DiscusO

D3.6

Final Report on Proposals for Standards Activities

Dissemination Level: PU

- **Dissemination level:**

  PU = Public,
  RE = Restricted to a group specified by the consortium (including the Commission Services),
  PP = Restricted to other programme participants (including the Commission Services),
  CO = Confidential, only for members of the consortium (including the Commission Services)

Abstract:

This deliverable reports on the final proposals for standards activities. The DISCUS consortium successfully initiated a discussion within the FSAN group to hold a workshop on "Future Access Networks". The consortium participated and contributed to the FSAN meeting in Atlanta on the 7th of October 2015 at which that workshop was held. The coordinator, Prof. David B. Payne (TCD), presented the DISCUS project and discussed the project results with the FSAN group members. He was supported by the system vendors and operators of the DISCUS project: ALUD, TI, TID and COR. The presented DISCUS slides and a summary of the followed discussion are provided in this deliverable as well as additional standardization activities are outlined with a key emphasis on the optical layer monitoring.

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The DISCUS Consortium consists of:

Participant Number	Participant organization name	Participant org. short name	Country
Coordinator			
1	Trinity College Dublin	TCD	Ireland
Other Beneficiaries			
2	Alcatel-Lucent Deutschland AG	ALUD	Germany
3	Coriant	Coriant	Germany
4	Telefonica Investigacion Y Desarrollo SA	TID	Spain
5	Telecom Italia S.p.A	TI	Italy
6	Aston University	ASTON	United Kingdom
7	Interuniversitair Micro-Electronica Centrum VZW	IMEC	Belgium
8	III V Lab GIE	III-V	France
9	University College Cork, National University of Ireland, Cork	Tyndall & UCC	Ireland
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V1.0	12/01/2016	First version sent to the commissions.

[1] Last row represents the current document version

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1 Introduction

The DISCUS consortium established a close relationship to standard bodies in its project duration. The DISCUS consortium successfully initiated a discussion within the Full service access network (FSAN) group to hold a workshop on “Future Access Networks”. On the 7th of October 2015, the DISCUS consortium participated and contributed at the FSAN meeting in Atlanta.

Additionally, the DISCUS partners participated and contributed to the discussions on the standardization of ITUT G.989.2 and ITUT G.989.3 (NG-PON2) TWDM/WDM-PON. The monitoring aspects of the DISCUS project have been used as part of the discussions in the Broadband forum working text WT-348 “Hybrid Access for Broadband Networks” and TR-287 “PON Optical-Layer Management”.

The key targets of the DISCUS project are a cost-effective architecture for ubiquitous broadband services overcoming the digital-divide. Major building blocks are an optical-centric solution such as extended reach in the passive optical access network and a flat optical core network, in order to reduce the total amount of electronic processing carried out. The utilization of a longer fibre reach from the end user to the DISCUS metro-core node and a larger split in the distribution network enable the LR-PON to serve a much larger number of customers using infrastructures based on traditional access systems. Additionally, the longer optical reach, allows concentrating fibre terminations from many PONs in a smaller number of “DISCUS” metro-core nodes, each covering large areas. Thus, a substantial number of nodes deployed in current telecoms networks, which carry out electronic packet switching and processing, can be consolidated as long reach access systems can by-pass local exchanges and terminate directly on a core node. The required loss budget is provided by optical amplifiers that enable to bridge the larger distances and the higher split. It should be mentioned here that DISCUS is targeting not only a space convergence, but also considers a service convergence which combines wireless, residential and business users. This service convergence demands for different requirements that may restrict the large reach in the DISCUS network down to a moderate fibre length. This approach is not contradicting the overall concept, but rather complementing the DISCUS network view.

The DISCUS node is a core edge node providing the only electronic packet processing interface between PONs and core transmission network. It is placed in a similar architectural position in the network as what are often called metro-core (M/C) nodes in today’s architectures. Each node has an access side, facing the LR-PON and a core side, facing the wavelength-switched optical core. The core is a flat optical network interconnecting DISCUS nodes through a full mesh of wavelength channels. These wavelengths traverse intermediate core nodes without entering the electronic sub-layers. All nodes belonging to the same flat core form a transparent island. Interconnection among transparent islands can be achieved through signal regeneration, or traffic grooming and processing where required.

A software-controlled networking approach is applied separating the data, control and application layer to successfully manage bandwidth allocation for different service needs. A network orchestrator controls core and access network controllers located within the M/C node that can configure optical and electrical switches and core router functions according to the needs.

