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Abstract:

The activities within TF-NGN on Optical Networking are discussed. Implementations of systems like: fiber specifications, DWDM systems, optical cross-connects are being investigated. Testbeds that utilise these products are described. Furthermore a future testbed (called ASTON: A Step Towards the provision of Optical Networking) as part of FP6 of the EC is being proposed.

Keywords: Optical networking, WDM, Optical Cross connect, OXC, WDM transmission systems, test bed, requirements on fiber.

Contents

1. Executive Summary

National and regional research networks often have to fulfill two remits: (i) to provide high-speed and high availability production networking services to their user communities and (ii) to support research into new networking technologies and network architectures in their own right. Clearly the latter provides invaluable input in to the development of the former.

It is also clear that the increased adoption of optical networking technologies by the research networks will play an important role in meeting both of these remits. It is likely that the next few years will see those that operate research networks taking on more of the functions that were previously only done by the suppliers of connectivity services. Thus a number of NRENs are gaining access to infrastructure such as dark fibre and starting to experiment with operating equipment such as DWDM transmission equipment.

There is also a great deal of discussion on issues such as Bandwidth on Demand (BoD) and whether research networks should be offering this to their user community. Optical networking technology (for example, wavelength switching) is one way in which BoD can be offered and at the same time allow support for very high capacity requirements (e.g. up to 10 or even 40Gbit/s). Indeed, it is likely that research networks will be required to support user groups and ad hoc projects with connectivity requirements of this order within the next few years.

However, there is a lot to learn with regard to optical networking and the technologies that enable it. As part of the TF-NGN activity on Optical Networking, DANTE, TERENA and the European NRENs have been gathering information on the state-of-the-art of optical networking technology. The ever-increasing demands of the research networking community in general are such that this community is likely to be an "early adopter" of cutting edge optical networking technology. At the very least, research networks are seen as presenting a useful testbed opportunity to try out fledgling optical networking technologies in a real network environment - especially when the current economic climate has meant that many commercial networking testbed activities have been severely cut back.

This document contains summaries of the current state of commercially available state-of-the-art optical networking technologies and covers DWDM transmission systems (including those that operate at 40Gbit/s) and optical switching systems. Clearly the current economic climate has had a massive impact on the development cycle in this sector and many product development programmes have slowed right down or been stopped altogether (notably in the case of Lucent's LambdaRouter all-optical cross-connect).

In addition, there are some descriptions of current and forthcoming optical testbeds. These include the Polish NREN's experiments with operating Alcatel DWDM transmission equipment over their own dark fibre, the IST LION project testbed and a planned optical networking demonstrator to be built by the Technology Center of T-Systems Nova.

Finally, a description of the ASTON integrated project expression of interest is included. ASTON (A Step Towards the provision of Optical Networks) has essentially emerged from the TF-NGN activity described in this document and the project is being proposed as part of the EC's 6th Framework Programme. It will concentrate on the dissemination of knowledge on optical networking and finding possible partners to do Europe-wide testing on technologies and methodologies needed for optical networking.

2. Introduction

The work within the GÉANT/TERENA TF-NGN working group on Optical Networking is based on its activity plan [1].

The main activities in this plan are: (a) to be a platform between the NRENs to exchange and discuss optical networking related activities and (b) to investigate whether practical pan-European tests can be arranged on the issues involved around optical networking. This last point has accumulated in an Expression of Interest (EoI) towards the European Commission's 6th Framework program. This EoI is called ASTON: A step towards the provision of optical networking.

The results of these two activities to date are discussed in the following sections.

3. Information Exchange on Optical Networking

Due to the present status of the telecommunications market, exchange of information is the most important item with regard to optical networking. The research networking community needs to understand what manufacturers can provide and needs to get ideas from people that have experience with these new and related technologies. The following sections will cover a broad scheme of subjects:

- **DWDM Transmission Systems**

  Several DWDM equipment manufactures have been asked to talk about their equipment. Short summaries are presented in the following.

- **Optical Testbeds**

  A number of optical testbeds are emerging and NRENs and operators have been exchanging information on these experiments with TF-NGN.

- **Optical Cross-Connects (OXC)**

  "Optical" cross-connects[1] are essentially of two types: OEO where optical signals are converted into the electrical domain for switching and/or (de)multiplexing before being converted back to optical signals and all-optical (often referred to as OOO) where switching is done entirely in the optical domain with no electrical conversion being required. An appealing feature of the all-optical cross-connect is that it is transparent to the (electrical) framing of the optical transport signals being switched whereas the OEO switch is not. Although the current market conditions are far from favourable for the development and marketing of OOO switches, there are still a number of vendors developing products and some of these have been exchanging information with TF-NGN/DANTE.

- **Specification of dark fiber or lambda services**

  NRENs do not yet have much experience with running dark fiber or lambda services of their own. This section will provide some ideas on the specification of such services.

[1] In order to avoid confusion, the term "optical cross-connect" is here taken to mean a device which has the functional capability of space switching at the level of optical wavelengths, bundles of wavelengths or an entire fibre's worth of transmission (all wavelengths).

3.1 *Definition of the term* "Channel"

In this document the term *channel* will be used for describing a link with a certain capacity and QoS between two points. This *channel* can be realized by: a dark fiber, a pure lambda, an optical path, an SONET/SDH container, Ethernet channel, ATM PVC, etc.

In this document *channel* is most of the time a dark fiber, an SONET/SDH container or an Ethernet channel (the last two sometimes also called light channel). In the future it is expected to be extended to pure lambda's or optical paths.

3.2 *DWDM Transmission Systems*

A short summary of DWDM equipment features will be provided in this section. To date, equipment from Alcatel, Lucent and Photonex has been investigated by TF-NGN/DANTE.

