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Workshops on DISCUS architecture and supporting technologies

Dissemination Level: PU

- **Dissemination level:**

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  RE = Restricted to a group specified by the consortium (including the Commission Services),
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Abstract:

In this deliverable, the Workshops organized during year 2 of DISCUS are described.

First, the main DISCUS workshop "Network protection and resiliency in Next Generation access and core networks" organized at the major conference Optical Network Design and Modeling 2014, 22nd of May in Stockholm (Sweden) is described. Next, a summary of the contributions and discussions related to DISCUS architecture and supporting technologies on the workshop "Is NG-PON2 an ultimate access solution? Is there anything coming afterwards?" co-organized by DISCUS in ECOC 2014, 21st of September in Cannes (France) are also reported.

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1 Introduction

The aim of the workshops described in this document has been to showcase the outcomes of the DISCUS project. All DISCUS participants were involved and international experts have been invited. During the workshops our findings on the architecture design and supporting technologies have been presented, and there was a discussion on how those may impact and steer standardization and regulatory activities.

During the second year of DISCUS, a major workshop has been organized by DISCUS within the Optical Network Design and Modeling (ONDM) 2014 conference in Stockholm (Sweden), 22nd May 2014, entitled “Network protection and resiliency in Next Generation access and core networks”, the workshop program and a summary of the contributions are described in detail in Section 2.

Additionally, DISCUS has co-organized a workshop in the European Conference on Optical Communications (ECOC) 2014 conference, entitled “Is NG-PON2 an ultimate access solution? Is there anything coming afterwards?”. The main contributions and discussions related to DISCUS access architecture and technologies within this workshop are described in detail in Section 3.

2 ONDM'14 Workshop: "Network protection and resiliency in Next Generation access and core networks"

2.1 Introduction

In optical networks the scale of survivability problems is expanding together with a growing variety of failures types. It is of the outmost importance to withstand and recover from failures ranging from the single network equipment malfunctioning, to natural disasters causing large network segments disruptions, e.g., earthquakes, tsunamis, floods and power outages. Moreover, malicious attacks can span large areas and are becoming a threat to the survivability of optical networks. High data rate per-user and the increasing importance of uninterrupted access to the network services has triggered a growing interest on how and up to which level resiliency should be offered in fibre access networks. Obviously, adding redundant components and systems will improve network reliability. However, network cost is shared by a limited number of users. Therefore, both system deployment cost and network management cost should be minimized.

This half day workshop includes presentations of the DISCUS results, the talks given by the external experts in the field, and panel discussion. The scope of the workshop consists of the following topics:

- Protection techniques in long-reach fibre access networks
- Attack-aware optical network design and modelling
- Resiliency in a converged wired-wireless access scenario
- Management of survivable networks
- Fault management, monitoring and control
- Planning and optimization of reliable networks, systems, and services
- Disaster recovery

2.2 Program

The chair of the workshop was Lena Wosinska (KTH Royal Institute of Technology).

The detailed program was the following:

- 9:00 Introduction to the workshop
    - Marco Ruffini (Trinity College Dublin, Ireland)
- 9:10 Multi-layer Survivability
    - Ori Gerstel (SDN Solutions)
- 9:35 Optimization of the DISCUS LR-PON Access Network - How Many Metro-Core Nodes are Needed?
    - Roland Wessäly (atesio, Germany)
- 9:50 Disaster Preparedness for Network and Information Infrastructures
    - Biswanath Mukherjee (University of California Davis, USA)
- 10:15 Attack-Aware Optical Network Planning
    - Marija Furdek (KTH Royal Institute of Technology, Sweden)

- 10:30-11:00 Coffee break

- 11:00 Impairment Aware Restoration in GMPLS Networks
    - Marco Tacca (University of Texas at Dallas, USA)
- 11:25 Sharing Protection Resources in Fibre Access Networks
    - Marco Ruffini (Trinity College Dublin, Ireland)
- 11:40 Planning and Optimization of Reliable Networks, Systems and Services
    - Marc Ruiz (Universitat Politecnica de Catalunya, Spain)
- 12:05 Efficient Resiliency Schemes for Next Generation Optical Access Networks
    - Jiajia Chen (KTH Royal Institute of Technology, Sweden)
- 12:20 Panel discussion - moderator David Payne (Trinity College Dublin, Ireland)

2.3 Summary

2.3.1 Multi-layer Survivability

Speaker: Ori Gerstel (SDN Solutions).

In this presentation, proactive protection and multilayer restoration were analysed in order to increase network survivability considering multi-layer models.

First, proactive protection consisting on the use of a pre-FEC BER threshold monitored on each IPoDWDM port, so that when this security threshold is reached, L3 protection mechanisms are notified in both link ends before the link is down. This way, the IP/MPLS layer can start the convergence process and reprogram forwarding tables so that the failing link is progressively drained and new traffic uses a new route. An schematic of this flow is shown in the following figure.

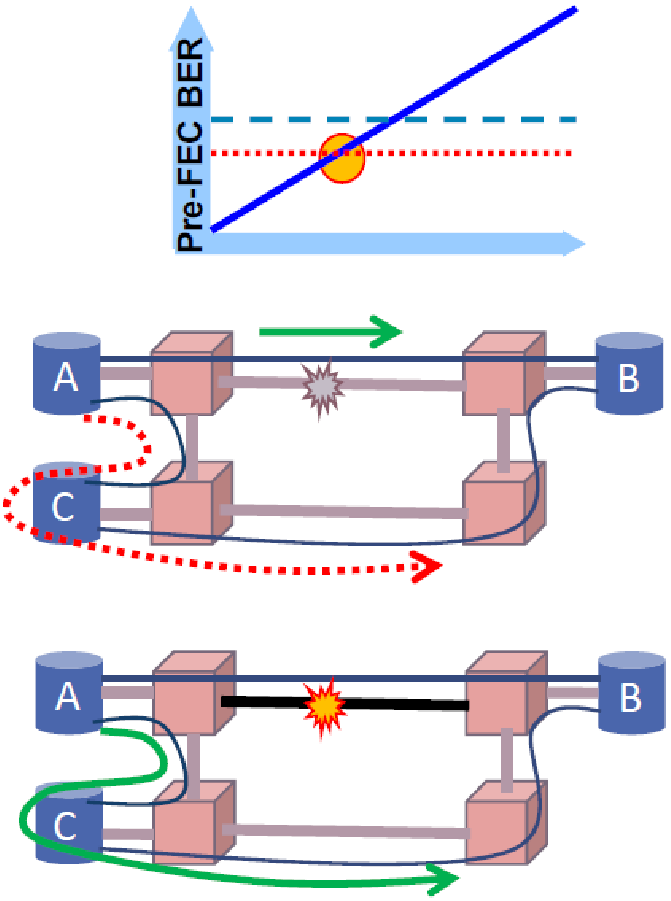

Figure 1 - Proactive protection flow.

Experimental results show relevant improvements using proactive technique in MPLS Fast-Re-Route (FRR) protection, reducing in two orders of magnitude the time of packet loss.

With regards to multi-layer restoration, the reuse of expensive resources instead of relying on extra spare resources in case of failures is recommended as a general principle for cost-efficiency.

An interaction between Layer 3 and Layer 0 (optics) is proposed in order to reduce the cost of the network survivability. It is proposed that routers own L3 induced constraints when setting up traffic paths, and negotiate alternative paths with L0 upon failure. Due to the slowness of photonic restoration, failed connections may not recover immediately. This implies that the IP layer must carry the load until restoration is complete. However for sake of cost savings, there will be insufficient capacity in the IP layer to support all peak traffic. L3 QoS can be relied upon to ensure that premium traffic will always go through, while only best - effort traffic will experience temporary congestion. This process is shown in the following figure.

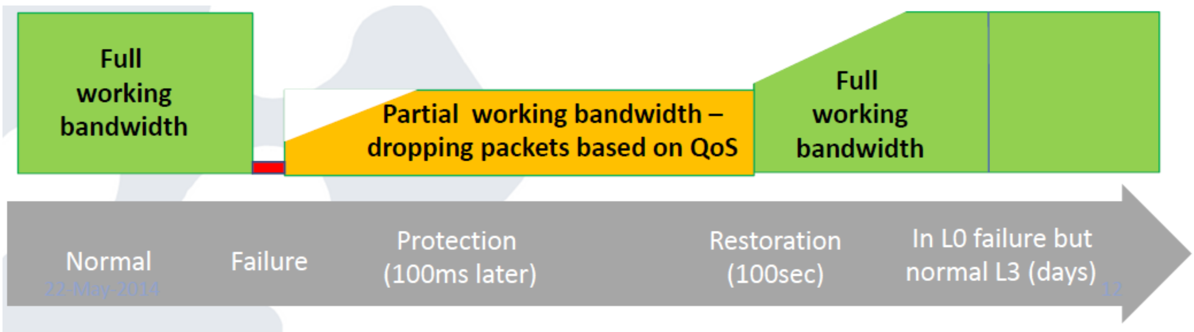

Figure 2 -Transient traffic impact during restoration.

Estimations show that multi-layer restoration savings can reach more than 50% of baseline cost in Deutsche Telecom and Telefonica networks in 5 years [1].

2.3.2 Optimization of the DISCUS LR-PON Access Network - How Many Metro-Core Nodes are Needed?

Speaker: Marco Ruffini, standing for Roland Wessäly (atesio, Germany).

In this presentation, the DISCUS objectives and generic architecture were presented, and an analysis of the number of converged metro-core nodes achieved using Long-Reach PONs was presented to the audience.

DISCUS aims to produce an end-to-end architecture economically scalable and evolvable from todays network when sustained customer bandwidth grows by 1000 during next decade, supporting the “principle of equivalence” so that all access points have equal potential bandwidth to access edge [2].

In order to achieve the former objectives, it is critical to reduce the electronic processing due to the high number of optoelectronic conversions, switching steps and port numbers in current network architectures.