The main guiding principles of the DISCUS architecture design are as follows:

Propose a highly simplified network architecture, which is composed of a long reach access and a flat optical core, connected by a number of Metro-Core nodes.

Reduce cost and power consumption by consolidating the large amount of network nodes and reducing or eliminating electronic grooming in the core.

Increase the split of the PON to allow sharing infrastructure cost among a larger number of users. The architecture will be flexible enough to allow sharing a PON network between both residential and business users.

Produce a network architecture with a combined wireless edge with ubiquitous optical access and demonstrate the benefits to customers that the combined architecture produces.

Produce a solution that can gracefully grow sustained bandwidth over the installed network infrastructure without service disruption or major infrastructure modification/upgrades. Ensure the solution is able to adopt new technologies as they arise while co-existing with previous generation technologies (i.e., graceful evolution).

Propose the 'Principle of Equivalence' for connections, i.e., that any user connected to the PON fibre can in principle access any type of service, from residential broadband service, to dedicated point-to-point high speed (100 Gbit/s today and higher in the future), independently of its location.

Ensure the solution provides service resiliency mechanisms in case of faults in the physical infrastructure including total metro-node failure (i.e. disaster recovery will be considered as an inherent part of the design).

In chapter 2, the FSAN workshop presentation of the DISCUS project is presented and a general feedback discussion is provided.

In chapter 3, the outstanding areas for further standardization work is summarized.

Chapter 4 concludes the deliverable.

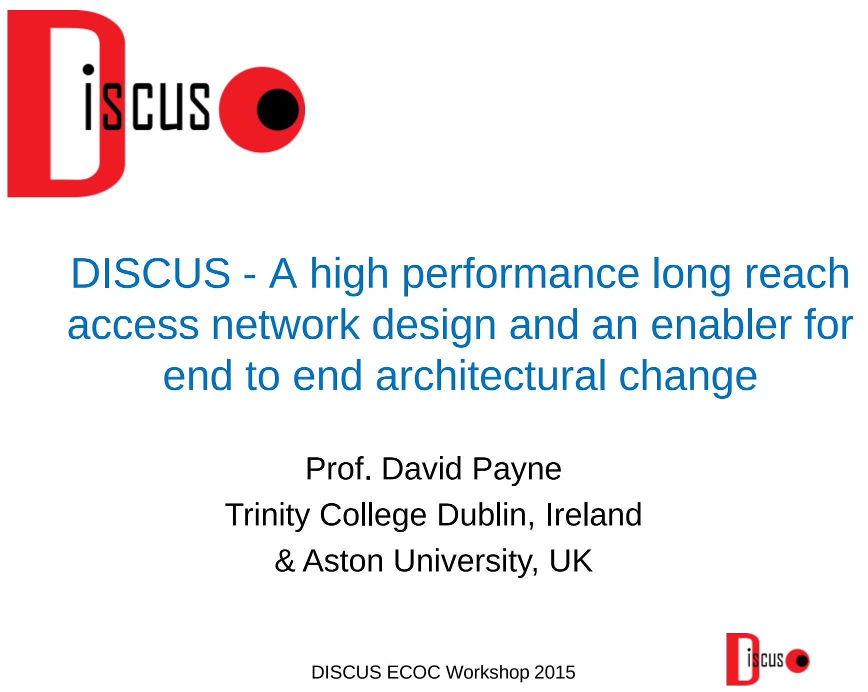
2 Achievements in Standard Activities

2.1 FSAN Workshop Presentation

The DISCUS consortium successfully initiated a discussion within the FSAN group to hold a workshop on “Future Access Networks”. We participated and contributed at the FSAN meeting in Atlanta on the 7th of October 2015. Prof. David B. Payne (TCD) presented the DISCUS project and discussed the project results with the FSAN group members. He was supported by the system vendors and operators of the DISCUS project: ALUD, TI, TID, COR. We received feedback from the FSAN group that is subject for ongoing internal DISCUS discussions.

In this chapter, we will first provide the slide deck that has been shown to the FSAN group and subsequently, we will provide a generalist feedback of the workshop that is limited in its depth, because of the non-disclosure agreement of FSAN.

