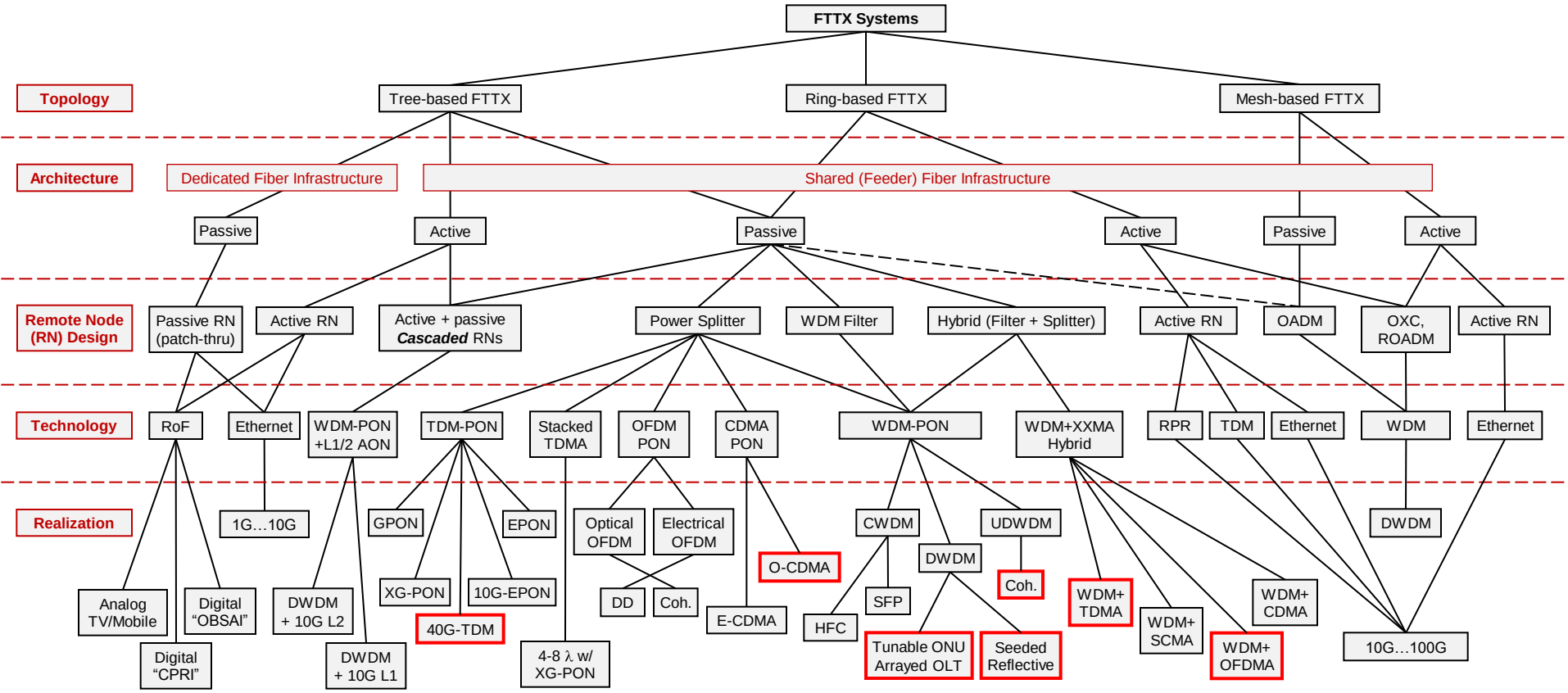
- The basic set of requirements for future FTTH solutions within OASE is the same as the FSAN "NG-PON2 basic requirements – Strawman"

- The material of this contribution comes mainly from Deliverable D4.1
  http://www.ict-oase.eu/public/files/OASE_WP4_D4_1_29th_October_2010_v1_0.pdf
  - This deliverable includes absolute cost numbers
  - In this contribution, cost numbers are normalized by "GPON ONT data only" cost

- In particular, a number of NG-PON related technologies and solutions have been investigated and compared