DISCUS

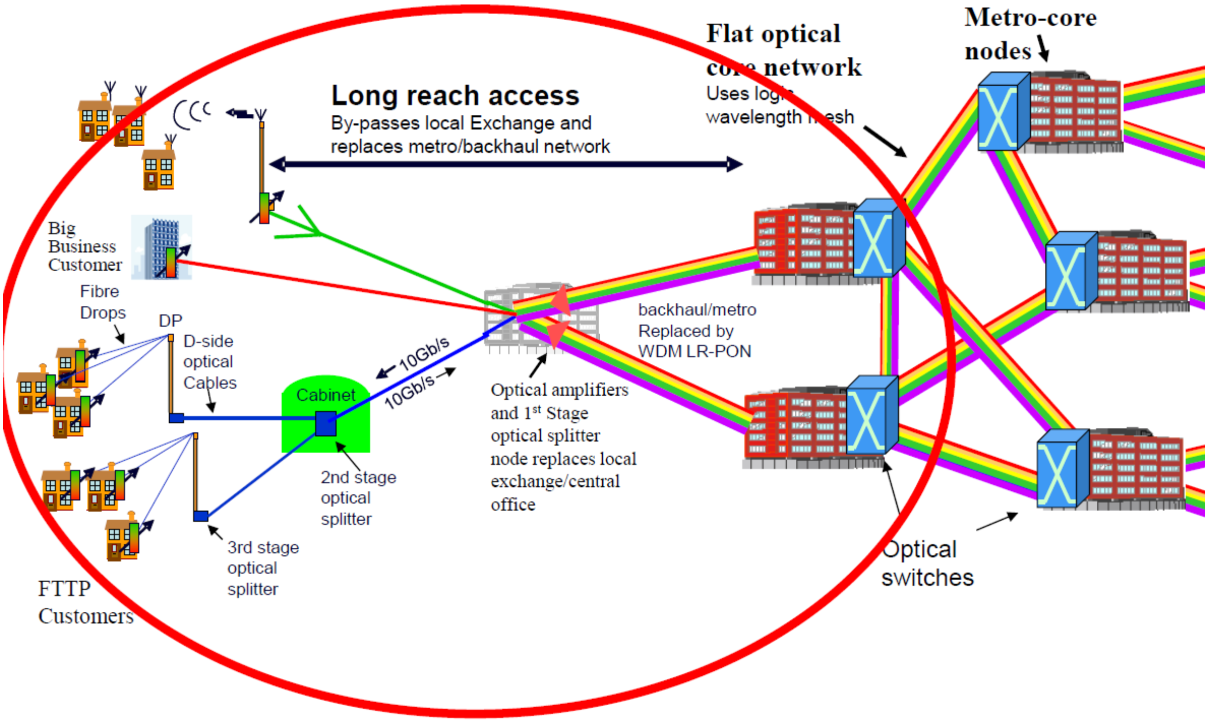

Figure 3 - DISCUS optical network architecture.

The reduction of electronic processing is achieved in DISCUS by using optically-amplified nodes replacing Local Exchanges (LE) or small Central Offices (CO) thus forming a Long-Reach PON as fibre access network with direct access to Metro/Core Nodes.

The success of DISCUS proposal depends on the real possibility of reducing the number of sites with electronic processing significantly in real networks. Thus, a case study is presented considering a realistic Italian reference network with 10 thousand local exchanges, as well as the number of households/inhabitants per region and Open Street Maps (OSM) information.

It must be noted that the number of Metro/Core (MC) nodes depend on several parameters such as the single or dual homing protection (w/ or w/o maximally disjoint paths), as well as the maximum distance allowed in backhaul links. Calculations varying some of these parameters and under different conditions have been evaluated.

The results obtained are promising, as the potential for the use of a small number of MC nodes (<2% of original sites) has been demonstrated using dual homing and maximally disjoint paths.

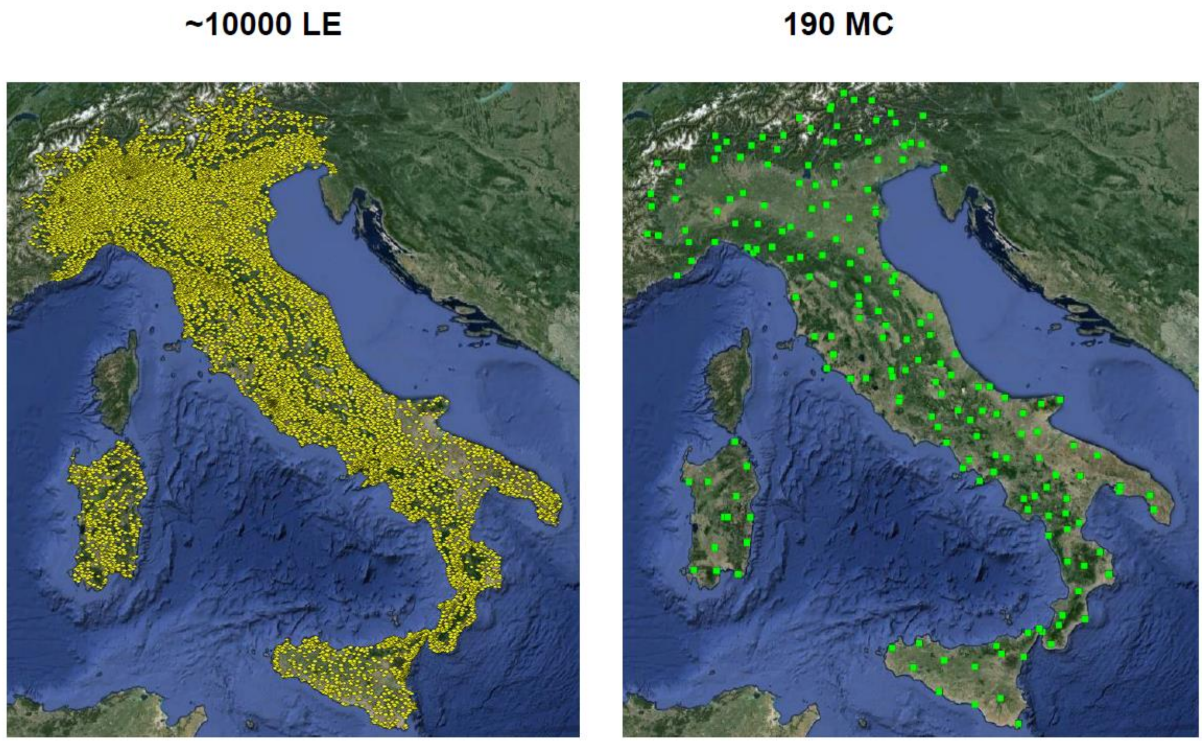

Figure 4 - Access optimization in the italian reference network.

2.3.3 Disaster Preparedness for Network and Information Infrastructures

Speaker: Biswanath Mukherjee (University of California Davis, USA).

In this presentation, protection/restoration techniques are analysed considering disaster failures.

The work shown in this presentation is in the framework of the activities of the Defence Threat Reduction Agency (DTRA), which aims to conduct basic research in order to develop methods for protecting networks and information infrastructures and to combat attacks with weapons of mass destruction. This has also a broader objective, with the applicability to both military and non-military applications and also against natural disasters (ex. Hurricane Sandy, Japan Tsunami, etc…).

The problems addressed in case of disaster failures cover Traffic Engineering (TE), Network Engineering (NE) and Network Planning (NP). While TE has a ms time scale and deals with packet delay/loss and blocking probability, NE is an intermediate problem with months of time scale and NP is even a more static issue with dimensioning considerations that may have several years time scale.

Some of the most relevant recent natural disasters had a huge impact in communications. For example, the Shichuan Earthquake in 2008 damaged 30,000 km of fibre optic cables and 4,000 central offices. Telecommunication network availability was reduced from 99.99% to 85% due to power outages and floods caused by

Hurricane Katrina in 2005. Most global warming simulations show an increase in the number of Category 4 and 5 hurricanes, so the adaptation to a disaster-prone world of the networks is a must. Risk maps of such disasters can be obtained and matched with the physical topology of a network to help develop a disaster-aware network design.

Possible strategies against disaster failures are normal/better preparedness and post-disaster actions.

In a normal preparedness approach, an excess capacity can be exploited to protect network against possible disasters, considering a map of risky regions and provisioning the traffic paths minimizing the risk probability.

In a better preparedness approach, additional to normal preparedness, if a disaster is predicted, network resources can be rearranged to better prepare network for a predicted disaster.

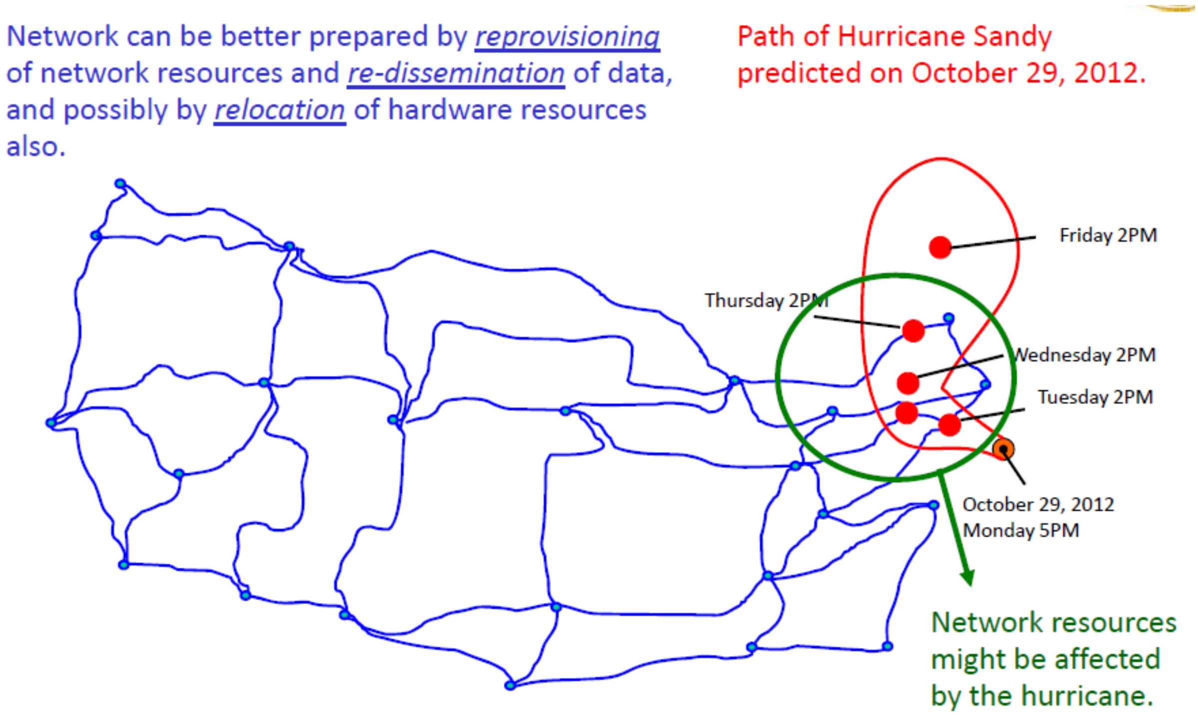

Figure 5 - Hurricane Sandy case study for better preparedness strategy.