2.1.1 Slide Deck presented to the FSAN group



The DIStributed Core for unlimited bandwidth supply for all Users and Services

Co-ordinating partner: Trinity College Dublin, Ireland
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Duration 1-11-2012 to 31-10-2015
Funding Scheme: IP
Total Cost: € 11,652,198
EC contribution € 8,112,824
Proposal No. 318137:

- Universities
- Telecoms vendors
- Telecoms components fabrication facilities
- National operators
- National research centres
- SME

DISCUS ECOC Workshop 2015

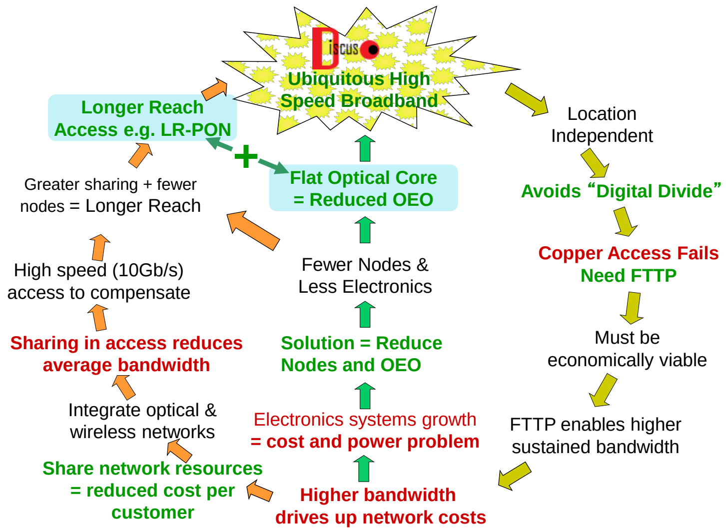
DISCUS - finding solutions to the 3 major problems facing future broadband networks:

Problems:

1. **Financial** - The cost of network provision:
2. **Environmental** -The huge growth in power used by the worlds telecommunications networks.
3. **Social** - The need to avoid a “digital divide”.

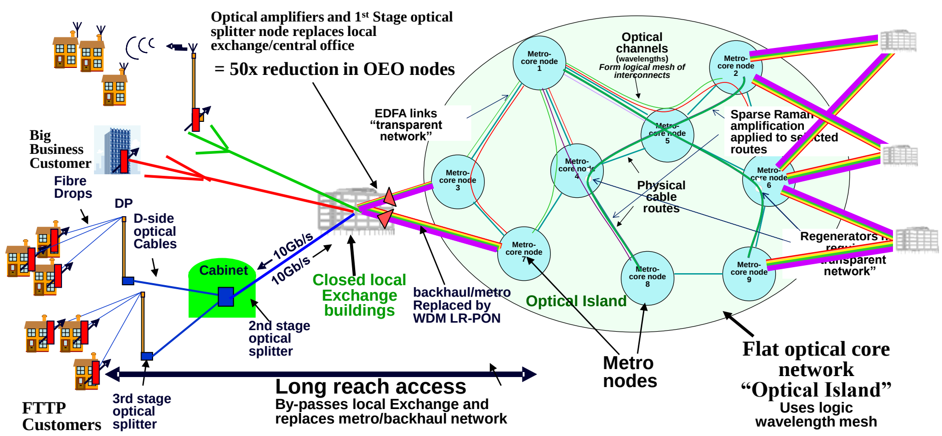
DISCUS ECOC Workshop 2015

How do we choose a solution?