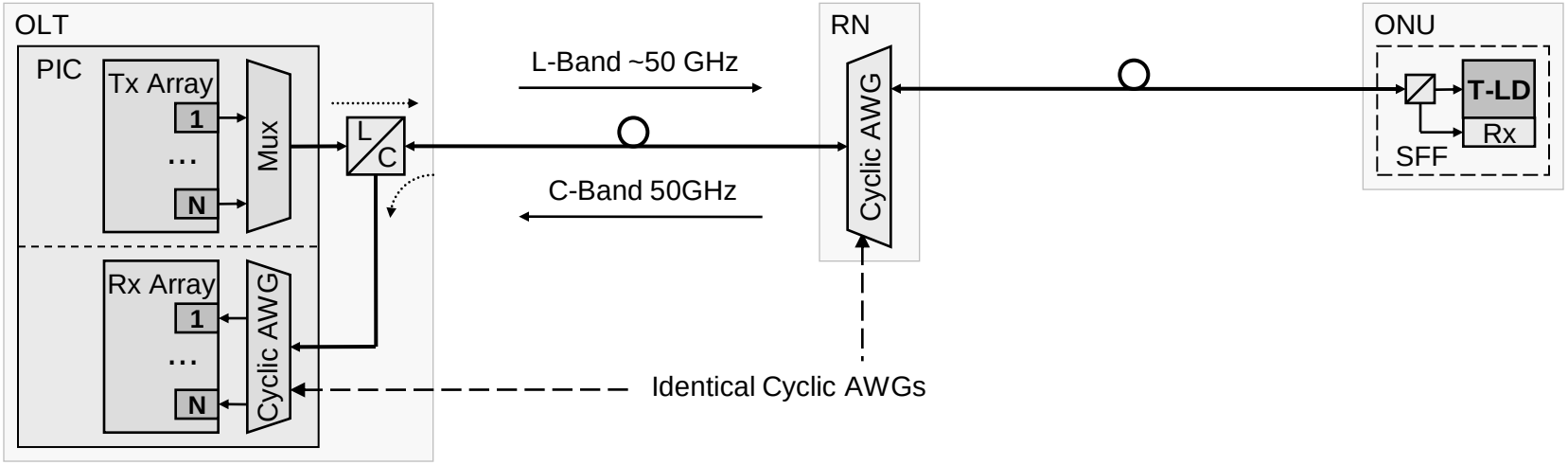
*) For more info, see http://www.ict-oase.eu/%3Cp%3E%3Ca%20href=%22/Eng%22%3Eprojekt.hansanet.ee/Eng%3C/a%3E%3C/p%3E

Possible Solutions



- There are many possible, potential solutions
- Not all of them fit the (Strawman) requirements
- The solutions covered in this contribution is indicated by red frames

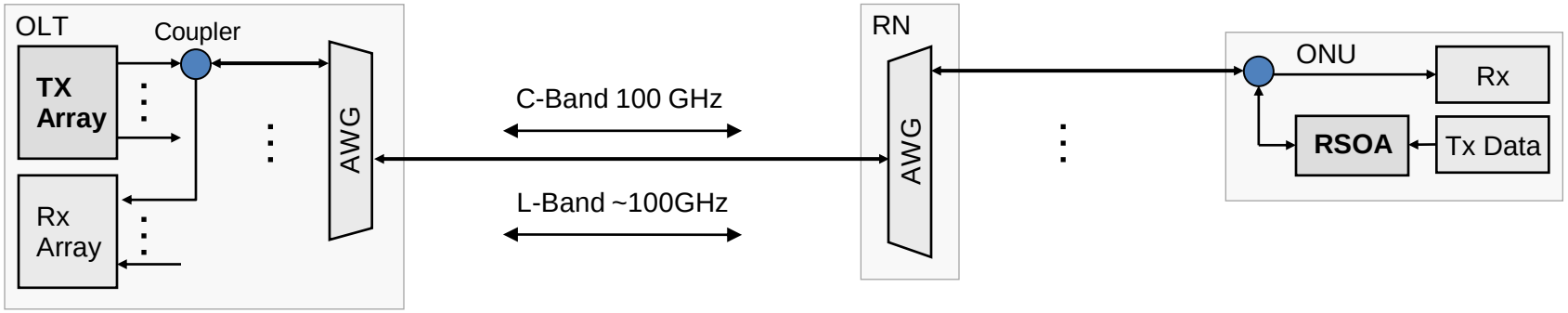
WDM-PON with tunable laser



- Low cost for **dedicated 1G** per line
- Low-medium fan-out, 64…96 / 128…180
- Example: 1:80 AWG, 80 lines
- ODN insertion loss (50 km, 1:80 AWG): 15 dB + OLT AWG (20 dB total)
- Cost drivers: AWG ports, OLT-array port, ONU transceiver