Post-disaster actions aim to recover at least the most crucial services, by reprovisioning resources using the excess capacity of the undamaged parts of the network, considering the cascading failures during the re-provisioning process. While connection's full bandwidth may not be provided, a degraded service with less bandwidth can be provided using multiple paths for provisioning.

Not only communication networks but also the content itself stored in the cloud and data-centers must be protected. Actually, 90% of the total internet traffic is generated due to content dissemination, so connectivity to content needs to be protected.

Placement of data-centers should consider aspects such as the probability of disaster occurrence, expected loss of content and connectivity, access latency, content priority and popularity, as well as storage constraints, among others. A comparative example between an aware and an unaware datacentre placement, considering the risk of weapons of mass destruction attacks due to the presence of major military facilities is shown in the following figure. By maximizing the content connectivity, the service restoration is ensured.

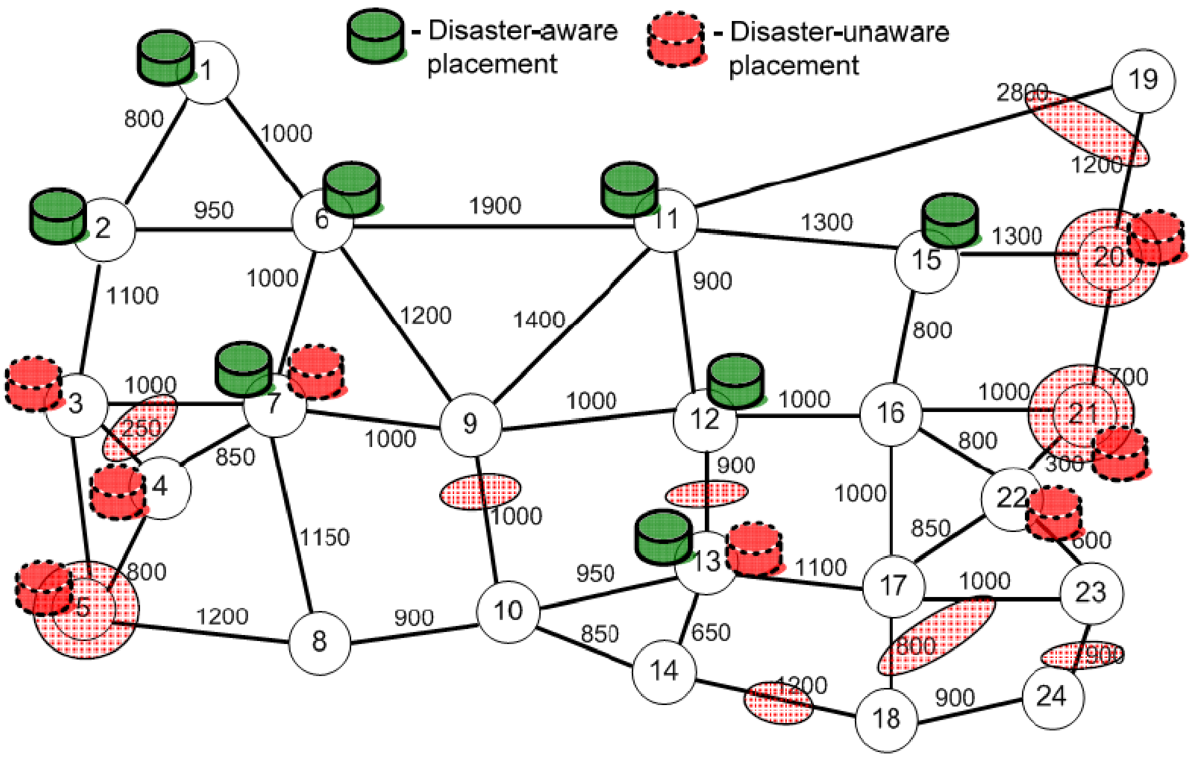

Figure 6 - Example comparing between disaster aware (green) and unaware (red) data-center/content placement.

Finally, different service levels can be considered in the network as resources are unavailable due to disasters, thus degraded services may be temporarily provided and upgraded after recovery. The problem of interdependent networks should also be considered, for example between powerline and communication lines.

2.3.4 *Attack-Aware Optical Network Planning*

Speaker: Marija Furdek (KTH Royal Institute of Technology, Sweden).

This presentation was focused on the modelling of algorithms for network survivability in the presence of jamming attacks targeting the optical layer. Spying scandals on all network layers are discovered almost on a daily basis. In the case of transparent optical networks, the security problem is due to the fact that no Optical-Electrical-Optical conversions are done in every path, thus intermediate nodes might not discard anomalous signals and sophisticated methods of attacks are hard to detect.

In this work, physical layer attacks based on high power jamming signals are analysed and algorithms to improve network survivability in the presence of attacks are proposed and studied. This high-power jamming signals can appear due to deliberate malicious insertion of signals by someone with access to network infrastructure or by misconfiguration of network equipment. Harmful effects to co-propagating signals include out-of-band crosstalk in optical fibres, in-band crosstalk in optical switches and gain competition in optical amplifiers. The following figure illustrates an example of the effects of a jamming signal in an optical network mesh.

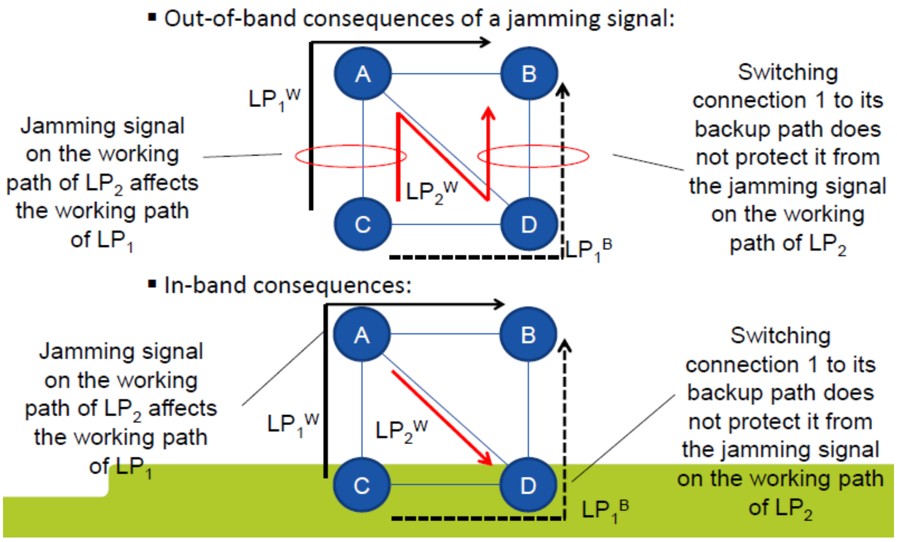

Figure 7 - Effects of a jamming signal.

In order to provide survivability approaches in the presence of physical layer attacks, the working and backup path should be both out of the reach of the attacker. In order to achieve the maximum survivability to attacks, the concept of attack group (AG) is introduced. For a given light path LPi, an AG(LPi) comprises all the lightpaths that can affect LPi in case of an attack. To achieve protection in the presence of attacks, AG disjointness must be guaranteed between the AG of both the working and backup paths for LPi.

Two attack aware routing wavelength algorithms are proposed:

- Dedicated Path Protection (DPP), where both working and backup LPi are physically and AG-disjoint.
- Shared Path Protection (SPP). Same as previous, but backup paths of different LPs sharing resources if their working paths are physically and AG-disjoint.

Simulations have been performed in several test cases on two small sized networks with 6 and 8 nodes, considering two objectives in the algorithms: routing phase minimizing the total path length, and wavelength assignment phase, minimizing the number of used wavelengths. Both DPP and SPP are compared with the same objective.

The following figures show that in the best cases, the attack-aware RWA algorithm can guarantee protection even to more than 50% of the connections in the presence of jamming attacks.

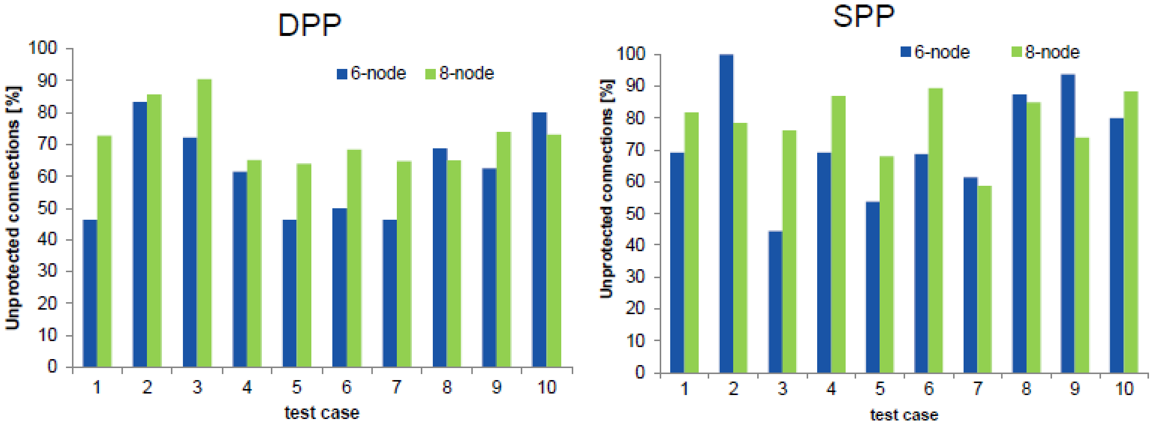

Figure 8 - Percentage of connections unprotected in the presence of jamming.