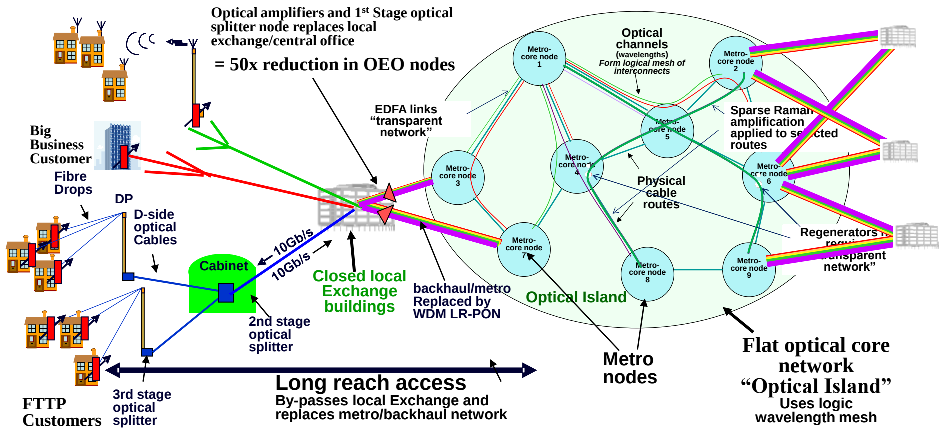
DISCUS ECOC Workshop 2015

The DISCUS end to end architecture



DISCUS ECOC Workshop 2015

The DISCUS end to end architecture



DISCUS ECOC Workshop 2015

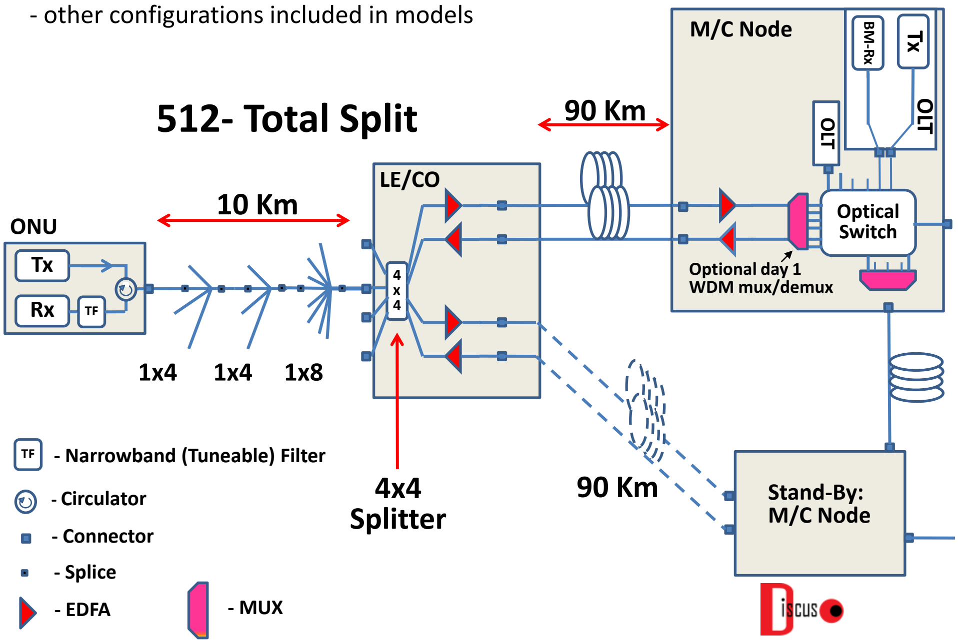
Why LR-PON network solution?

- The three problems: **Economic Viability**, **Power Consumption** and the **Digital Divide** are fundamentally investment problems.
- We face an "**Investment Crunch**" not a "**Capacity Crunch**"!
- Revenue growth not sufficient. Need to reduce network costs and also redistribute CapEx from Core and Metro towards access.
- In DISCUS we have shown that removing hierarchical layers from the network reduces costs and power consumption.
- Hence the DISCUS solution of LR-PON and flat core optical core.
- But a flat core needs fewer nodes than today
- Fewer nodes means Exchange bypass which means much longer reach access – LR-PON
- ~100km reach can produce a ~50x reduction in network nodes

DISCUS ECOC Workshop 2015

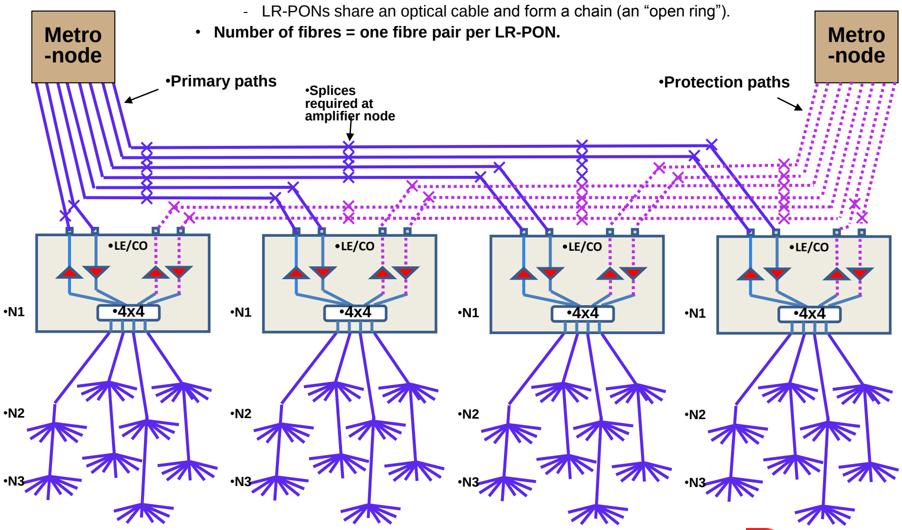
DISCUS general LR-PON design

- other configurations included in models



Cable chain model for connecting LR-PONs to MC nodes

- **Cable chain model for dense areas**
  - One amplifier node for each LR-PON
  - LR-PONs share an optical cable and form a chain (an "open ring").
- **Number of fibres = one fibre pair per LR-PON.**