Relative Cost (per line)	***1.5 total***	**Power consumption (per line)**	***2.5 W***
AWG ports	0.2	OLT array port	0.5 W
OLT array port	0.5	OLT switching	1.0 W
ONU TRX	0.75	ONU TRX	1.0 W
OLT switching	0.05		

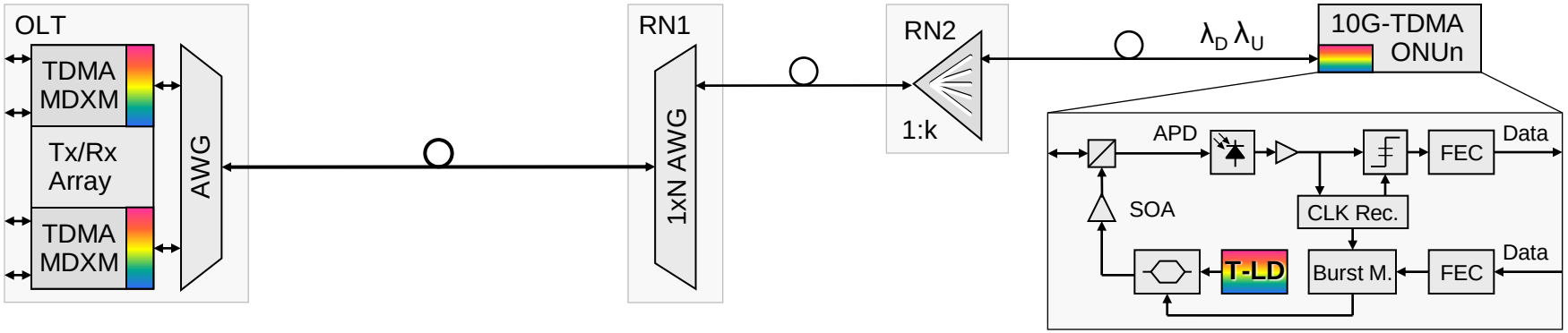
WDM-PON with wavelength re-use



- Lowest cost for **dedicated 1G…10G** per line, Tx 10G-ready (!), 1G Rx (!)
- Low fan-out, 40…96
- 1:48 AWG, per each C- and L-band, up to 96 lines
- ODN insertion loss (50 km, 1:48 AWG): 15 dB + RN AWG (20 dB total)
- Cost drivers: AWG ports, OLT-array port, ONU transceiver

Relative Cost (per line) (1G Rx!)	***1.35 total***	**Power consumption (per line)**	***2.5 W***
AWG ports	0.20	OLT array port	0.5 W
OLT array port incl.	0.50	OLT switching	1.0 W
ONU TRX incl	0.60	ONU TRX	1.0 W
OLT switching	0.05		