3.2.1 Alcatel

Alcatel make a number of DWDM transmission systems aimed at the core and regional/metro sectors. These include:

- The Alcatel 1640 system (80/160 channel long haul DWDM system)
- The Alcatel 1660 system (adds optical channel protection and path switching capability to the above)
- The Alcatel 1686 WM (32 channel DWDM system for regional/metro networks)
- The Alcatel 1696 Metro Span (32 channel DWDM system for amplified or non-amplified metro networks)

Hands-on experience with the Alcatel 1686 WM and 1696 Metro Span systems has been gained by the Polish NREN (PSNC) and this is summarized in the section on optical testbeds (section 3.3).

3.2.2 Lucent LambdaExtreme

Lucent is the only large network equipment vendor that has not shelved its development of (or, at least, delayed their market introduction of) a 40 Gbit/s DWDM transmission system. Their "LambdaExtreme Transport" system supports up to 64 × 40 Gbit/s wavelengths over distances of up to 1000 km and includes OADM capabilities. As with the Photonex offering, the only client interfaces that are currently supported are STM-16c and STM-64c (4-port versions of each).

This system has been successfully lab and field trailed by T-Systems (but using third-party PMD compensators since Lucent's own were not ready).

Little more detail is known about the LambdaExtreme system since face-to-face meetings Lucent and TF-NGN/DANTE have not yet been held.

Further details on the LambdaExtreme Transport system can be found at:

http://www.lucent.com/solutions/core_optical.html.

3.2.3 PhotonEx

PhotonEx is a US-based optical transmission equipment startup that has developed a 40Gbit/s DWDM transmission system. They claim to be able to support 40 wavelengths each at 40Gbit/s over distances of up to over 2000km using optical amplifiers alone (i.e. no OEO 3R regenerators required) using standard single mode fibre (G.652 or G.655 NZ-DSF).

In addition, their equipment has OADM functionality that can optionally be added to their optical amplifier equipment shelves. In the current product this allows up to 25% of the wavelengths passing through an amplifier site to be switched (under software control) between being pass-through (express) wavelengths or add/drop wavelengths. However, the 25% of the total number of wavelengths must be pre-selected at the time of installation. The remaining 75% cannot later be switched between express and add/drop unless hardware reconfiguration is performed. PhotonEx plans, in its next product release, to support the ability to be able switch *all* of the wavelengths between being express or add/drop.

Currently the only service interfaces supported by the PhotonEx terminal equipment (their optical multiplexor shelf) are STM-16/STM-16c and STM-64/STM-64c. They plan to support a native 40 Gbit/s service interface and 10GE interfaces in the future.

As with the Lucent 40G equipment, the PhotonEx equipment has been successfully lab and field trailed by Deutsche Telekom AG.

A presentation on the PhotonEx transmission system was given at a recent TF-NGN meeting but, since some of the contents of the presentation were confidential, no link to the presentation can be provided here. Further information (in the public domain) can be found at http://www.photonex.com.

3.3 Optical Testbeds

3.3.1 Polish Optical Internet Testbed (POIT)

The following describes the experience to date of the Polish NREN PSNC with optical transmission systems.

The purpose of creating the Polish Optical Internet Testbed (POIT) in the begining of 2000 was to test all, or as many as possible, technologies which allow us to build the optical Internet within the environment of different telecommunication operators.

Alcatel 1686WM tests

First built POIT network has been connected to the operating MANs (in Poznan, Gdansk, Wroclaw and Lodz) and via the POL-34/155 national network with the MANs taking part in the pilot applications testbeds (Krakow, Gliwice) to the FAIRnet - the network operating within the Poznan International Fair that connects all exhibitor stands providing Voice over IP services and conference events boadcasting.

The following connections were used:

- Poznan – Wrocław (180 km) based on the DWDM 1686WM system delivered by ALCATEL, with a bandwidth of 12,5 Gb/s (5x2,5 Gbit/s lambda) and one multi-rate card (accepting signals fro 100Mbit/s to 1.2 Gbit/s. Three of them used for ATM transmission (2,4 Gbit/s delivered by Fore/Marconi), POS transmission (155 Mbit/s and 2,5 Gbit/s delivered by ALCATEL) and Gigabit Ethernet (1/2,5 Gbit/s delivered by 3Com).It has been built on dark fibers delivered by the Polish Railway Telecommunication Company (PKP), with single optical signal regenerator.

- Poznan – Gdansk (300 km) – based on ATM technology (Fore/Marconi nad Cisco switches) with a bandwidth of 622 Mbit/s, built on dark fibers delivered by PKP and optical signal regenerators delivered by RAD
- Poznan – Łódz span (210 km) – based on ATM technology (Fore/Marconi switches) with bandwidth of 155 Mbit/s, 155 Mbit/s SDH channel has been delivered by TEL-ENERGO Company.
- PSNC – ISThmus 2000 Exhibition (10 km) based on the ATM technology (Fore/Marconi switches) with a bandwidth 622 Mbit/s, built on dark fibers delivered by PSNC.

The following pilot applications have been run on the testbed:

- National Computing Grid,
- Distributed Data Archiving,
- Live Video Transmission,
- Distributed Three-Dimensional Life Simulation

Availability of advanced equipment allowed the performance of a number of tests of the DWDM transmission system, including:

Testing cooperation with SDH systems – the aim of the test was to check the interoperability of SDH devices and Alcatel 1686 WM system connected by a standard optical fiber G.652. SDH signal has been looped to pass 2 DWDM terminals and BER has been measured by SDH analyser.
Signal quality depending on the number of DWDM channels – the test aimed at measuring the influance of different signals to each other in DWDM line during changes in configuration: i.e. switching individual channels on and off in DWDM system. These tests have been done with the use of optical spectrum analyser, SDH analyser, and tunable lasers.
Optical budget – measurement of the maximum attenuation which could be inserted in the optical network in tested system. A tunable optical attenuator has been installed in optical line and BER has been measured by the SDH analyser.
Signal spectrum analysis – aimed to gather an overall spectral characteristics in different measurement points.