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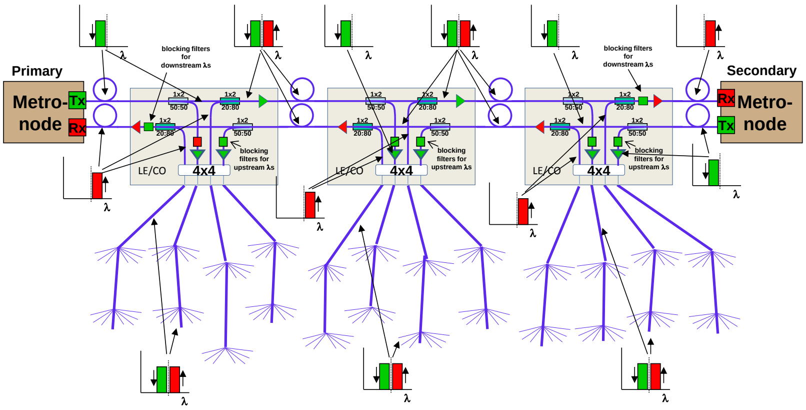
LR-PON Rural amplifier chain model

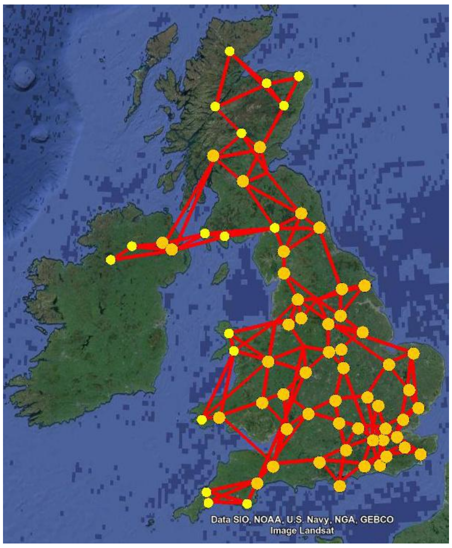
- Distributed amplifier LR-PONs for sparse rural areas.

Chain cable model for rural LE exchanges “Open Ring”

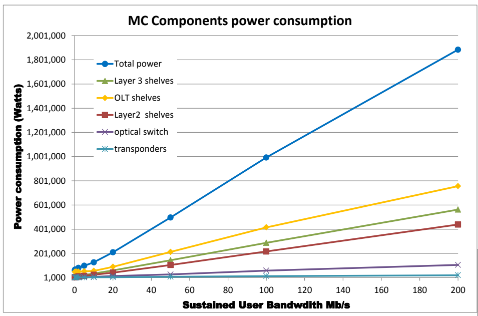


DISCUS ECOC Workshop 2015

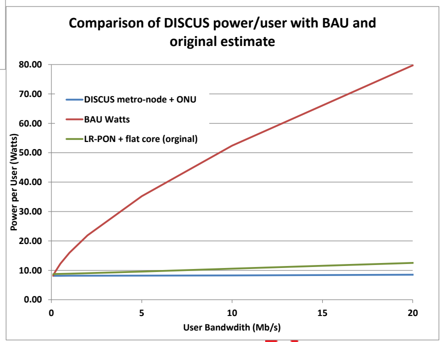
DISCUS architecture applied to UK network
(LR-PON to 73 node Flat Core)



Power Consumption



- OLT shelves largest consumption
- Followed by layer 3 router/switches
- The layer 2 switch
- Optical switch only ~6% of total MC power,
- Transponders small power because of relatively small numbers.



- The new more detailed model shows DISCUS to be lower power consumption than originally estimated.
- Power consumption per user dominated by ONU power.

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Technology Issues Studied

- Dispersion – Burst mode EDC
- Error correction – Burst mode FEC (in parallel project)
- 40Gb/s upgrade downstream (using bit interleaved protocol)
- 100Gb/s DP-QPSK co-existing with 10Gb/s OOK
- Transient suppression in EDFAs
- Use of SOAs for opening other optical windows.
- Resilience options
- DWA solutions for crosstalk and rogue behaviour.

