A keynote from the project coordinator Traffic demand is increasing dramatically, with a continued growth of around 35% per year in backbone networks due to the proliferation of high bandwidth applications, such as high resolution video or cloud services. IDEALIST EU project proposes an Elastic Optical Network (EON) architecture based on the combination of new transmission, switching and control technologies to overcome this situation. Modularity and programmability are the main requirements for IDEALIST node and network architectures to enable flexible deployments and smooth upgrades for different scenarios and variable traffic conditions.

Transmission Technologies
One key aspect of a EON is a flexible transponder. Next generation transponders proposed in IDEALIST have a range of flexibility enables the operator to optimize network capacity by configuring the transponder to have the most spectrally efficient format for the distance required. A single transponder with this capability is known as a multi-flow transponder or a Sliceable Bandwidth Variable Transponder (S-BVT). S-BVTs enable the generation of multiple optical flows, that can be routed into different media-channels (a media-channel is a specific portion of the optical spectrum and an optical path through the EON between two end-points) and flexibly directed towards different destinations. IDEALIST proposes a complete architecture for the S-BVT, including client and line side as well as the required internal switching.

Node Architecture
IDEALIST proposes a flexible node architecture composed by different modules:
- Elastic and flexible optical interface. A flexible OTUflex line is not at present specified, however, a rate-flexible OTU line interface, et complementing the flexibility provided by ODUflex in the Low-Order ODU (LO-ODU) service layer, is expected to be one of the distinguishing attributes of the OTN hierarchy evolution “beyond 100G” (B100G). IDEALIST proposes an interface modular enough to allow the partition of the common hardware pool in “sub-transponders”, one per OTU flow set active on that SBVT.
- Optical Backplane. This module provides greater flexibility since the components used for optical processing are not hard-wired allowing component interconnections in an arbitrary manner. In this way it offers beneficial features to the network, such an enhanced scalability and the implementation of self-healing capabilities (the optical node can recover from a component failure by reconfiguring the system to

HOT TOPICS
- Our Vision: the Sliceable Bandwidth Variable Transponder
- Publication Bonanza!
- Improving the “All Seeing Eye”
replace faulty modules). Moreover, it has demonstrate adaptability to different transmission dimensions, since it is able to process optical signals in space, frequency and time and it enables bandwidth virtualization. SERANO. The functions provided by a SERANO module include 3R regeneration, modulation format translation (using the S-BVTs to translate the modulation format of a flow) and changes of carrier central frequency (to avoid spectrum conflict). These can have a wide range of applications including complex network procedures such as defragmentation. In this way, the BVTs transponders in SERANO can flexibly shift the received slots to any appropriate slot in the output fiber increasing the network utilization. Other ways to utilize SERANO include optimizing the optical reach and unblocking by relaxation of frequency continuity.

**Interoperability**

IDEALIST is designing and prototyping an interconnection node enabling data plane interoperability between different vendor domains by using a software-defined network for centralized management and interoperability between nodes. IDEALIST already carried out a first experiment to challenge the interoperability between two different systems. **Control Plane** IDEALIST proposes a control plane distributed protocols, which provides a real-time response and let the network survive against failures; and a centralized intelligence called Adaptive Network Manager (ANM). The objective of the control plane is to provide an interoperable and scalable multi-vendor flexi-grid optical network, applicable to multi-domain and multi-layer scenarios. Furthermore, the ANM proposed by IDEALIST to efficiently manage EONs, provides a point of optimization and interface with the applications.

It monitors network resources and decides optimal network configuration based on the status, bandwidth availability and user service. One of the applications of ANM is in-operation planning. In this sense, lightpath provisioning can be automated and network resources can be made available by reconfiguring and/or re-optimizing the network on demand an in real time.

The ANM architecture is based on ABNO Application-Based Network Operations). ABNO provides coordination of Operating Operating Support System (OSS) and Network Management System (NMS) requests to compute paths, enforces policies and manage network resources for the benefit of the applications that use the network.
The Path Computation Element (PCE) is an “All Seeing Eye” capable of determining the network path across a variety of physical or virtual networks. It is an integral component of the IDEALIST network control platform, furthermore the PCE provides network path intelligence within a variety of recent OpenSource Software Defined Network (SDN) controllers. The IDEALIST team have been researching PCE and identifying the technical gaps for elastic optical networks and other applications, these were then documented in an Internet Engineering Task Force (IETF) proposed Request for Comments (RFC) document entitled “Unanswered Questions in the Path Computation Element Architecture”. An RFC is a publication of the IETF and the Internet Society, the principal technical development and standards-setting bodies for the Internet. We are pleased to announce that our research was successful and our proposal was adopted by the IETF working group responsible for technology and recently published as RFC7399 in October, 2014.  
Flexible transponder evolution.

Traditional optical transmitters and receivers convert a single traffic flow of a fixed capacity (e.g. 10 Gb/s or 100 Gb/s bit rates) from the electronic domain into optics and vice versa, to allow transmission of light through an optical fibre for reaching a faraway destination. A specific adaptation and shaping of the signal is necessary to cope with

- the needs of the transmission media (fibre has a huge but finite usable bandwidth, and propagation introduces distortions),
- the distance to the destination nodes (often intermediate optical amplification is required, which means addition of noise tending to mask the signal),
- and the need to optimize the capacity by squeezing several optical signals in the same fibre.

Traditional transponders do this job in a fixed and un-flexible way. Further, if we also consider the new emerging requirements of flexibility of each traffic flows in terms of capacity and routing in the network, together with the effort of maximizing reach and spectral efficiency at the same time, we can easily realize that a traditional transponder is most likely inadequate.