Alcatel 1696 Metro Span tests

Between April and June 2002 PSNC was able to perform functional testing of metropolitan WDM platform, Alcatel 1696 - a new generation WDM system, equiped with OADM, tunable lasers, optical protection and multi-rate cards. The delivered system was able to transmit 32 channels, 2.5 Gbit/s each with multi-rate cards able to adapt to user side signals between 100Mbit/s and 2.5Gbit/s. It was connected with two OADM devices capable of adding/droping eight or four lambdas, thus creating a 3-node ring. This system has been tested in our local laboratories and the tests included:

BER measurement for different (STM-1, STM-4c, STM-16c) speed interfaces.
Optical power of signal delivered to user interface from multi-rate card.
Optical power of signal delivered to WDM multiplexer interface from multi-rate card.
Sensitivity of transponder multi-rate card.
Optical budget measurement for optical line.

Additional tests were performed to confirm the functionality of management systems, including configuration, monitoring of physical parameters, maintenance functionality, optical protection and alarms.

PSNC also started work on the Open Network Management model, which would allow for an integrated management of optical network components, including fibers, terminals, alarm management and wavelength routing.

3.3.2 The IST LION Testbed

The main goal of the IST Project LION is to design and test a resilient and managed infrastructure based on an advanced Automatic Switched Optical Network (ASON) carrying multi-clients. Innovative functionality (such as dynamic set-up of optical channels driven by IP routers via User Network Interfaces and OS) will be developed and validated in an Optical Internetworking test bed; particularly the test bed integrates IP Giga Switch Router (GSR) over Optical Network Elements. The project's main activities regard the definition of the requirements of an integrated multi-layered network; the implementation of both data (Digital Wrapper - ITU-T G.709) and signaling of UNI (User Network Interface) and NNI (Network Node Interface); the design and implementation of an "umbrella" management architecture enabling an end-to-end view over domains with different management technologies (eg. SNMP, WBEM, $Q_{3,}$ CORBA) and over the different network layers, the analysis of OA&M concepts at the protocol level (LMP); and the definition of effective resilience strategies for IP over Optical Networks. Finally, network planning and evaluation activities will identify convenient areas for IP over Optical Networks deployments.

More information can be found at: http://www.telecom.ntua.gr/lion.

3.3.3 The T-Systems Global Seamless Network Testbed

The Global Seamless Networks project is a work package being conducted by the Technology Centre of T-Systems Nova that is intending to examine the issues associated with building heterogeneous, multi-domain advanced (switched) optical networks. A key part of this work is the design and construction of a wide area as well as a metropolitan area testbed making use of real Deutsche Telekom fibre infrastructure in Germany. This is currently still in the specification and planning stage and it is intended that the testbed will be operational during the second half of 2003. The likely topology of the optical core of this testbed will be based on having four geographically separated optical switches (two in Berlin, one in Hannover and one in Darmstadt. From one of the Berlin switches will be UNIs to a 10 GE MAN and a router and similarly in Darmstadt there will be UNI's to some 1 GE and 10 GE Ethernet switches (currently being tested) and another router. This is shown below in Figure 1.

Standards work that will be incorporated in this testbed include the OIF UNI and NNI specifications, the ITU-T ASON, G.8080 and other related specifications, the IETFs GMPLS recommendations (as extended to SONET/SDH and G.709) and the IEEE 10 GE standard. The project will also look at management of the optical transport network using a centralised NMS and a decentralised control plane model.

The proof of concept demonstrations performed on this testbed will be based around a number of show cases that will include: the ASON/GMPLS NNI and UNI, broadband client network access at up to 10G, ASON/GMPLS to Ethernet MAN interworking and enabling technologies (ULH DWDM and high capacity TDM systems).

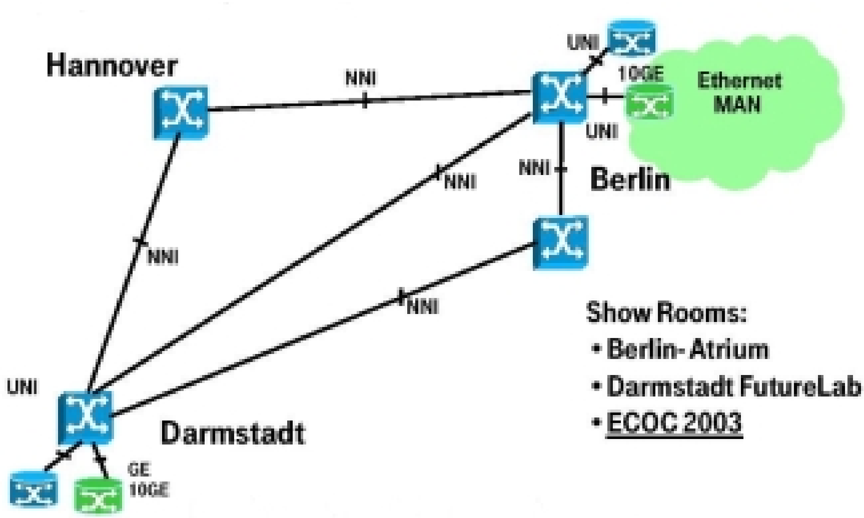

Figure 1: Proposed Topology of T-Systems Global Seamless Network Testbed

3.4 Optical Cross-Connects

A few short years ago, during the telecommunications boom years, the concept of the all-optical cross-connect was very much in vogue and many network operators saw a place for OOO switches in their transmission networks. Numerous startups appeared investing many millions of venture capital dollars into developing the new technologies that are required to do OOO switching. Many of these were bought by the larger, more well-established telecommunications equipment vendors wishing to add OOO switches to their product ranges. However, the rationalisation that has taken place in the market over the last couple of years has seen a significant decline in the drivers for the deployment of such switches by operators and therefore the drivers for the vendors to continue with any significant investment in their development. Thus we have seen a number of the startups failing and the larger vendors shelving development. A significant example of the latter was the recent announcement by Lucent that they are to halt development of their LambdaRouter OOO switch (see below).