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Dynamic Wavelength Assignment Issues

Complex relationships exist between services, ownership, co-operation, bandwidth assignment protocols & ONU laser tuning precisions

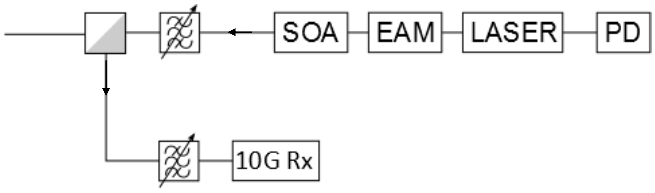
Solutions for DWA must support ONU start-up, normal operation, power levelling and laser tuning:

- in the presence of interferometric & linear crosstalk
- for different potential ONU laser tuning precisions:
  - Poor (uncalibrated):
    - e.g. +/- 100 GHz (into wrong channel)
  - Good (calibrated in manufacture, at 1 power level per λ to reduce cost):
    - e.g. +/- 10-15 GHz (within correct channel)
  - Good (locally λ-referenced):
    - e.g. +/- 5 GHz (well within correct channel)

Potential Solutions Considered

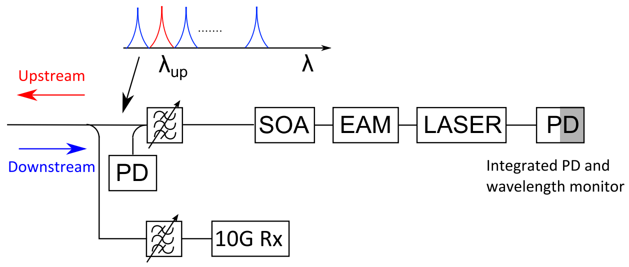
- **synchronised ranging (quiet) windows across all λ channels**
- **λ-isolated network operator channel for start-up at high speed & power**
- **AMCC at low power & low bandwidth to avoid rogue λ behaviour**
  - with & without quiet windows
- **start-up mitigation protocol against interferometric crosstalk**
  - ONUs randomly choose protocol time slot/λ channel in each registration attempt
  - ensures ≤10 ONU bursts collide in same protocol time slot/λ channel, even if all 1023 ONUs attempt start-up simultaneously
  - with adequate outage probability (>10 colliding) for working channels over entire lifetime of all LR-PONs within a country
- **Fall-Back Solution: feedback from OLT, separate US/DS l bands**
  - transfer good λ precision to higher power levels locally via tuneable filter
  - OLT feedback for fine tuning and perhaps fine power levelling
- **Preferred Solution: local ONU λ referencing/calibration, interleaved US/DS λ channels**
  - 100 GHz channel spacing provides ~30 dB adjacent channel Xtalk isolation
  - no λ monitoring equipment at OLT nor protocol/feedback control from OLT required
  - greatly simplifies start-up procedure

Wavelength Referencing for Fall-Back Solution: feedback from OLT, separate US/DS λ bands



- requires accurate λ monitoring at OLT (shared cost between all PON users)
- tracks & corrects slow drift of US laser λ due to temperature & ageing
- coarse laser calibration in manufacture to within correct channel, plus US tuneable filter, eliminates rogue λ behaviour and SMSR issue at start-up
- calibration at only 1 power level per λ to reduce cost
- start-up (registration) attempts undertaken from low power level until ONU discovered
- complicated power levelling requirements at start-up, including additional ON/OFF attenuators not affecting laser wavelength

Wavelength Referencing for Preferred Solution: local ONU λ referencing/calibration, interleaved US/DS λ channels



- DS channels adjacent to US channel act as λ references to tune Tx tuneable filter
- SOA acts as detector for tuning the filter, by interpolating the λ settings
- DS channels also provide absolute references for integrated semiconductor based wavelength monitor
- Tuneable laser self-calibrates using wavelength monitor
- with SOA gain OFF & Tx filter set, laser can be tuned without letting rogue wavelengths
- into network

Start-Up (ONU registration) Results

Poor λ Precision (uncalibrated) e.g.+/- 100 GHz wrong channel	Mitigation protocol spread across multiple λs without quiet windows Separate US/DS bands	AMCC: ~1.6 bit/sec -70 dBm at amp. I/P no Xtalk isolation
Good λ Precision (calibrated at 1 power level per λ) e.g.+/- 10-15 GHz correct channel	Mitigation protocol spread across multiple quiet windows Separate US/DS bands	AMCC: ~25 Mbit/sec -50 dBm at amp. I/P ~12 dB Xtalk isolation (50 GHz ch. spacing)
Good λ Precision (local ONU λ ref.) e.g.+/- 5 GHz correct channel	Mitigation protocol uses a single, normal quiet window per protocol run Interleaved US/DS channels	AMCC not required: registration at full working speed/power ~ 30 dB Xtalk isolation (100 GHz ch. spacing)