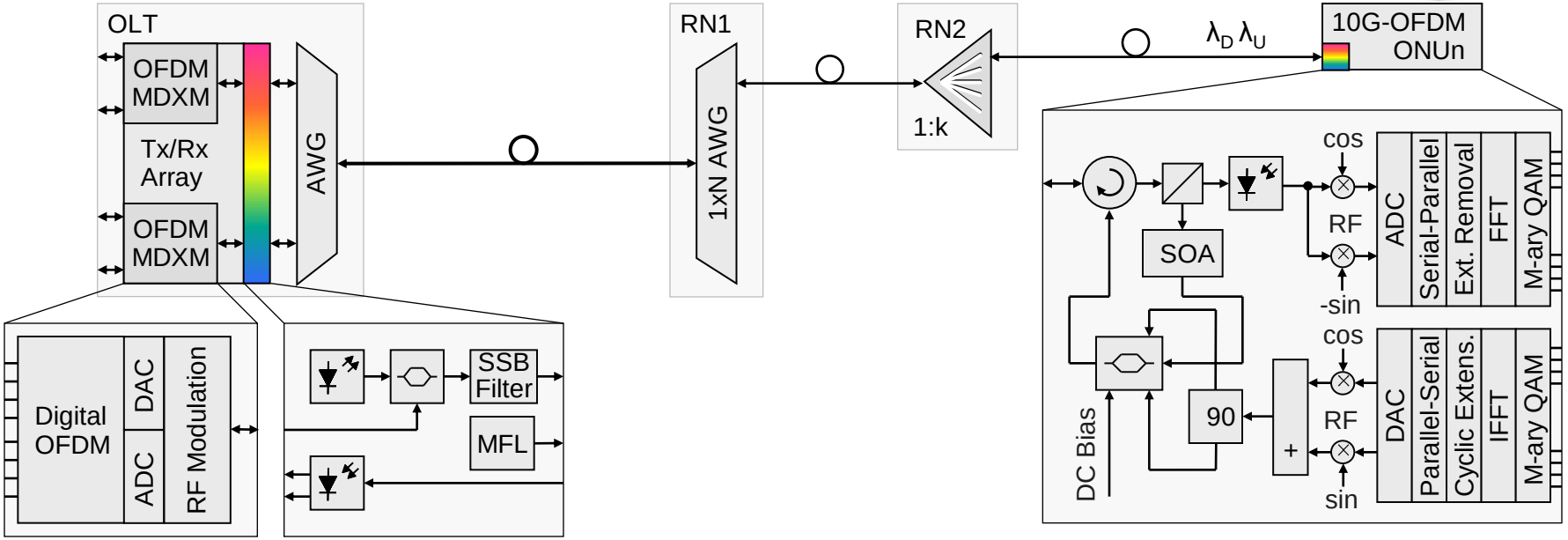
Hybrid WDM/TDMA-PON with lambda split



- 1:40 AWG, 1:16 power splitter/combiner (**640** lines, ~575M guaranteed)
- ODN insertion loss (50 km, 1:40 AWG, 1:16 split): 34 dB + OLT AWG
- Cost drivers: AWG + splitter ports, OLT amplifiers, OLT 10G BM TRX, ONU 10G TRX (APD, BM, FEC)

Relative Cost (per line)	***2.17 total***	**Power consumption (per line)**	***3.8 W***
AWG/splitter ports	0.12	OLT port	0.25 W
OLT port	0.22	OLT switching	1.0 W
OLT amplifiers	0.03	OLT amplifiers	0.05 W
ONU TRX	1.75	ONU	2.5 W
OLT switching	0.05		