The increase of wavelength usage in case of attacks for the different test cases is also shown in the following figures.

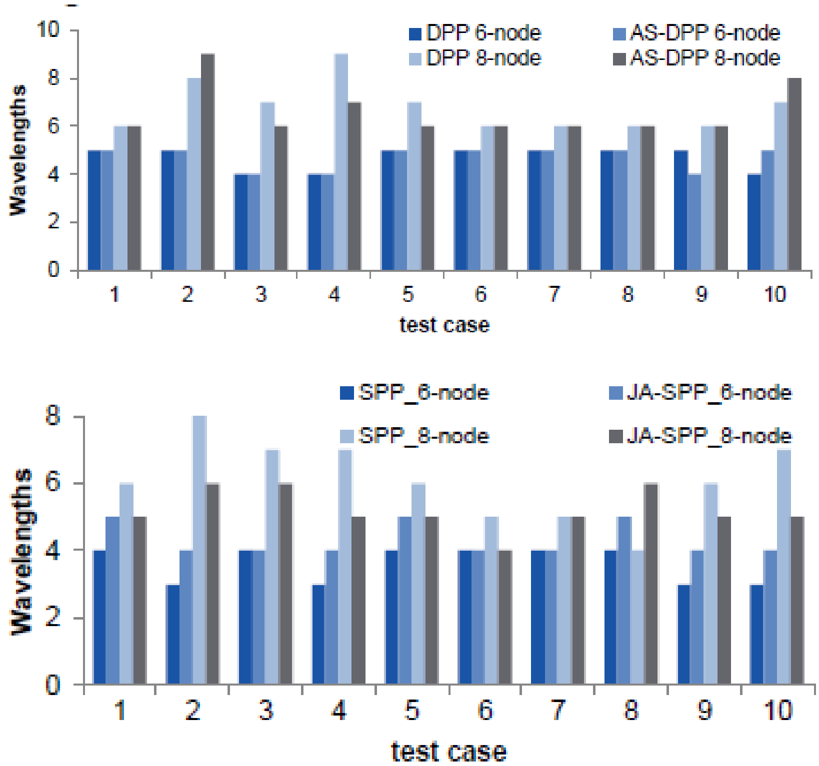

Figure 9 - Simulation results: resource usage

2.3.5 Impairment Aware Restoration in GMPLS Networks

Speaker: Marco Tacca (University of Texas at Dallas, USA).

This presentation is focused on the analysis of restoration in Physical Layer Impairment (PLI) aware GMPLS networks. The basic idea is that OSPF collects fibre state information and compute end-to-end-routes (hop count based), and that RSVP protocol takes care of wavelength reservation and handling of PLIs. The proposed wavelength assignment (WA) methods are used to efficiently mitigate race conditions in both normal network status and link failure cases.

Three WA methods are considered:

- First fit, either high frequency first (FF-HF) or low frequency first (FF-LF).
- Random
- Mixt: FF-LF + Random.

Simulations are performed in a reference network topology as shown in the following figure.

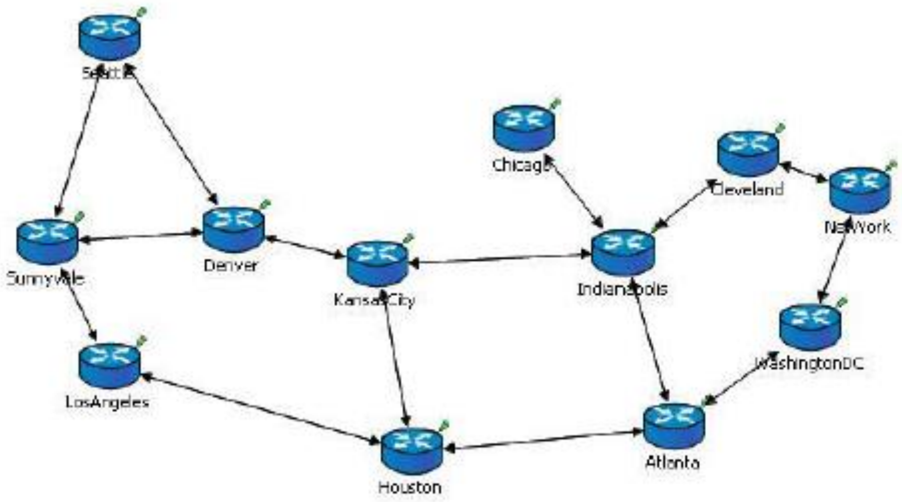

Figure 10 - Reference network topology for simulations.

Simulations are performed studying a number of different link failure cases, assuming 100GHz channel spacing and 40 wavelengths per fibre with latency only applied to RSVP messages.

Probability of blocking, Label Switched Path (LSP) utilization, average route hops and restoration times are obtained versus link utilization. Enhancements are shown in all the parameters using the proposed WA methods.

An example of simulation results is shown in the following figure.

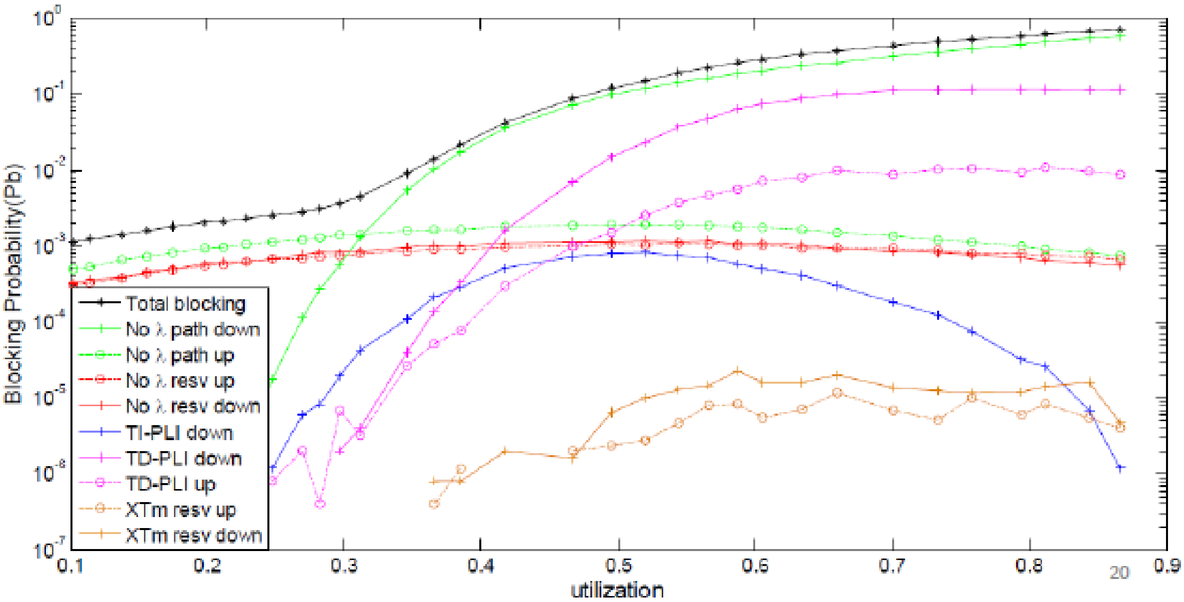

Figure 11. Blocking probability versus utilization for FF-LF (1 ms RSVP latency).

2.3.6 Sharing Protection Resources in Fibre Access Networks

Speaker: Marco Ruffini (Trinity College Dublin, Ireland).

Protection is a key aspect for network reliability and it can almost double the cost of network equipment, so it is required to develop approaches for sharing protection resources over an optical access network.

LR-PONs pose an interesting problem because it merges access and metro, making protection essential. This is a key aspect to be considered in a metro-access converged network such as the DISCUS architecture [2].

The problem targeted in this presentation was how to reuse equipment to protect for failures that are far away. The presented results are basically:

- Mechanism for sharing IP protection equipment
- Mechanism for sharing Optical Line Terminals
- Prototype implementations: results on 1+1 fast protection in OLT, ongoing work in End-to-end 1:1 and 1:N access protection.

Sharing IP protection can be achieved by overlapping of coverage of the nodes. This is modelled using hexagons, as shown in the following figure. In the figure, the primary coverage of each node (A, B, C, D) is half the size of the hexagon, and backup is provided by the three adjacent nodes. Backup IP router resources are shared among the adjacent nodes. As an example, if node A fails, B/C/D provide backup for a section of A primary area (one third each). IP overprovisioning is only 1/3 compared to simple 1+1 solution, and power consumption is also reduced. This triple coverage protection is shown in the following figure (left). The spreading of the algorithm for further sharing is shown in the right figure. It consists of furtherly sharing the traffic protected in an adjacent node, between far away nodes. In this case, the load from failed node A that goes to C is actually protected by E and F, thus the overprovisioning is actually reduced per node.

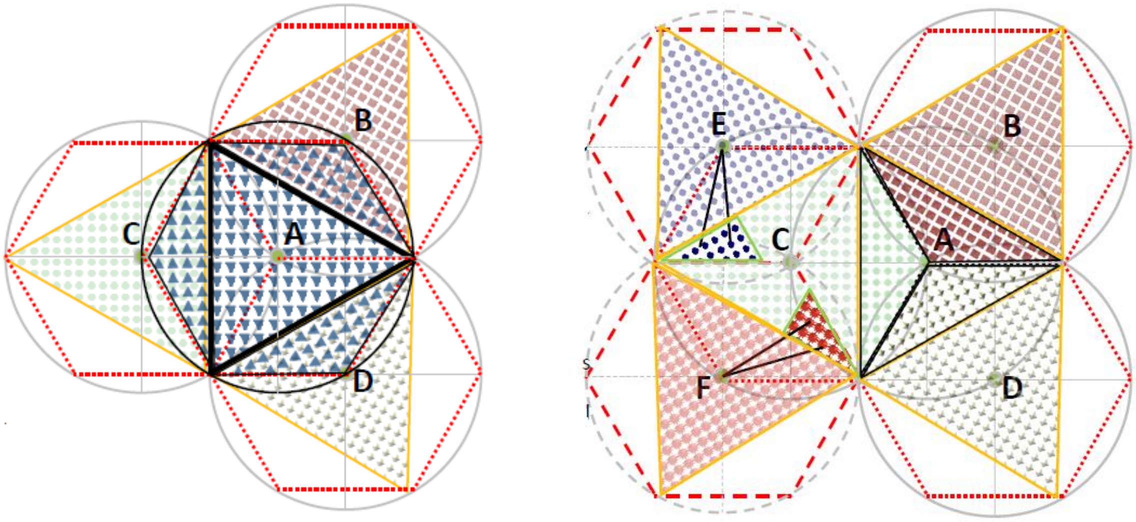

Figure 12 - Geometrical model for IP protection sharing among nodes. Left: triple coverage; right: spreading algorithm.