Nevertheless, some OOO switch vendors still remain and it is likely that research networks could become early adopters (or, at the very least, serious trialists) of such technologies. In this section are presented summaries of the products of a number of optical cross-connect vendors that have met with TF-NGN/DANTE during the past year.

3.4.1 Calient Networks

Calient Networks is an advanced optical networking startup founded in 1999 by three experts with strong backgrounds in switch design, optical components and GMPLS. Their product is the DiamondWave Photonic Switching System which can be looked upon as a "photonic server" at the core of which is a 3-D MEMs array based optical switch.

The concept of a 3-D MEMs array optical switch is shown in Figure 2 below. The only functionality that this component has is to switch an entire fibre's worth of optical channels (wavelengths) from one port to another. It is based on two arrays of MEMs that can be oriented in any direction. A switching operation relies on a given optical path being reflected from one of the MEMs in *each* of the two arrays (e.g two reflections) to give the non-blocking characteristic to this switch.

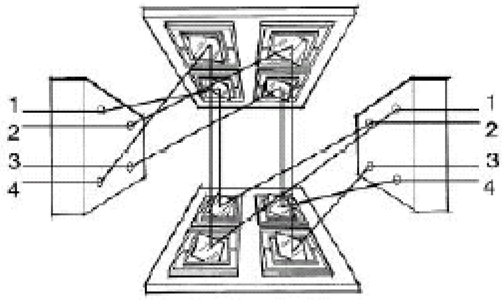

Figure 2: A Simple 3-D MEMs Array

Clearly the individual MEMs must be positioned to within a very high tolerance and moreover this position then be accurately maintained. This necessitates a large amount of highly sensitive analogue electronics and complex feedback mechanisms for each and every MEM in the two arrays. Indeed much of the hardware complexity in the DiamondWave optical switch is associated with these analogue electronic systems.

The "photonic server" nature of the DiamondWave switch arises from the fact that the (bidirectional) input/output ports can be connected to external systems (e.g. DWDM line systems) or to service modules that can be plugged into the DiamondWave chassis. These modules can provide functionalities such as optical add-drop multiplexing, amplification, OEO multiplexing, wavelength shifting and so on. They can be switched in and out of a given optical path in various combinations thereby allowing the DiamondWave switch to be more than just an all-optical switch.

With regards to the control plane for the DiamondWave switch, CALIENT are closely involved with the emerging GMPLS standard and release 2 of their switch software will support full GMPLS networking, auto-restoration, network-wide provisioning, topology discovery, etc.

The DiamondWave switch currently comes in two sizes: the DiamondWave 256 has a 256 bidirectional port switch fabric at its core and the more compact DiamondWave CE system can support up to 128 bidirectional ports.

For more information see: http://www.calient.net.

3.4.2 Network Photonics

Network Photonics is a US-based optical networking startup that has developed a so-called 1-D MEMs array based Wavelength Selective Cross Connect (WXC) subsystem. The principles of this are as follows. Firstly, the MEMs arrays used are 1-D. This means that the micromirrors are fabricated in linear arrays with each mirror see-sawing between two distinct positions. Each mirror thereby acts as a (bidirectional) optical 2-way switch. This is illustrated below in Figure 3.

A significant advantage of this approach over that of the 3-D MEMs array is that the control electronics is much more simple than the delicate analogue electronics needed to adjust and maintain the positions of the fully steerable mirrors in a 3-D MEMs array. However, this comes at the expense of versatility and, in order to produce a non-blocking optical switching matrix with a reasonable number of physical ports, it is necessary to combine many of the 2-way switching elements in a potentially complex configuration. In addition, where an optical path is traversing many of the 2-way switching elements, there will be significant attenuation of the signal meaning that further optical amplification will be required in traversing a single node.

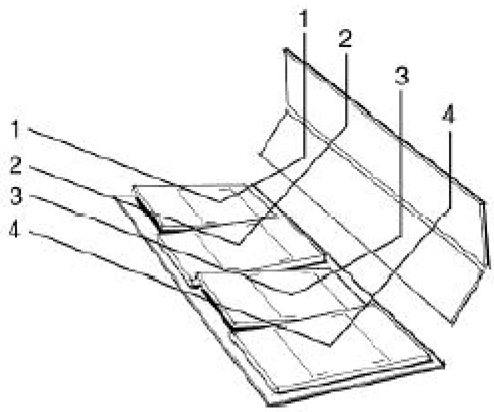

Figure 3: A 1-D MEMs Array

The "wavelength selective" nature of the Network Photonics Cross Connect arises from the fact that wavelength dispersive elements, passive splitters/combiners and wavelength extinction devices are included within the configuration to demultiplex the wavelengths on an incoming port, selectively switch them and recombine them on different output ports. Of course, all of this is done purely in the optical domain.

A shortcoming of this approach is that the number of physical ports in a given discrete WXC subsystem is low when compared with the 3-D MEMs array approach of Calient, Tellium, Lucent and others. A typical port count in a subsystem might be as low as 4 ports (2 x 2) which is significantly less than the 128 or 256 ports on the Calient optical switch. However, each port can carry up to 96 wavelengths and each of the wavelengths on the two input ports can be independently switched to either one or both of the two output ports. This can then be used as either a WXC or as an OADM.

Two such WXC subsystems can fit into a single 3RU chassis - a significantly smaller space than the full rack occupied by the 256 port Calient optical switch.

One key feature of Network Photonics' business model is that they are not intending to manufacture and sell their own standalone all-optical switch but rather their CrossWave Wavelength Switching subsystems are really designed for OEM DWDM and DSC system providers.

For more information see: http://www.network-photonics.com.