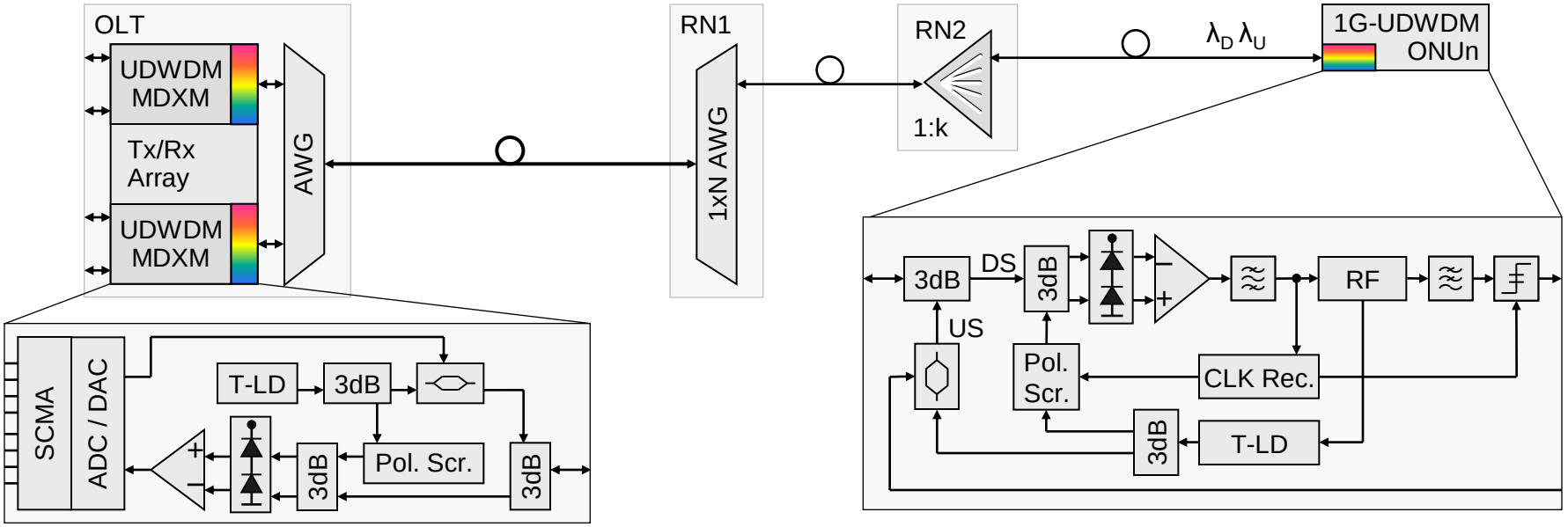
Hybrid WDM/OFDMA-PON



- 1:40 AWG, 1:16 power splitter/combiner (**640** lines, ~600M guaranteed)
- ODN insertion loss (50 km, 1:40 AWG, 1:16 split): 34 dB + OLT AWG
- Cost drivers: OLT amplifiers, ONU amplifiers?, electronics, ONU TRX, OLT TRX (APD), AWG/splitter ports

Relative Cost (per line)	***3.62 total***	**Power consumption (per line)**	***7.8 W***
AWG/splitter ports	0.12	OLT port incl. digital Tx	0.75 W
OLT port	0.22	OLT switching	1.0 W
OLT amplifiers	0.03	OLT amplifiers	0.05 W
ONU TRX	2.75 (Circulator!)	ONU	6.0 W
ASICs + switching	0.55		

Ultra-Dense WDM



- Example: 40Ch/100-GHz filter, each 100-GHz channel accommodating 16 UDWDM channels
- ODN insertion loss (50 km, AWG, 1:16 split): 34 dB + OLT AWG
- Cost drivers: coherent, polarization-diverse (-scrambled) TRX

Relative Cost (per line)	**4.12 total**	**Power consumption (per line)**	**4.5 W**
AWG/splitter ports	0.12	OLT port incl. digital Tx	1.5 W
OLT port incl. SCMA	1.20	OLT switching	1.0 W
ONU TRX	1.75	ONU	2.0 W
OLT switching	0.05		

Comparison Table I

	System concept	Per-Client DS Bit Rate sustained [Gb/s]	Per-Client DS Bit Rate Peak [Gb/s]	Per-Client US Bit Rate sustained [Gb/s]	Per-Client US Bit Rate Peak [Gb/s]	Client Count per Feeder Fiber	Reach w/o RE [km]	Power Budget w/o RE [dB]	RE Technology	Reach w/ RE [km]	Power Budget w/ RE [dB]	Per-Client OLT Power Consumption today [W]	ONU Power Consumption today [W]	Footprint OLT	Maturity	Time to market [Y]
TDMA	40G serial TDM-PON	1.25	40	1.25	40	32	20	27	3R	60	50+	2.5	15	~2 PON Ports per 1HU	First Demo	2
WDMA	WDM-PON w/ tunable Laser	1-10	1-10	1-10	1-10	40-400	15-50	5-17 for Fibre	EDFA Raman SOA TDFA	60-100+	22-34 for Fibre	4	8	25-100% of 9HU	First Demo	3
WDMA	WDM-PON w/ Lambda reuse	1	1	1	1	96	40	12	-	-	-	4	8	25-100% of 9HU	First Demo	2
WDMA	UDWDM	1	1	1	1	512-1024	30-100	-	OA	100+	-	10	12	Half Rack	First Demo	> 4
OFDMA	Serial 40G OFDM-PON	0.63	40	0.63	4+	64	20	-	-	-	-	5	20	25-100% of 9HU	First Demo	>5
CDMA	OCDM-PON	10	10	10	10	513 Theory 12 Demo	59	-	-	-	-	-	-	25-100% of 9HU	Lab	>5