The overprovisioning required for a network with 20, 50 and 100 nodes are shown versus the number of hops from failed node [3]. The higher the number of hops where the protection IP resource is available, the lower the overprovisioning required.

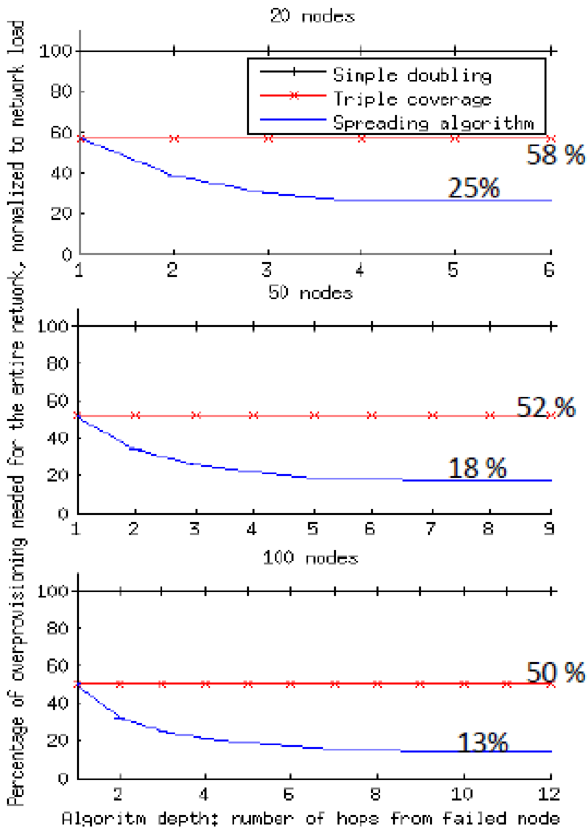

Figure 13 - Overprovisioning savings versus 1+1 IP protection.

A similar principle of operation for OLT sharing between MC Nodes in the DISCUS architecture is also studied, see the following figure (upper side). Results of the simulations with savings in OLT overprovisioning are shown in the lower side figure [4].

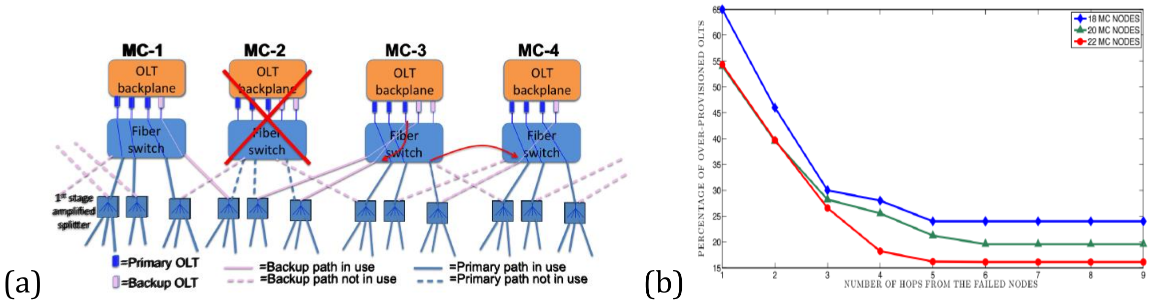

Figure 14 -OLT sharing between MC nodes: (a) principle of operation (b) Simulation results.

In order to implement these algorithms, fast redirection of IP traffic is required as well as fast OLT reactivation. In case of OLTs protection, the total protection time equals the fault detection time and the PON reactivation time. PON reactivation times <10ms are estimated and 1+1 OLT protection has been tested [5]. Work is also ongoing in End-to-end considering 1:1 and 1:N access protection with core network redirection.

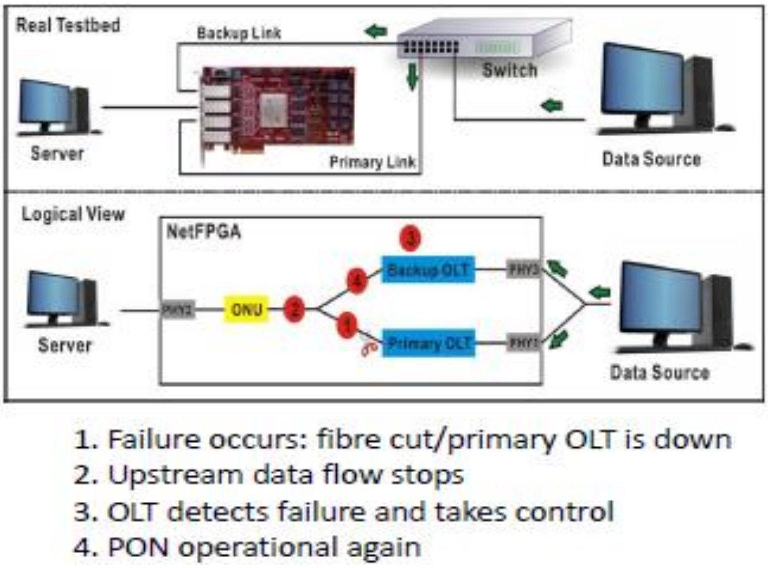

Figure 15 - 10Gbit/s OLT reactivation experiment in 1+1 protection scenario.

2.3.7 Planning and Optimization of Reliable Networks, Systems and Services

Speaker: Marc Ruiz (Universitat Politecnica de Catalunya, Spain).

The work reported in this presentation was within the framework of the IDEALIST project. IDEALIST (Industry-Driven Elastic and Adaptive Lambda Infrastructure for Service and Transport Networks) is and FP7 which aims at designing and developing innovative transport solutions, compatible with new bandwidth consuming applications (e.g. 3D video, cloud, etc.) based on elastic optical networks equipped with a multi-domain and multi-technology control plane enabling adaptive network and service interworking.

IDEALIST proposes gradual migration from fixed to flexgrid technologies, so that this technology is introduced where it has more benefit at a certain time, without having to start again with a new network build. Thus, drivers such as cost-effective 400 Gbit/s transmission, sliceable Bandwidth Variable Transponders (BVT) and, in the end, full capacity exploitation lead to gradual migration actions starting flexgrid deployment in highly congested areas, then in extensive areas and finally replacing legacy fixed grid equipment.

In-operation network planning is a scenario in which automatic lightpath provisioning allows network resources to be made available by reconfiguring and/or re-optimising the network on demand an in real time. This is allowed due to a control plane providing the capability of automated lightpath setup using remotely configurable optical cross connects (OXC) within minutes or even seconds.

The ABNO (Application-Based Network Operations) architecture is now being proposed as a candidate solution for dynamic network operation. It consists of a number of standard components and interfaces which, when combined together, provide a method for controlling and operating the network. The in-operation planning tool can be deployed as a dedicated back-end PCE (Path Computation Element) for performance improvements and optimisations. ABNO architecture is proposed as an alternative to current static transport networks, currently configured with big static fat pipes based on capacity over-provisioning for QoS guarantees. Different vendors typically include a centralised service provisioning platform, using vendor-specific NMS implementations along with an operator-tailored umbrella provisioning system. This approach leads to complex and long workflows (i.e. weeks) for network provisioning.

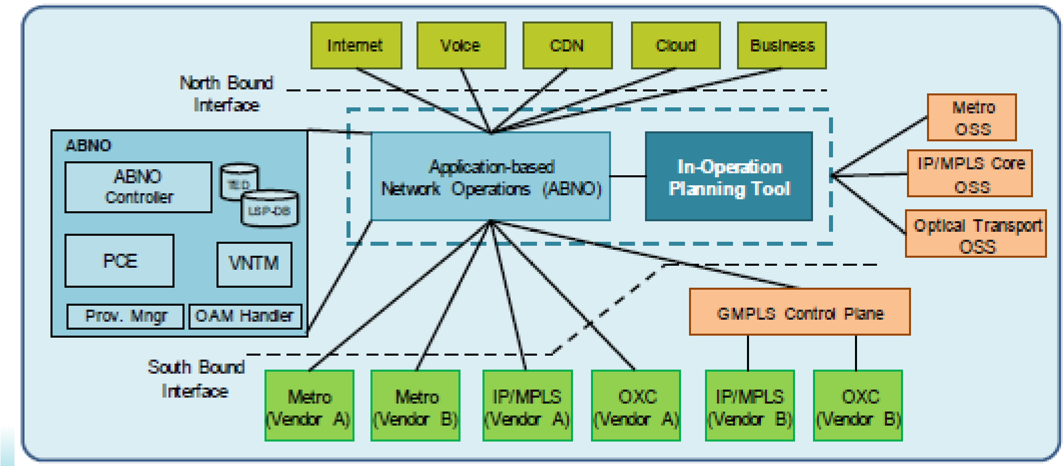

Figure 16- Future dynamic architecture based on ABNO.

IDEALIST proposes the use of a Planning Tool for Optical Networks (PLATON) architecture divided into 4 main modules: the communications module, the optimization algorithm framework, the databases, and the plugged algorithms.

A PLATON use case for optical restoration and optimization is shown in the following figure.