- NB Interleaved US/DS λ channels also mitigates non-linear crosstalk between 10Gb/s OOK channels and DP-QPSK 100GB/s channels

Summary

- DISCUS is and end to end solution to tackle the three problems : **Economic Viability**, **Power Consumption** and the **Digital Divide.**
- LR-PON is a key enabler for the architecture change.
- TDMA+DWA provides future proof bandwidth allocation to all users.
- LR-PON protocol channels can co-exist with 100Gb/s DP-QPSK.
- 40Gb/s upgrade using bit-interleaved protocol.
- Technology gaps investigated: burst-mode EDC and burst mode FEC (not in DISCUS) demonstrated.
- SOA amplifier options can open up other optical windows on same LR-PON fibre infrastructure.
- DWA solutions analysed and preferred solution identified.

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Thank you

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2.1.2 General Discussion and Feedback from the Workshop

During the FSAN workshop, together to DISCUS presentation about the project architecture, some technological presentations have been shown and discussed.

The advantage of collecting residential and business traffic via a LR-PON with a radius greater than 100 km, as DISCUS proposes, offers interesting advantages in terms of both cost saving in the access and a dramatic simplification of the core. Said advantages will be enhanced if it would be possible to provide LR-PON. In other terms it would be a very appreciated architecture if it consists of passive components, i.e. without optical amplifier. Technological solutions proposed by COCONUT [1] enable this kind of solution. If fact they propose simplified coherent optical receiver able of more than 40 dB of power budget, that however, are significantly limited in bandwidth and thus may be applicable to lower speed WDM networks (2.5 Gbit/s).

Taking into account 40 dB overall PON power budget, 256 factor splitting implies a 24 dB loss plus 3 dB excess loss. The remaining 13 dB power budget is compatible with a fibre length up to 65 km (assuming fibre losses of 0.2 dB / km in C-band).

Even if this figure does not completely match with DISCUS distance requirements, this technology might represent a promising solution towards a completely passive LR-PON in case the coherent receiver bandwidth limitations are overcome supporting also 10 Gbit/s operation.

3 Outstanding Areas for Further Standardization Work

3.1 Reminder on Involvement of DISCUS Partners in Standardizations

Standards Organizations	Involved DISCUS partner	Type of involvement
FSAN	ALUD TID COR	Monitoring and contributions to NG-PON2, specifically TWDM-PON, and to OE (Operations and Engineering) Task Groups Monitoring NGPON and OE (Operations and Engineering) Task Groups. Participation in FSAN Operators meetings. Monitoring and contributions to NG-PON2 specifically point-to-point WDM
ITU-T SG15 Q2	ALUD COR	Monitoring and contributions to NG-PON2 specifically TWDM-PON Monitoring and contributions to NG-PON2 specifically point-to-point WDM
BBF	ALUD TID	Monitoring and contributing to Fibre Access Network (FAN) Working Group activities, specifically on PON Optical-Layer Management and Fibre Infrastructure Management System (FIMS) (TR-287 [2], TR-311 [3]). Monitoring Fibre Access Network (FAN) Working Group activities
ITU-T SG15 Q12	TI	Monitoring and contributions to the evolution of transport network architecture

DISCUS partners for instance contribute to the FSAN group. FSAN is a forum for the world's leading telecommunications services providers, independent test labs, and equipment and component suppliers to work towards a common goal of truly broadband fibre access networks. In FSAN, PON evolution is being analyzed in two main task groups (TG): Next Generation PON (NGPON) and Operations and Engineering (OE), with involvement of the major operators and vendors worldwide. On the other hand, FSAN studies can be reported as material to Broadband Forum (BBF) and ITU-T standards.

The international leading global organization for information and communication is the International Telecommunication Union (ITU). A standards branch of ITU is the ITU-T. The work in ITU-T is divided in so-called Study Groups (SG). For the DISCUS project the SG 15 “Networks, Technologies and Infrastructures for Transport, Access and Home” is relevant. SG 15 is sub-divided in so-called Questions (Q). DISCUS partners contribute to Q2 “Optical systems for fibre access networks” and to Q12 “Transport network architectures”.