Issue to meet FSAN Strawman requirements

Not compliant with FSAN Strawman requirements

Comparison Table II

System concept		Per-Client DS Bit Rate sustained [Gb/s]	Per-Client DS Bit Rate Peak [Gb/s]	Per-Client US Bit Rate sustained [Gb/s]	Per-Client US Bit Rate Peak [Gb/s]	Client Count per Feeder Fiber	Reach w/o RE [km]	Power Budget w/o RE [dB]	RE Technology	Reach w/ RE [km]	Power Budget w/ RE [dB]	Per-Client OLT Power Consumption today [W]	ONU Power Consumption today [W]	Footprint OLT	Maturity	Time to market [Y]
Hybrid WDM/TDM	Hybrid WDM/TDM broadcast & select	0.31	10	0.31	10	1024	-	31/34/37	EDFA, Raman, SOA	46/36/26	11/14/17	1	10	Half Rack	First Demo	2
	Hybrid WDM/TDM with lambda split	0.31	10	0.31	10	1024	20/10/NA	22/25/28	EDFA, Raman, SOA	80/70/60	2/5/8	1	10	Half Rack	First Demo	3
	Hybrid WDM/TDM with lambda switch	0.31	10	0.31	10	1024	-	32/35/38	EDFA, Raman, SOA	40/30/20	12/15/18	1	10	Half Rack	First Demo	> 3
AON	AON GbE access	1	1	1	1	-	70	-	Higher quality optics	120	-	1	5	32 Ports per HU	Deployed	0
WDM-PON Backhaul	Two-Stage WDM-PON	0.1-1	1	0.1-1	1	1k-10k	100	15+15	EDFA active sites required	150+	25+25	5	8	Main: Half Rack In-Field: 1 Shelf	Can be demonstrated today	3
	WDM-PON AON	0.1-1	1	0.1-1	1	2304-9216	60	15+10	EDFA active sites required	85+	25+10	5	8	Main: Half Rack In-Field: 2HU each	Can be demonstrated today	1

Issue to meet FSAN Strawman requirements Not compliant with FSAN Strawman requirements Requires active sites

Summary and conclusions

- Many of the NG-PON2 candidates meet all Strawman requirements
- Some exceptions found:
  - 40G-PON have issues with split/reach, power consumption and cost
  - UDWDM have issues with power consumption and very high cost
  - Hybrid WDM/TDM PON have issues with sustainable bitrate per PON line.
- From this study, WDM-PON seems the best candidate
  - In comparison, WDM-PON is a more mature technology
  - Low cost per line is possible while achieving 1 Gbps per line
  - Tunable lasers provide higher link budget/reach while wavelength re-use has lower cost
- Two-Stage WDM-PON and WDM-PON/AON not considered herein any further due to their active-site requirement

Back-up slides

A joint contribution from EU FP7 “OASE” consortium members in FSAN:
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FSAN NG-PON2 Workshop, Tokyo, Jan 2011