(a)

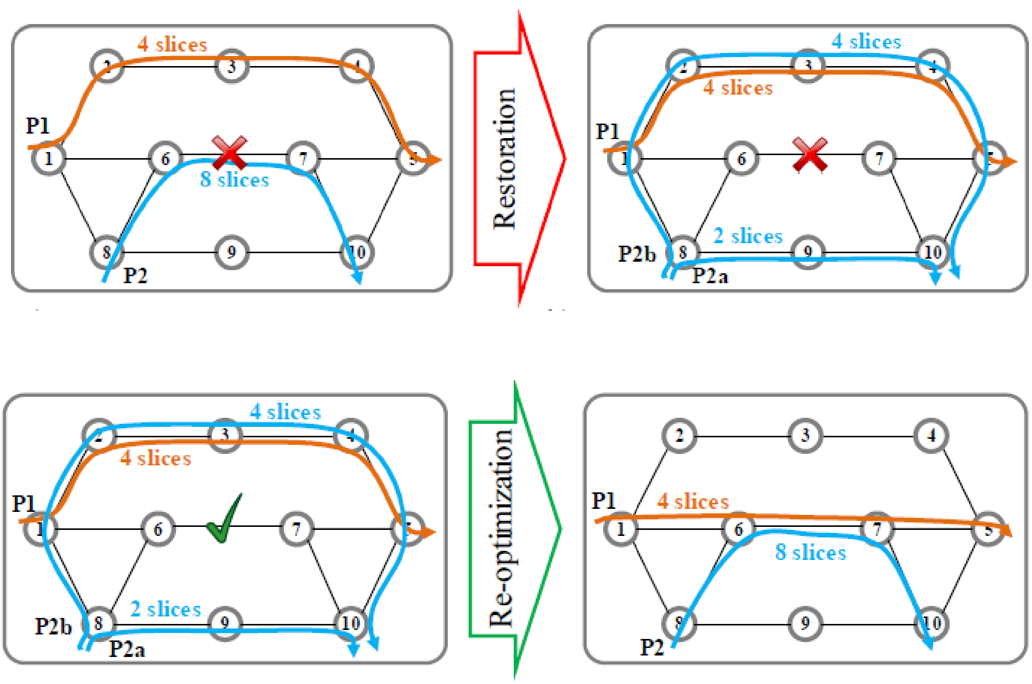

Figure 17 - PLATON architecture use case for optical restoration (a) and optimization (b).

The messages exchanged between ABNO in Telefonica premises (Madrid) and PCEs in UPC (Barcelona) and CNIT (Pisa) experimentally demonstrated the PLATON use case.

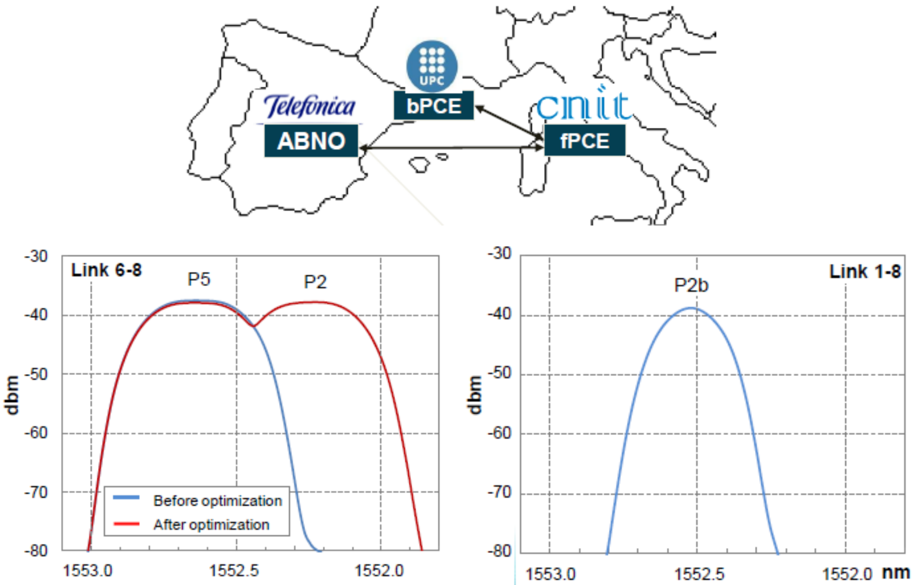

Figure 18- PLATON use case scenario for the demonstration of exchanged Patch Computation Elements Protocol (PCEP) messages and optimization results.

2.3.8 Efficient Resiliency Schemes for Next Generation Optical Access Networks

Speaker: Jiajia Chen (KTH Royal Institute of Technology, Sweden).

In this presentation, two reliability performance parameters, connection availability and failure impact factor, are considered and analysed in next generation optical access network scenarios, specifically focusing in the long reach PON architecture proposed in the DISCUS project.

The reliability performance parameters are defined as follows:

- Connection availability: the probability that a logical connection (e.g. a connection between the OLT and ONU) is operable. It depends on the mean time to repair (MTTR) and mean time between failures (MTBF).
- Failure Impact Factor (FIF) [6]: it accounts for the risk that a certain number of end users is affected by any failure. Two important factors are included:
    - Failure penetration range (FPR): it is defined as the number of users simultaneously affected by the failure of a certain component.
    - Unavailability (U): it indicates how often a connection/component is not available due to a failure of a component or link.

First, in a long reach PON scenario modelling the reliability of the components building the DISCUS access network is considered, considering three deployment scenarios with 7500, 400 and 1000 central offices (COs) with working and backup fibres. Two technologies are considered:

- WDM-PON, using a filtered optical distribution network to guarantee point to point dedicated optical channels to each customer;
- Hybrid PON, using a power splitter based optical distribution network.

The lower the number of COs, the higher number of end users served by a single one, thus the more important the protection scheme to guarantee the network reliability performance. In the following figures, the increase of connection availability due to protection for both feeder fibre and OLT in LR-PONs can be seen.

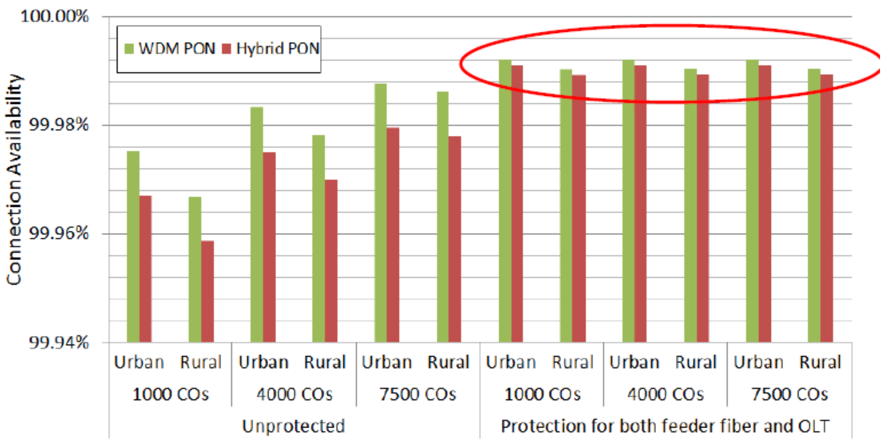

Figure 19- Connection availability.

Analysis results of the failure impact factor (FIF) are also shown in the following figure.

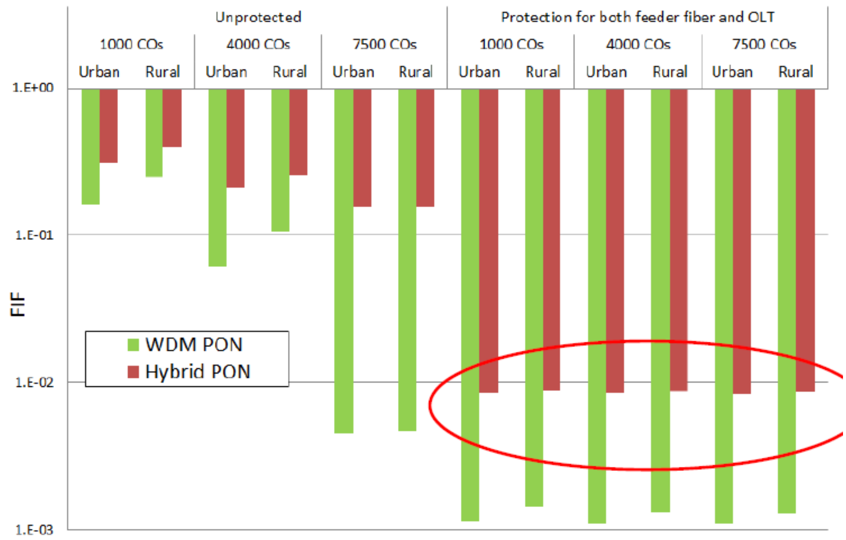

Figure 20 - Failure impact factor.

In general, there are two main reasons that WDM-PON is more reliable than hybrid WDM/TDM PON:

1) WDM PON has a lower splitting factor so that the number of affected users by the failure occurred in the feeder section could be smaller than in hybrid PON and
2) to keep the same sustainable data rate per user, WDM PON requires the transceivers having much lower data rate (in turn also having higher availability) than the hybrid case..

It can be seen that, in the unprotected case, the higher the number of COs, the lower the FIF, as a single failure in the access network affects a lower number of users. On the contrary, in the protected case, it is possible to consolidate 7000 COs in a much lower number, 1000 COs, and still guarantee that the FIF will be lower than 1%. This means that in average, each failure in the protected access network will affect less than 1 user out of 100, even dramatically reducing the number of COs from 7000 to 1000.

As a conclusion, protection can guarantee a high reliability performance even in a such highly consolidated access network as proposed in DISCUS.

In order to reduce the cost of full protection (including protection of the end user connection), a hybrid wireless fibre protection scheme is also studied, see the following figure.