3.4.3 Lucent

The LambdaRouter

The LambdaRouter is Lucent's 3-D MEMs based all-optical switch. There are two fabric sizes: 128 ports and 256 ports. In addition to the transparent I/O interfaces (with optical power level monitoring), there are also selective OEO 3R I/O ports with advanced SONET/SDH monitoring.

As with the Calient switch, the LambdaRouter supports GMPLS.

As with the other Lucent products, little more is known about this product since face-to-face meetings with Lucent have yet to be held.

HOWEVER, what is known is the fact that Lucent have recently announced that it will discontinue development of the LambdaRouter due to the current adverse market conditions.

Further details on the LambdaRouter can be found at:

http://www.lucent.com/solutions/core_optical.html.

The LambdaUnite Multiservice Switch

Lucent's LambdaUnite MultiService Switch (MSS) is basically a large SDH switch with support for direct and passive DWDM optical systems.

T-Systems are currently employing the LambdaUnite MSS as the core OXCs in their so-called "Global Seamless Networks" demonstrator.

Further details on the LambdaUnite MSS can be found at:

http://www.lucent.com/solutions/core_optical.html.

3.4.4 Other Optical Cross-Connects

Optical cross-connects (OXC) from a number of other vendors have yet to be studied. These are:

- The Alcatel 1660 Cross Light Photonic Cross-Connect (http://www.alcatel.com/products/productsbysubfamily.jhtml?subCategory=Optical+Cross+Connects)
- The Aurora Wavelength Switches from Tellium (http://www.tellium.com/products/auroraOpticalSwitchfeatures.html)
- The Optical Convergence Switch (OCS) from Corvis (http://www.corvis.com) and
- The CoreDirector products from Ciena (http://www.ciena.com/products/switching/index.asp).

The last two products use a different technology to the MEMs-based offerings discussed above: instead they use liquid crystal technology from Corning and therefore cannot support the switching of as many wavelengths as the MEMs-based equivalents.

4. Dark Fibre and Light Channel Service Specifications

This section will discuss items that are important when investigating the deliverable services looking at dark fibre and light channel services. No specification is given for a "lambda service" (a pure wavelength), because at this moment it is not expected to have such services in the next few years. The overview of the specification provides the list of questions but not the values that are needed (these will depend heavily on the use of the services). A good overview of the ideas can also be found in the following Cisco PowerPoint presentation: http://www.sura.org/events/2001/optical/cavanaugh1.ppt

4.1 Dark Fibre Service

The following items are important to evaluate when asking for a dark fibre service:

- In a true dark fibre service, no equipment is between the two end points of the service. So check this beforehand. In long distance systems, regeneration equipment can be installed, thus making the service less transparent.
- When asking for dark fibre services also ask for co-location space. Sometimes you will want to install multiplexers or repeaters at the ends of the dark fibre.
- In case one needs a dark fibre of a long distance ask how the sections of the dark fiber are routed and whether co-location is available at all the end points of these sections.
- If the dark fibre section is not made from one single strand (if longer than 2 km), ask how many splices and/or connectors are in the path.

- Going into the specification of the dark fibre:

  - Give to the supplier of the service information about which frequencies (wavelengths) will be used over the dark fibre service.
  - Define a connector panel with the correct connector type or splice. Remember every patch cable adds 0.5dB attenuation, so specify the correct connectors (e.g. SC/PC).
  - Ask the type of fiber (G.652/G.655), the brand, mode (multi mode or single mode) and full specification sheets of the fibre. Remember that every brand has its own details (even if they align to the same ITU-T standard).
  - Ask the cleaning procedures used when splicing and connecting strands of fibre (remember that at 10 Gbit/s and higher, cleaning procedures for the strands before making any connection is **very** important).

- Ask the following information for **each** section the dark fibre service is composed of:

    - Number of splices in section
    - Number of connectors in section
    - The attenuation in both directions [dB] in section
    - The optical return loss (at both ends of the section) [dB]
    - The Chromatic Dispersion (CD) [ps/nm] in section
    - The Polarization Mode Dispersion (PMD) [ps] in section. (This is of particular importance for transporting speeds of 10 Gbit/s and higher.)
    - The route each section takes and its expected mean time between failure (MTBF). MTBF is dependent on e.g. if a route is through a city, building estate, railway, countryside, etc.
    - The mean time to repair (MTTR) for each section. This is very important to know, for instance when one has dark fibre along overhead high voltage power transmission lines, the MTTR can be high (several weeks) because priority is with power distribution instead of fibre/data services.

    - For each deliverable section the above parameters need to be tested by the provider (and documented)
    - The providers needs to provide indication on deterioration values of the above

- An overview must be presented on which test equipment the provider has in its possession (for faultfinding or helping out the customers), like OTDR, LTS and CD/PDM measurement equipment.

4.2 Light Channel Service

At present a light channel is defined as something with a so-called black & white colour (as defined in SDH/SONET/GE interfaces), so **not** a lambda colour as defined by ITU-T G.694.1 for DWDM or G.694.2 for CWDM (100 GHz line spacing). Currently the optical characteristics of the SONET/SDH interfaces (G.957 for 2.5 Gbit/s, G.691 for 10 Gbit/s, etc.) and the framing methods used for SDH/SONET (G.707 and G.783) and for 1 or 10 GE are normally mandatory for these light channel services.

In the future digital wrapper technologies (like G.709 or the ideas on generic wrapping) will enhance the light channel service.

The following points are important for a light channel service (if it is known that the terminating interface of a provider is close to the customer interface, some of these questions are not so important):

- What is the framing supported (SDH including concatenation, SONET, GE, etc.) and what are the speeds supported?
- What is the wavelength of the light used (850, 1310, 1550 nm or other)?
- What connectors are provided at the connector panel?
- What is the minimum and maximum transmitter power [dBm]?
- What is the receive saturation power [dBm]?
- What is the minimum receiver sensitivity power [dBm]?
- What are the Chromatic Dispersion [ps/nm] and Polarization Mode Dispersion [ps] provided to the end points?
- What is the guaranteed BER?
- What are the MTBF and MTTR of the service?
- What routing is used (path diversity)?
- What equipment does the provider have available (also to support customers) like: OTDR, LST and CD/PMD measurement equipment?