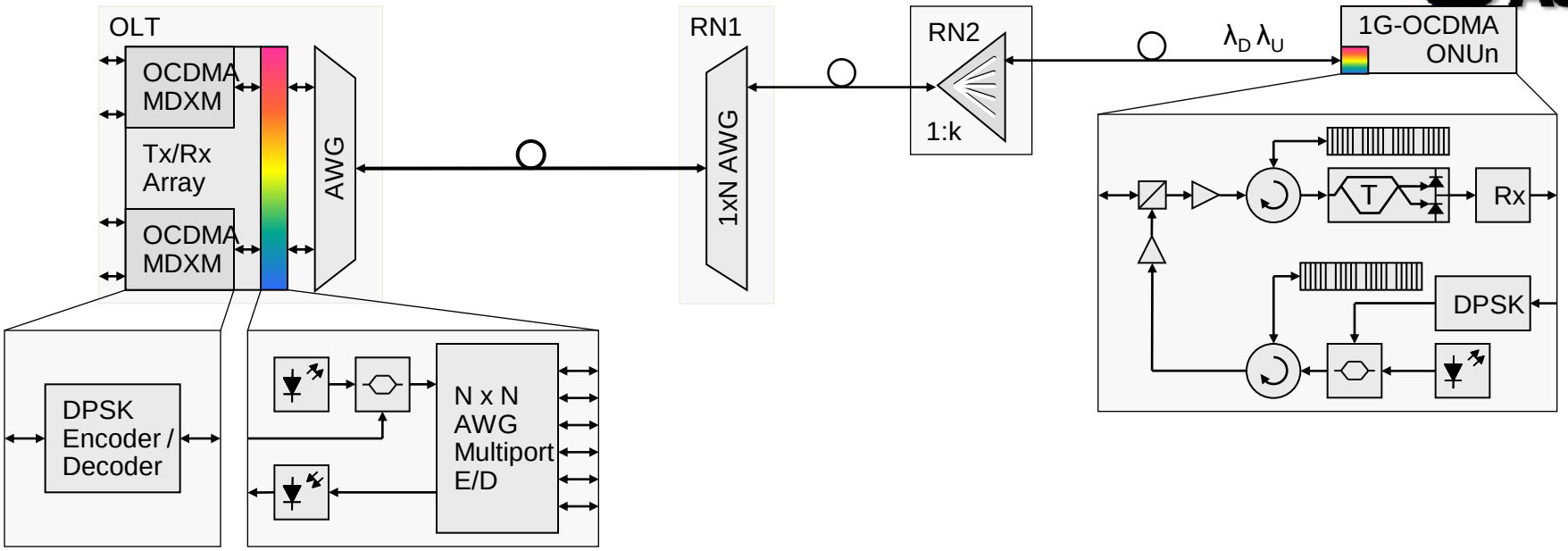
OASE Consortium

- JCP-Consult (F)
- Deutsche Telekom AG (D)
- Interdisciplinary institute for BroadBand Technology vzw (B)
- Technische Universität München (D)
- Kungliga Tekniska Högskolan (S)
- ADVA AG Optical Networking (D)
- Ericsson AB (S)
- Ericsson Telecomunicazioni S.p.A (I)
- Acreo AB (S)
- Magyar Telekom (H)
- Slovak Telekom (SK)
- University of Essex (UK)

NG-PON2 candidates

- 40G Serial TDM-PON
- WDM-PON with tunable laser
- WDM-PON with wavelength re-use
- Serial 40G OFDM-PON
- OCDMA-PON
- Hybrid TDM/WDM Broadcast and select
- Hybrid WDM/TDM with lambda split
- Hybrid WDM/TDM with lambda switch
- Ultra-dense WDM (UDWDM)
- PON-in-PON

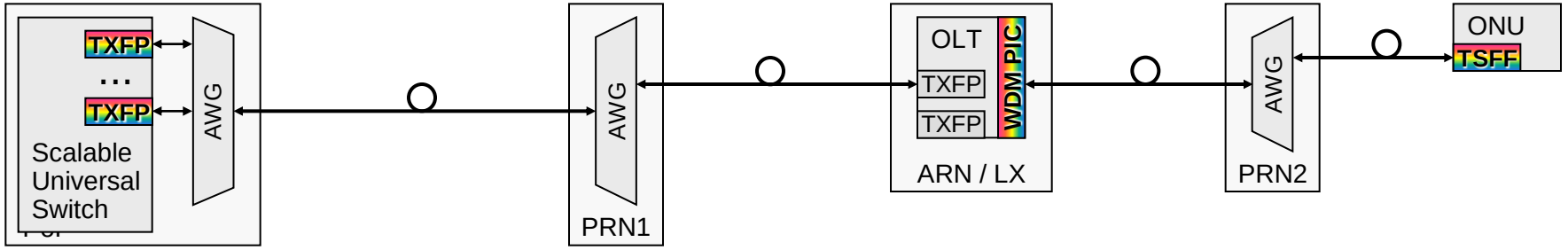
Hybrid WDM/OCDMA-PON



- Low fan-out (up to a max. of 16 OCs per wavelength, few wavelengths)
- 1:8 (TFF) WDM, 1:16 power splitter/combiner (**128** clients, ~600M guaranteed)
- ODN insertion loss (50 km, 1:8 TFF, 1:16 split): 33 dB + OLT filter
- Cost drivers: AWG/splitter ports, OLT amplifiers, OLT TRX incl. E/D, ONU TRX incl. E/D and circulators (!)

Relative Cost (per line)	***3.94 total***	**Power consumption (per line)**	***2.75 W***
AWG/splitter ports	0.13	OLT port	0.55 W
OLT port incl. E/D (N x N AWG!)	***0.60***	OLT switching	1.0 W
OLT amplifiers	0.16	OLT amplifiers	0.2 W
ONU TRX incl. E/D	***3.00*** (Circulators!)	ONU (DPSK)	1.0 W
OLT switching	0.05		

Two-Stage WDM-PON



- Fairly low cost for high fan-out, but active sites required (but less (main) fibers than P2P AON)
- Still comparatively low energy consumption
- Sufficient for 50 + 50 km
- Example: 40 x 10G, each pair carrying 40 lines (~500M guaranteed)

Relative Cost (per line)	***2.62 total***	**Power consumption (per line)**	***3.6 W***
AWG ports	0.12	PoP switching	1.0 W
10G TRX	1.20	LX TRX (2 x TXFP)	0.35 W
Switch (PoP)	0.05	OLT Array port	0.5 W
WDM-PON OLT port (LX)	0.50	ONU TRX	1.0 W
CPE TRX (2 x grey SFP)	0.75	OLT Switching	0.75 W