Within the Broadband Forum (BBF) the optical access network related topics are dealt within the Fixed Access Networks group (FAN). Topics under discussion are launched as Study Documents (SD), are then – if of sustained interest - promoted into Working Texts (WT) which after approval acquire the status of Technical Report (TR). ALUD was involved in BBF discussions about WT-287 (PON Optical Layer Management) and was consulting WT-311 by new ideas on future intelligent optical distribution network (ODN) systems architecture and requirements.

As outlined in chapter 2, the DISCUS project successfully participated to the mentioned standard organizations. In the future, the DISCUS partners will use various results obtained by the project to further discuss these options within the various groups. Interesting items that have been addressed in the DISCUS framework and that may become crucial in the near term future in standardization framework are listed:

- Energy-efficient and future-proof metro-access architectures (DISCUS D2.1, D2.3)
- Software-defined (or controlled) access and metro networks (SDN) using network function virtualizations (NFV) (DISCUS D6.1, D6.3, D6.5)
- Converged services and systems over a single infrastructure, i.e. residential, wireless (including low-latency solutions for 5G requirements) and enterprise customer on a single network (DISCUS D4.11, D2.7)
- Intelligent M/C nodes comprising optically and electronically switching and routing mechanisms that are combined with SDN and NFV approaches (D6.1, D6.3, D6.5)
- Low cost ONU laser technology (DISCUS D5.8)
- Higher speed TDM rates using duo-binary modulation formats (DISCUS D5.2, D5.6)
- Silicon technology for e.g. low-cost filter realizations (DISCUS D5.5)

3.2 Optical Layer Monitoring

In task 3.4, DISCUS has proposed and experimentally tested various novel optical layer monitoring techniques for FTTH long-reach PONs. In the following, we explicitly outline possible future standardization work that is proposed related to last drop fibre monitoring.

- DISCUS results: In deliverable D4.13 [4], we have analysed microwave protection and resiliciency for fibre fixed access (section 2.2) and embedded OTDR (eOTDR) monitoring from ONU side (section 4.2). Drawbacks and challenges for ONU side

OTDR monitoring have been analysed. In combination with a radio link, this approach may have a business case and thus its future standardization may be possible.

- Related standards: Broadband forum Working Text WT-348 "Hybrid Access for Broadband Networks" and TR-287 "PON Optical-Layer Management".
- Future standardization work: The use case of eOTDR from ONU with a wireless backup path for monitoring purposes could be proposed within Broadband Forum work area Fibre Access Network (FAN). If the use case is accepted by the work area, DISCUS partners ALUD and TID could support further standardization work.

4 Summary

This deliverable reported on the final proposals for standards activities. The DISCUS consortium successfully initiated a discussion within the FSAN group to hold a workshop on "Future Access Networks". The consortium participated and contributed to the FSAN meeting in Atlanta on the 7th of October 2015 at which that workshop was held. The coordinator, Prof. David B. Payne (TCD), presented the DISCUS project and discussed the project results with the FSAN group members. He was supported by the system vendors and operators of the DISCUS project: ALUD, TI, TID and COR. The presented DISCUS slides and a summary of the followed discussion are provided in this deliverable as well as additional standardization activities are outlined with a key emphasis on the optical layer monitoring.

5 Reference

[1] M. Presi; F. Bottoni; R. Corsini; G. Cossu; E. Ciaramella, "All DFB-based Coherent UDWDM PON with 6.25 GHz Spacing and a > 40 dB Power Budget", IEEE Photonics Technology Letters; no. 26; 107:110 (2014).

[2] PON Optical-Layer Management: Broadband Forum, TR-287, Issue: 1, Issue Date: June 2014.

[3] Fiber Infrastructure Management System: Architecture and Requirements: Broadband Forum, TR-311, Issue 1, Issue Date: February 2015.

[4] DISCUS deliverable 4.13, Resilience in heterogeneous long reach access networks, June 2015.

Abbreviations

BBF	Broadband Forum
DWA	Dynamic Wavlength Allocation
EDC	Electronic Dispersion Compensation
eOTDR	Embedded Optical time domain reflectometry
FAN	Fibre Access Network
FEC	Forward Error Correction
FSAN	Full service access network
ITU	International Telecommunication Union
LR-PON	Long Reach Passive Optical Network
M/C Node	Metro/Core Node
NFV	Network Function Virtualization
NG-PON2	Next Generation of PON 2
ODN	Optical distribution network
OE	Operation and engineering
ONU	Optical network unit
PON	Passive Optical Network
SD	Study document
SDN	Software Defined Network
SG	Study Group
TDM	Time Division Multiplexing
TG	Task Group
TR	Technical Report
TWDM	Time and Wavelength Division Multiplexing
WT	Working Text