5. Future Work in TF-NGN on Optical Networking

The TF-NGN activity on optical networking has culminated in the production of an Expression of Interest (EOI) for an Integrated Project to be funded under the 6th Framework Programme of the EC. The main goal of this project will be to exploit, disseminate and understand optical features by building and operating a wide-scale testbed. Moreover, it aims at creating a feedback loop with providers and manufactures that can greatly speed up the bandwidth deployment in Europe. The results will be used for engineering new network architectures and provisioning models. A copy of this EOI can be found in Annex A (page 17).

The future work of TF-NGN on optical networking will be around the above mentioned EOI. Some items will be picked out in more detail, like:

- Continuation of knowledge dissemination and discussion will be an important part of the future meetings on this subject.
- A more detailed ASTON WP description will be made with regard to 'Bandwidth on Demand' (a brainstorm will be held in September 2002). This activity will be managed by HEAnet.
- Work has been started in defining what tests can be done on 40 Gbit/s and beyond. This activity will be managed by INFN and PNSC.
- Work has been started on 10 GE over long distances. CESnet wil coordinate this activity.
- Cooperation with EC projets like: LION, OPTIMIST and SERENATE.
- Progressing the Expression of Interest into an EC FP6 Integrated project. The coordination will be done by HEAnet and TERENA.

6. Abbreviations

ASTON	A Step Towards the provision of Optical Networking
ASON	Automatic Switched Optical Network
BER	Bit Error Rate
BoD	Bandwidth On Demand
CD	Chromatic Dispersion
DWDM	Dense Wavelength Division Multiplexing
EOE	Electrical Optical Electrical
Gbit/s	Gigabit per second
GE	Gigabit/s Ethernet
GMPLS	Generalized Multiple Protocol Label Switching
LTS	Loss Test Set
MEM	Micro-Electro-Mechanical
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
NNI	Network-Node Interface
NREN	National Research and Educational Network
NZ-DSF	Non Zero Dispersion Shifted Fibre
OADM	Optical Add Drop Multiplexer
OTDR	Optical Time-Domain Reflectometer
OIF	Optical Internetworking Forum
OOO	Optical Optical Optical
OXC	Optical Cross Connect
PMD	Polarization Mode Dispersion
POIT	Polish Optical Internet Testbed
POS	Packet Over Sonet
TDM	Time Division Multiplxing
TTC	Terena Technical Comity
TF-NGN	Task Force-Next Generation Networks
UNI	User Network Interface
3R	Regeneration, Reshaping and Retiming

7. Annex A

ASTON: A step towards the provision of optical networking

This Integrated Project EoI (ASTON: A step towards the provision of optical networking) is a result of the TF-NGN activity on optical networking, which concentrates on dissemination of knowledge on optical networking and finding possible partner(s) to do Europe-wide testing on technologies and methodologies needed for optical networking.

This Express of Interest is based on the above mentioned activity and holds the following sections:

- Needs & relevance
- Scale of ambition & critical mass
- The activities in the integrated project that will be undertaken, including information on:
  - the proposed time scale and
  - the resource (services, manpower and equipment) needed to realize the activities
- The project's organizational structure

Needs & Relevance

This Integrated Project addresses the Thematic Priority 1.1.2ii.

The main goal of this Integrated Project will be to exploit, disseminate and understand optical features by building and operating a wide-scale testbed. Moreover, it aims at creating a feedback loop with providers and manufactures that can greatly speed up the bandwidth deployment in Europe. The results will be used for engineering new network architectures and provisioning models.

The project will provide an opportunity to get real hands-on experience within pan-European networks in the areas of Bandwidth on Demand, Network Management, Transport at 40 Gbit/s and beyond, and 10 Gbit/s Ethernet over long distances. Going beyond 10 Gbit/s is a real quantum shift for all the technologies involved, hardware and software, as well as for the challenges in organisation and network operation and planning. Additionally, monitoring at 40-80 Gbit/s and higher is a new realm with many consequences in terms of sampling, storage, processing, etc all needing to be addressed in the very near future. These goals together put the ASTON project in a position of strategic importance to maintain and improve the cutting-edge role of European Research Networking.

ASTON will set up experiments at a pan-European network level, but also at the local, national and small-scale international level, as these complement each other. Gaining knowledge and experience in the context of NRENs and international organizations, will be the first outcome of this project. Based on this experience, the ASTON consortium will pilot services to be provided as a pre-production service in the future. The operational experience with international carrier service providers and equipment (IP, optical, test, etc) manufacturers is essential in this process, as well as the co-operation with other network organisations like Internet2 and CANARIE.

The ASTON EoI has a number of relationships with other FP6 EoIs. It is viewed as a fundamental development activity complementary to the FP6 activities on deployment of research infrastructure - GÉANT, as expressed by the NRENPC. It is also viewed to be complementary to the IPOTESI EoI which aims at defining a new operational service relationship between research networks and carriers.

Scale of Ambition & Critical Mass

The evolution of NRENs depends on a good understanding of optical networking. This is being done more and more on a national level so inter working at an international level is crucial.

Interest in the subject of optical networking is becoming of the outmost importance due to a lot of existing activities in NRENs like CANARIE, GRnet, SURFnet, PSNC, etc. Other NRENs in Europe are using comparable initiatives. A good example of this interest is the successful 1st International Lambda Workshop organised by TERENA in collaboration with CANARIE, Internet2, STARLIGHT and SURFnet in September 2001.