The Bandwidth Variable Transponder (BVT) was invented to address these issues. In general, BVTs represent a transponder class able to dynamically tune the required optical bandwidth and transmission reach by adjusting parameters such as gross bit rate, Forward Error Correction (FEC) coding, modulation format and shaping of optical spectrum. BVTs enable a trade-off between spectral efficiency and transmission reach, using spectrally efficient modulation formats (e.g., PM-16QAM, PM-64QAM) for short-reach connections, and more robust but less efficient modulation schemes (e.g. PM-QPSK) for long-haul links. The transmission bandwidth (up to a maximum value) is still exclusively dedicated to a single traffic demand and a single optical carrier is generated, feeding a single channel.

A Sliceable Bandwidth Variable Transponder (S-BVT) attempts to overcome this type of exclusiveness between the generated optical carrier and the served traffic relation. In this sense, the S-BVT is a further enhancement of the general BVT concept: S-BVTs enhance BVT functionalities being able to allocate their capacity into one or several independent optical flows that are transmitted towards one or multiple destinations. Consequently, unlike BVTs, their transmission net bandwidth may be spread (or sliced) to serve several independent traffic demands simultaneously. All S-BVT electronic and optical resources can be flexibly partitioned into a number of groups equal to the number of simultaneous independent optical flows. As a result, the optical output of an S-BVT is a group of super-channels (i.e., optical connection composed of several adjacent sub-carriers independently modulated with traffic) with different destinations and modulation formats employing different portions of the optical spectrum. Thus, an S-BVT should be considered as a collection of “virtual” lower-capacity BVTs (one for each elemental sub-carrier), logically associated in groups to generate independent super-channels.

S-BVT find application whenever transmission characteristics can be set based on actual traffic demands

- by dynamically expanding or contracting the bandwidth of an optical path (e.g. varying the number of sub-carriers),
- by adapting the optical reach in dependence on the optical signal-to-noise ratio (OSNR),
- by directing the super-channels towards multiple destinations,
- or when recovering unpredictably failed IP router connectivity by the aid of a single S-BVT spare interface.

To achieve these functionalities, modulation format or code-rate of
The IDEALIST’s S-BVT modular architecture.

General specifications:
- Support of existing and future 400 Gb/s and higher bit rate services of yet-unknown bandwidth.
- Total net capacity: up to 1200Gb/s.
- Number of slices: from 1 to 12 without limitations (from 100Gb/s to 1200Gb/s net in 100Gb/s steps).
- Few cards (2 or 3, see schematic below) to accommodate:
  - Several clients modules.
  - OTN mapping and fabric electronic.
  - Flexible OTN framer.
  - Multi-flow optical transmitter modules.
- Modular solution with two hot pluggable multi-flow optical modules with 2 sub-carriers or 4 sub-carriers, respectively.

Client side:
One or more “client side” cards with state-of-the-art pluggable modules to hold:
- 3x 400G OTN next generation/400GEth,
- 12x 100G OTN/100GEth,
- 120x 10G OTN/10GEth/STM64,
- Or any mix of the previous interfaces.

Line side:
- PM-QPSK, PM-8QAM, PM-16QAM, PM-64QAM modulation formats or optical Time-Frequency Packing (TFP) methods.
- Variable net baud rate per sub-carrier from 25Gbaud up to 35.
- FEC overhead variable from 7% up to ≈23.
- Potentially support of flex-rate schemes like Time-Division Hybrid Modulation (TDHM)
- Support for several transmission techniques, coding and shaping.
Several technical papers supported by IDEALIST have been presented by consortium partners at the European Conference on Optical Communications conference:

6. “CAPEX Impact of Fixed/Flex-Rate Modular Line Interfaces in Multi-Period Network Planning with Equipment Reuse” by António Eira, João Pedro, João Pires, Juan Fernández-Palacios.
12. “Non Quadrature Intensity Modulation Formats” by J.C. Antona, P. Layec, G. De Valicourt.
17. “Network optimization exploiting traffic grooming techniques under fixed and elastic spectrum..."
IDEALIST’s Work Package 1 leader Andrew Lord from BT provide a one hour tutorial of honor on flexgrid and Elastic Optical Networks, at the European Conference on Optical Communications in September in Cannes.

Andrew heads up Work Package 1 of IDEALIST which is concerned with determining the benefits of elastic transceivers and a more flexible grid for European operators.

ECOC is one of the two premier optical communications conferences and it is highly prestigious for IDEALIST to have a prominent role in a tutorial of this nature. The talk began with a detailed introduction to the concept of a flexible grid with a fine spectrum control down to a few GHz, and a similar discussion on the scope for tuning transceivers via different modulation formats and forward error correction rates.

One central message from the talk involved some network capacity results as shown in table 1. Here we see the effect of loading traffic onto key reference networks using an IDEALIST simulation tool. Traffic is loaded on until there is 10% blocking. As can be seen, the flexible grid provides a roughly similar benefit irrespective of network size, whereas the scope for moving to higher QAM modulation is much greater in shorter scale networks such as the UK.

The talk finished by raising the open questions surrounding this highly popular field of research. These included:

- To what extent will the optical layer see dynamic traffic in the future?
- IP over flexgrid – will the layers finally come together?
- Will we see a revolution in transponders towards Sliceable-Bit Rate Variable Transponders?
- As spectral efficiency limits are reached, the next step logically is towards multiple parallel fibres or even SDM. How will flexibility be extended in a multi-fibre scenario?

IDEALIST, now in its final year, continues to look in detail at these challenging questions and will no doubt provide more up to date answers at ECOC 2015.

<table>
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<tr>
<th>Network</th>
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