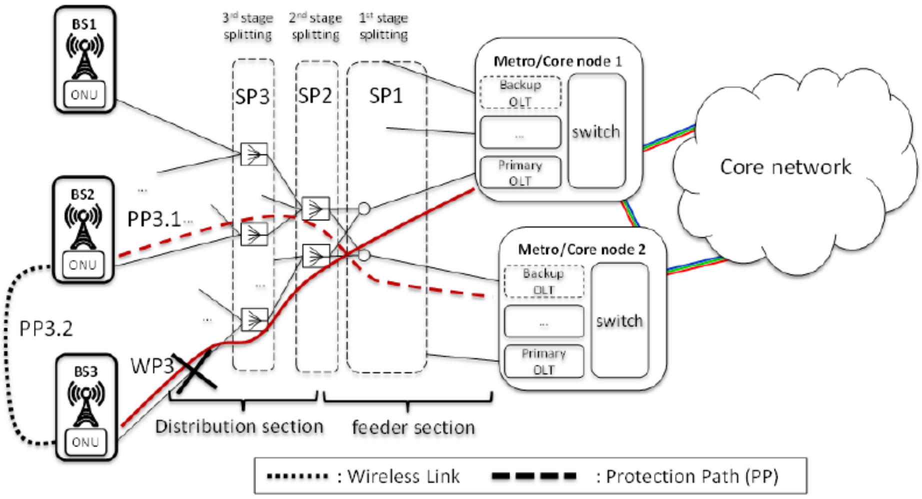

Figure 21 - Full protection scenario using a wireless backup link in the end user connection (mobile scenario).

Analysis results show that this full protection proposal can increase availability, in a cost effective way, from 99.9% (3 nines) in the unprotected case to more than 99.9999 % (6 nines).

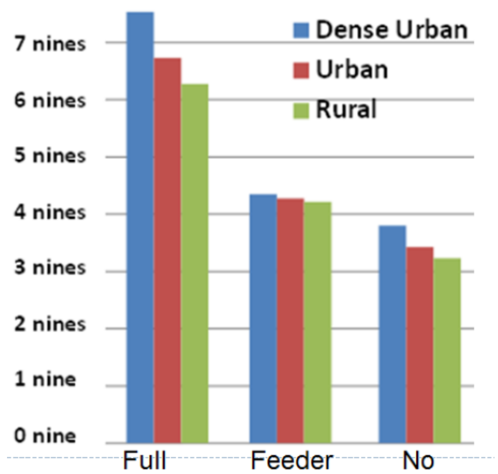

Figure 22 - Connection availability comparison between full protection using a wireless backup link, feeder fibre protection and no protection.

2.4 Panel discussion

The following questions were proposed to the panel participants and the audience.

1. Could shared protection or restoration be sufficient to eliminate the need for 1+1 protection?

2. In multi-layer networks which layer is the most problematic from a protection and restoration perspective?

3. Could fibre sensors be used to reduce or prevent faults by thirds parties (e.g. dig-up) or malicious attacks, particularly if used with pro-active reroute?

4. If we provide protection/restoration for disasters (defined for this question as a complete single node failure). Do we ensure protection for simpler network failures such as an equipment item or a cable dig-up?

5. Do we need central control for disaster recovery and protection generally rather than autonomous system re-routing?

6. Could distributing content to the network edge (e.g. into CPE) for general content access be a way of protecting content without doubling (or more) content capacity at network based data centres?

Regarding question 1, the consensus seemed to support shared protection or restoration could be sufficiently good to remove the need for 1+1 protection the only uncertainty was the speed and whether the 50ms target could be met with shared protection. The discussion then went into the old issue of where did the 50ms target come from and do we need it today.

On question 2, the majority of the feedback seemed to suggest that the rerouting of traffic in the higher layers and co-ordination across these layers was a major issue but fibre/optical path switching if centrally controlled could reduce these problems.

On question 3, it seemed generally accepted that fibre sensing can help to help prevent physical damage to fibre cables.

Regarding question 4, there was no definite statement confirming this but general consensus particularly supported the proposition that disaster recovery of a node failure would probably mean all other element failures were also protected.

Answers from the panel to question 5 stated that central control is required for fast reroute and traffic restoration. It is likely that whole network calculations for reconfiguration and that parallel action to implement the new routes is required to minimise restoration times, while autonomous systems tend to be too serialised to get fast restoration particularly in multi-layer networks.

Finally, it was fairly obvious from the answers/comments on question 6 that the panel hadn't considered content distribution in CPEs previously from a protection/restoration point of view in detail. Most comments were non-committal although the wide distribution of content probably meant that is was more survivable in wide area disaster situations.

3 ECOC'14 Workshop: "Is NGPON2 an ultimate access solution? Is there anything coming afterwards?"

3.1 Introduction

Next-Generation Optical Access (NGOA) solutions are mandatory to keep pace with the steady traffic growth in residential, business and backhaul markets. The pervasiveness of high-quality multi-media applications paired with a shift from broadcast to unicast services calls for future-proof solutions which are scalable to per-user data rates in the (multi) gigabit region for residential users. At the same time backhauling and business applications require even higher data rates of 10 Gbit/s and beyond. A single platform for residential, business and backhaul applications, the consolidation of local exchange offices, and the minimization of active field equipment are further NGOA drivers. They result not only in simplified network planning and more integration but also in reduced energy costs.

Due to the high transmission capacity offered by optical fibre (especially as PON standards evolve towards multi-wavelength solutions), PONs can provide high speed access at lower cost compared to bespoke point-to-point architectures, making it a potentially attractive solution also for high-end business applications (e.g. mobile back-haul, logical high-capacity links for small SPs, or any institution that used to be served by point-to-point leased lines). However, designing a PON access architecture that is able to satisfy the heterogeneous requirements of different services and applications, while maintaining low cost and energy consumption, is a challenging problem.

The aim of this workshop is bringing together speakers from system vendors, carriers and academia to create an open discussion. Latest results from research projects will be presented as well as current standardization efforts.

The workshop was divided in two main parts. DISCUS co-organized one of the slots of the second part of the workshop. In the current delivery, we will focus on the presentations related to DISCUS project in the corresponding slot.

3.2 Program

The complete program for the workshop was the following. The workshop was divided in two main parts. DISCUS co-organized the slots of the second part of the workshop, entitled "How much node consolidation are we likely to see and what are the associated challenges?" and "Will SDN find its way in the access and what are the control plane challenges in multi-service consolidated access nodes?". In the current delivery, we will focus on the presentations related to DISCUS project in the corresponding slots.

PART 1

What is NG-PON2 and what will be the opportunities for operators?

- A system vendor’s perspective
  Frank Effenberger, Futurewei Technologies, USA
- An operator’s perspective
  Martin Carroll, Verizon, USA

Multi wavelengths and the challenge to control and manage the wavelength resources

- Using protocols or embedded-communication channels PLOAM/OMCI messages
  Dora van Veen, Alcatel-Lucent, USA
- WDM-PON using pilot-tones
  Michael Eiselt, ADVA Optical Networking, Germany

Using a physical layer implementation

- Colorless seeded WDM-PON
  Ola Wikström, Transmode, Sweden
- Self-seeded WDM-PON
  Paola Parolari, Politecnico di Milano, Italy

PART 2

Is frequency-division multiplexing the next degree of freedom to improve access performance?

- Physical layer & component perspective
  Philipp Schindler, KIT, Germany
- An operator’s perspective
  Benoît Charbonnier, Orange, France

Are access networks affordable for mobile front-haul?

- Existing solutions for front-haul transport
  Peter Kwangho Cho, HFR, South Korea
- Front-Haul challenges for future access systems
  Shigeru Kuwano, NTT Corporation, Japan

How much node consolidation are we likely to see and what are the associated challenges?

- Network architecture view
  David Payne, CTVR, Trinity College Dublin, Ireland
- An operator’s perspective
  Dirk Breuer, Deutsche Telekom AG, Germany

Will SDN find its way in the access and what are the control plane challenges in multi-service consolidated access nodes?

- SDN in converged access-metro scenarios
  Neda Cvijetic, NEC Labs, USA

- Architecturing SDN for optical access networks
  Daniel King, Lancaster University, United Kingdom

3.3 Summary

3.3.1 Network architecture view

Speaker : David Payne, CTVR, Trinity College Dublin, Ireland.

This presentation is related to the workshop topic « How much node consolidation and what are the challenges ? ».

According to basic statistics, in the UK and Ireland, as examples, 50% of customers are sernved by only 11% and 10% of exchanges, respectively. This gives the idea that consolidation has a big potential to reduce the total number of exchanges.

Increasing the node count increases the number of links or light paths in an n2 relation, and eventually requires an hierarchical core network rather than a flat optical core. Hierarchical cores require packet processing between the layers increasing network cost and power consumption.

On the opposite, reducing the number of nodes further strains the long reach optical technology for a low cost entry strategy. Among the advantages of node consolidation, in the presentation the following were stressed:

- Economies of scale in larger network nodes,
- Reduced accommodation costs (rates/rents, maintenance, personnel accommodation, lighting, heating/cooling),
- Reduced operational costs for network operations (service configuration, maintenance fewer site visits, etc.),
- Simplification and cost reduction of the network architecture,
- Alternative use of building infrastructure and/or capital recovery.

The DISCUS architecture is designed around the optical reach of LR-PON (~100km), this enables consolidation of nodes by a factor of 50, 100 nodes for United Kingdom (UK) network from 5600 nodes, 20 nodes for Ireland from 1100 nodes. This node consolidation achieves a flat optical core, with no hierarchy between nodes and reduced Opto-Electro-Optical (OEO) and packet processing. In the access, a massive sharing of ports is achieved (around 500 customers per port).