Meetings with FLAG Telecom and equipment manufacturers on a European testbed were started in July 200. A proposal for a TERENA Project has been made, but unfortunately this initiative had to be put on hold due to the present status of the telecommunications market. However, the initiative has created momentum and a huge amount of technical plans from a wide number of NRENs jointly participating in the ASTON group co-ordinated by TERENA. Work (on Bandwidth on Demand, 40 Gbit/s and beyond and 10 Gbit/s connectivity over long distances) has been started within TF-NGN using limited national and international infrastructure.

This project will provide an opportunity for carrier service providers, equipment manufacturers (IP, optical, test, etc.), researchers, students and engineers to get hands-on experience. It will also provide a springboard function to enterprises to continue the tested services in an operational service environment. The result of this project will stimulate the standardisation of services, interfaces and protocols in the optical networking environment.

The Testbed

The topology of the testbed should cover all the participating countries in this Integrated Project. So by definition it will be a pan-European testbed. The infrastructure is ideally provided on the side of GÉANT and/or additional carrier service partner(s). The project topology will depend on the availability of the links provided by these carrier services providers. The picture below (Figure 4) depicts a limited but reasonable expectation based on the current talks within the ASTON group.

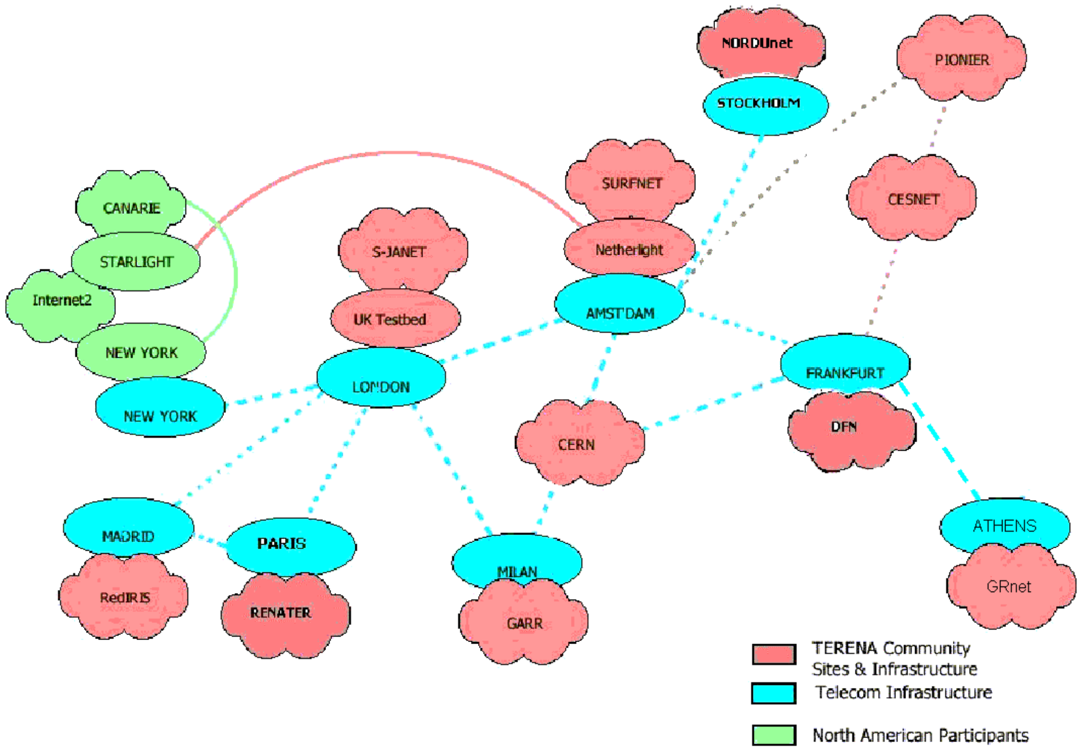

Figure 4: Indicative ASTON Testbed Topology

Implementation Plan

The project activities provide essential data to elaborate the future network architectures. This is focused on synthesizing the knowledge acquired to elaborate new network architectures and routing models, as a balance between simplicity, technical capabilities and flexibility. The network is required to grow in speed, size and physical or logical (like Grid applications) level of meshing. This growth impacts in particular the control routing plane and the capabilities of router hardware and routing protocols. The most appropriate network architectures and routing schemes will be elaborated.

The project activities covered by ASTON are:

Building the Infrastructure

The pan-European infrastructure will be built together with NREN's, equipment (IP, optical, test, etc) manufacturers and carrier service providers. The main characteristics of this network will be:

- Service provision to the NREN's and international organizations that take part in the project. In some cases this needs to be pan-European and in other cases it can be between national or local test beds.
- Providing a control routing plane for the BoD services (by means of G-MPLS, O-BGP, web services, etc.)
- Providing several interfaces per connected NREN/international organization at: 2.5 or 10 Gbit/s
- Providing testing facilities for LAN and WAN PHY 10 GE interfaces
- Providing testing facilities for European 40-80 Gbit/s and higher links.

Bandwidth on Demand (BoD)

Optical networking has brought *channel* provisioning (a clear path between two points) again in the picture. This would place more control in the users' hands (user empowered networking), which is worthwhile to investigate.

Optical Switching

During the lifetime of this Integrated Project it is expected that end-to-end optical switching will become feasible on a pan-European scale. If this indeed emerges, test activities and service provisioning around such an infrastructure will be started up. Another objective is to gain knowledge gathering on other technologies like Optical Packet Switches (OPS).

Network Management

To be able to manage these new services, ASTON will study issues which are specific to this channel provision environment. Issues that are selected are: channel-provisioning, configuration-, fault- and performance management.

Transport at 40-80Gbit/s and higher

NREN networks and pan-European networks (like GÉANT) are using at present times 10 Gbit/s POS interfaces. It is common knowledge that the actual IP traffic doubles every year, so new interfaces and methods are needed to support this increase. Testing and service provisioning for aggregated traffic at 40 – 80 Gbit/s and higher will be expected in two years time.

10 Gbit/s Ethernet over Long Distances

The 10 Gbit/s Ethernet (10 GE) interfaces are emerging on the market. This activity will investigate how to use these interfaces effectively inside NREN's (instead of using WDM using 10 GE responders) and pan-European networks.

Project Timeline

A general estimation of the Integrated Project timeline is:

- Start of project: assumed to be 1/7/2003
- Activity planning
- Building infrastructure, including a more specific optical switching infrastructure
- Getting test facilities in place
- Testing, including optical switching
- Pre-production services
- Project meetings (as much as possible to coincide with TF-NGN meetings)
- Interim reports
- Final report
- Follow-up planning
- End of project: assumed to be 31/6/2006

A drawing outlining the activity plan and timescale can be seen in the following picture:

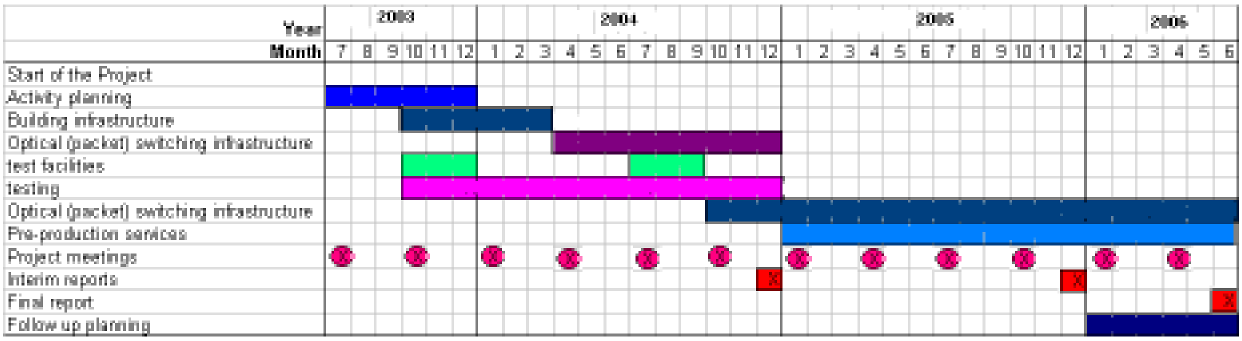

Figure 5: Proposed Activity Plan and Timescale for ASTON Project

Organisational Structure of the Project

The project will be organized into 8 work-packages, one WP per each technical activity, plus a management WP0 and a Dissemination/Exploitation WP7:

WP 0 Project Management
WP 1 Test-bed infrastructure, including
  1.1 Planning Activity
  1.2 Getting infrastructure in place
  1.3 Optical switching infrastructure
  1.4 Pre-production service provisioning
WP 2 Bandwidth on Demand testing
WP 3 Optical Switching
WP 4 Network Management
WP 5 Transport at 40 –80 Gbit/s and higher
WP 6 10 Gbit/s Ethernet over long distances
WP 7 Dissemination and Exploitation of results

Each of WP 2-6 will have a preparation task aimed at getting test facilities in place, tests will be carried out.

The consortium will include participants with the following roles:

- Several carrier service providers have expressed strong interest in the project at this stage, one or several of them will work in close cooperation with GÉANT and the NREN in provision of the international test-bed infrastructure.
- Equipment (IP, optical, test, etc.) manufacturers will collaborate in the project.
- NRENs will link available national test-beds with the ASTON test-bed and will carry out the test activities.
- DANTE and TERENA collaborate in TF-NGN, the Task Force on Next Generation Networking, which undertakes testing of new networking technologies in Europe on the GÉANT backbone and the NRENs. TERENA will be responsible for the project management, the provision of the project web site and mailing lists as well as for the organization of the project workshops.
- Users piloting the pre-production services.

A Management Committee (PMC) will manage the project with representatives from the main consortium partners. A Technical Committee (PTC) composed of WP leaders will look after the technical developments. The PMC and PTC will meet at regular intervals during the project duration. The PMC will issue a consortium agreement and will be responsible for all critical decision making. Web-based project management tools will be used. The public dissemination of results will make use of tools like a project web site, a general-interest mailing list, specific technical workshops, liaisons with technical representatives from similar initiatives world-wide. Early during the project life the partners will draft a Consortium Agreement to identify the IPR of the work produced in the project.

Review Procedures

The deliverables of the project will be reviewed through the following means:

- At least public presentations to get feedback on the steps taken.
- Progress reports will be provided during every meetings of TF-NGN.
- The deliverables will be sent to experts in the field.
- Continuous feedback and review is guaranteed by an open distribution list (aston@terena.nl).
- Dissemination workshops on the project results will be held at TERENA Networking Conferences in 2004, 2005 and 2006.

Publication of Deliverables

All activities will produce documents (topology drawings, test plans, results, etc.). The final document of the ASTON project will be also published as a TERENA technical report. TERENA will provide support for the production (editorial work) of this document.

All documents will be available through the web site of the ASTON project (at the time of writing this EoI): http://www.terena.nl/aston.html.

Initial Activity

An example of the dissemination and information gathering activity that forms part of the ASTON proposal is now described. In July 2002, a one-day meeting between a number of interested parties in the area of advanced optical networking was held at the EC offices in Brussels.

The key groups/projects represented were:

- The OPTIMIST project
- The TF-NGN ASTON project
- The European NRENs
- DANTE
- Commercial Network Operators
- The LION project
- The DAVID project

- The EC (including a number of project officers from various IST projects)

The objective of this meeting was to facilitate an exchange of ideas between:

- the NRENs and GÉANT (a "user group" seen to be an early adopter of high-speed, high-functionality optical networking technology) and
- representatives of a number of research projects involved in the development of these technologies and the components necessary to facilitate their development.

The meeting was deemed to have made a good start at meeting its objectives and a follow-up meeting is planned for some time in 4Q 2002. The minutes of the meeting (and some of the presentation material shown) can be found at http://www.ist-optimist.org/home.asp.