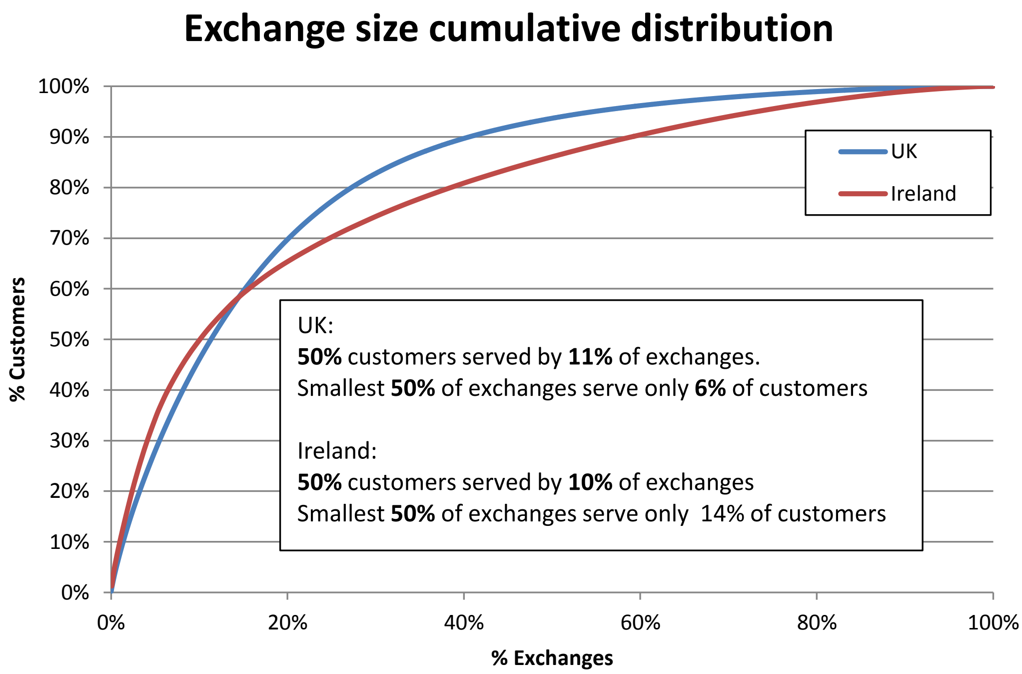

Figure 23 - Cumulative distribution of exchanges in UK and Ireland

Some technical challenges and barriers to node consolidation were identified. First, reducing access nodes requires longer reach with a cost - performance trade-off. Higher bandwidth access systems are also required to enable shared access, as point to point is uneconomic over long distances. All the former points result in challenging power budget and system design for low cost optical systems. At the same time, reducing number of nodes increases core distances but reduces number of light paths, so it is required to find the optimal balance.

There are some regulatory barriers also that are preventing from quick node consolidation. First, Local Loop Unbundling (LLU) may force exchanges to remain open because of legal/regulatory requirements and obligations to third party operators. Legacy technology cannot be removed rapidly and needs to be economically retired considering an economic life time. An strong FTTH policy is also required to push network node consolidation rather than FTTCab, which is not yet high on the agenda of most European operators.

3.3.2 SDN in converged access-metro scenarios

Speaker : Neda Cvijetic, NEC Labs, USA.

This presentation is related to the workshop topic « Will SDN find its way in the access and what are the control plane challenges in multi-service consolidated access nodes? ».

By definition, a SDN is a network in which the control plane is physically separated from the data-forwarding plane, and where a single control plane controls a plurality of devices. The relevance of SDN consists on how well it can solve native challenges of different network scenarios and technologies, such as intra/intra data center communications, optical transport, mobile/wireles, etc…

In this presentation, a generic scenario of a converged access SDN comprising several access technologies is proposed, see the folllowing figure.

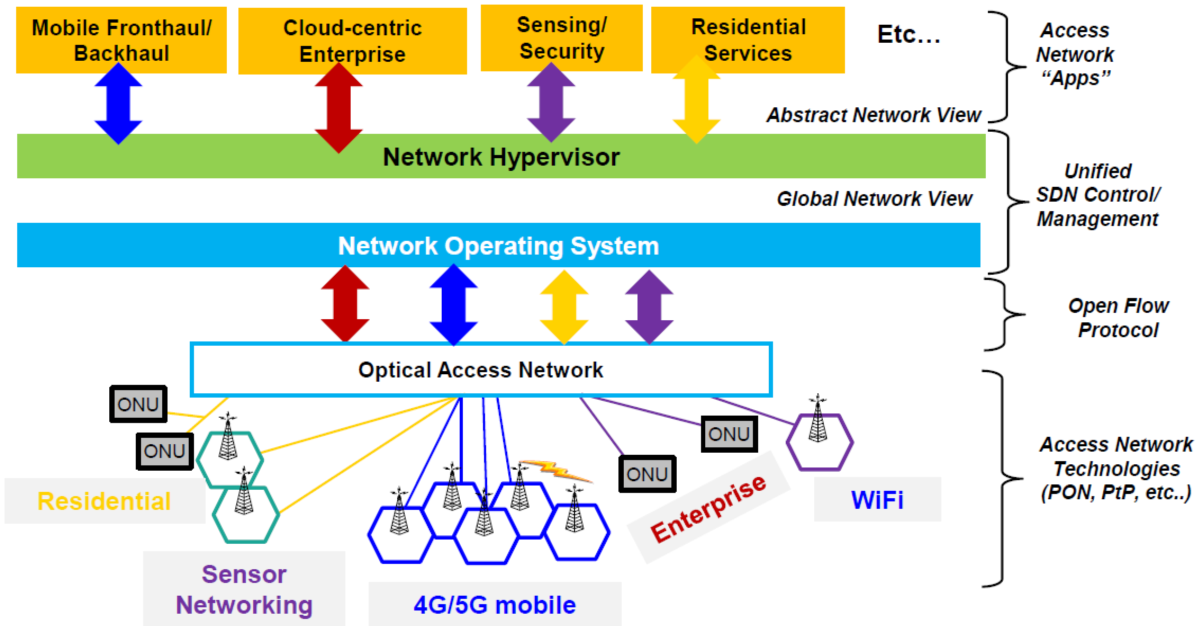

Figure 24 - Generic scenario of a converged access SDN.

In the proposed scenario, the unified control plane can be used for reducing provisioning time and optimized resource orchestration across the access segments.

SDN principles are language-oriented and OpenFlow is the language of SDN, allowing complex network policies to be intuitively described and implemente via simple flow-tables in switches. With the flexibility of openflow, any new matching conbination in the data plance can provide a new network functionality. This has the potential to provide multiple network convergence, rapid and on demand service introduction and trafic flow differentiation. Layer 0 OpenFlow extensions may be required to adapt to different access technologies.

In Passive Optical Networks, important benefits are possible, such as a centralized OLT control, more programmable OLT and ONUs, on-demand modifications of flow mapping policy/rules, thus opening new sources of revenues based on Quality of Services.

Strong research and development activities are performed by NEC in this nascent area of software defined control for multiple services, OpenFlow extensions for optical layers and software-defined transceivers.

3.3.3 Architecturing SDN for optical access networks

Speaker: Daniel King, Lancaster University, United Kingdom.

This presentation is also related to the workshop topic « Will SDN find its way in the access and what are the control plane challenges in multi-service consolidated access nodes? ».

In the presentation, the Application Based Network Operations (ABNO) scenario is presented in the framework of research of the FP7 IDEALIST project. ABNO is a Path Computation Element (PCE) based architecture for application-based network operations being developed by Internet Engineering Task Force (IETF).

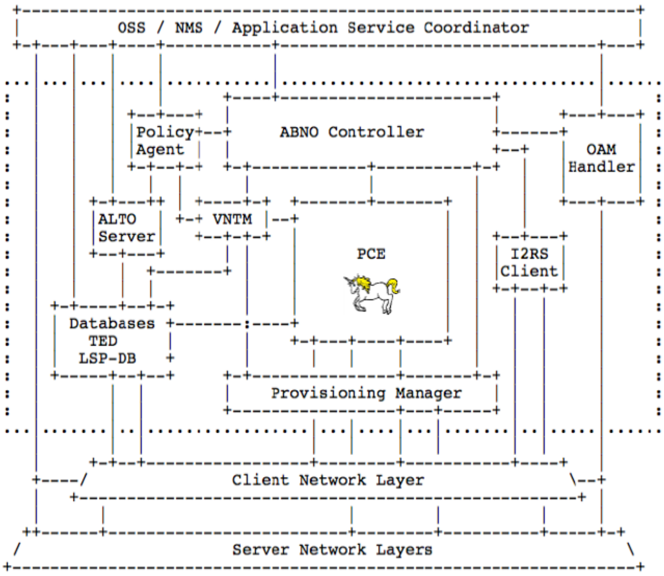

Figure 25 - Generic ABNO architecture.

ABNO is an scenario compatible with SDN, but offers a richer function set based on the same SDN concept, enabling the use of OpenFlow and other protocols, in order to make possible the deployment of SDN control platforms for real networks.

During the presentation, an example of ABNO operation provisioning a L3 path between two network nodes is described.

4 References

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[6] M. Mahloo, et al., "Toward Reliable Hybrid WDM/TDM Passive Optical Networks", IEEE Communications Magazine, vol. 52, pp.S14-S23, Feb. 2014.

Abbreviations

ABNO	Application-Based Network Operation
AG	Attack Group
BER	Bit Error Rate
BVT	Bandwidth Variable Transponder
CO	Central Office
DISCUS	The DIStributed Core for unlimited bandwidth supply for all Users and Services
DPP	Dedicated Path Protection
DTRA	Defence Threat Reduction Agency
DWDM	Dense Wavelength Division Multiplexing
ECOC	European Conference on Optical Communications
FF-HF	First Fit – High Frequency
FF-LF	First Fit – Low Frequency
FIF	Failure Impact Factor
FPR	Failure Penetration Range
FRR	Fast Re-Route
FTTH	Fibre To The Home
GMPLS	Generalized Multi-Protocol Label Switching
IDEALIST	Industry-Driven Elastic and Adaptive Lambda Infrastructure for Service and Transport Networks
IETF	Internet Engineering Task Force
IP	Internet Protocol
LE	Local Exchange
LLU	Local Loop Unbundling
LP	Light Path
LR-PON	Long Reach Passive Optical Network
LSP	Label Switched Path
MC	Metro-Core
MPLS	Multi-Protocol Label Switching
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NE	Network Engineering

NGOA	Next Generation Optical Access
NP	Network Planning
OEO	Optical-Electronic-Optical
OLT	Optical Line Termination
ONDM	Optical Network Design and Modeling
OSM	Open Street Maps
OSPF	Open Shortest Path First
PCE	Path Computation Element
PLATON	PLAnning Tool for Optical Networks
PLI	Physical Layer Impairment
QoS	Quality of Service
RSVP	Resource reSerVation Protocol
SDN	Software Defined Network
SP	Service Provider
SPP	Shared Path Protection
TE	Traffic Engineering
UK	United Kinddom
USA	United States of America
WA	Wavelength Assignment