

IIR WDM & Next Generation Optical Networking – 2009 edition

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Introduction

IIR's Next-Gen Metro Optical conference in Nice last week drew approximately 450 attendees this year, a very good showing in this economic climate. What keeps drawing in this kind of attendance after more than a decade, at the end of a quarter and during this climate of budgetary cutbacks? Valuable operator case studies, a broad representation of both operators and vendors, and great opportunities for networking all ranked high on the list, with the location being an added bonus.

The economy may be down and carrier spending decisions are being made with an extra element of caution these days, but the need for optical transport has never been greater.

Unprecedented growth rates in bandwidth demand continue unabated despite the soft economy, and best effort transport is decreasingly satisfactory in a market increasingly driven by the high performance requirements imposed by multimedia web-based services, video distribution, and mobile backhaul. The Internet and social networking are cultural phenomena that have overtaken the globe with unprecedented scale and speed.

The transport underlying this phenomenon may have become increasingly commoditized in recent years in the age of "all you can eat access", but savvy operators over the next few years will learn how to exploit its importance as a facilitator and enabler of differentiated high revenue IT-enabled applications and services. Fantastic growth rates in bandwidth demand are already a reality, the question now is how to turn that into greater operator revenue and profitability so that both the operators and a healthy mix of the vendors that supply them can survive and thrive.

The Internet has been said accurately to be giving the world an infinite number of "trade routes" that can be traversed by virtually anyone in the blink of an eye, and social networking is revolutionizing the entire concept of "community." The interaction between IT, networking, and mobile technology are now sowing the seeds of a potential transformation of the telecommunications industry to greater profitability as a key enabler of a myriad of potential applications and services that promise to change the way we work and live, and which will transform business models worldwide.

This vision is definitely possible, but the degree to which these seeds of our future can be harvested will depend entirely on our ability to successfully commercialize it. There are many applications that subscribers would like to have, but the question is for which ones will they be willing and able to pay? The subscriber wallet is not unlimited, and the costs of transport must be recovered with reasonable profit or at least be part of a profitable overall business model with cross subsidization. Vendors and component suppliers have already squeezed much of the capital cost out of the equation. Growth in bandwidth demand and new services means the network must now be a dynamic rather than a static asset. As a result, a lot of the service operator focus has understandably turned toward the reduction of OpEx in recent years.

The optical market might now be considered a transport equipment market, as greater integration of data transport technologies with optical continues. But whether in standalone optical platforms or integrated with higher layer functionality, optical will continue to play a key role in the future of telecommunications services alongside data. Growth in 40G and plans for 100G will address scalability needs in the core and thereafter the metro, aided by new modulation formats. The colorless and directionless ROADM will enable greater flexibility. GMPLS is helping drive automation and restoration. OTN is providing scalability and transparency. Metro WDM is increasing scalability and driving down latency. MPLS-TP standardization will come, and operators will wait for it. And IP/WDM promises a streamlined stack for the future, while WDM PON holds promise for providing access bandwidth that would have been simply unimaginable only a decade ago. And the debate over the value and challenges of integrated packet/optical transport platforms continues...generating a lot of genuine interest from carriers and some early sales, but less much commitment until development complexity can be mastered and reasonably near best of breed functionality is achieved for L0/1/2+.

Operators are thinking through how they need to transform their business models by integrating differentiated network performance and invaluable subscriber preference and location information with the transport network to play a key enabling role in the Internet economy. They need a solid, flexible, cost efficient transport network able to provide QoS beneath all that. So if you thought that the slow economy would mute the value of keeping abreast of market changes in Nice this year, you were wrong. In a down economy, the over-optimistic hubris for which our industry is historically known might seem a bit muted. And some of the optical technologies discussed were now, others had been around for 10 or more years. But all are competing in a market environment with new carrier service opportunities and objectives - and the changes in the transport equipment market taking place today, discussed in detail at IIR's WDM & Metro Optical conference in Nice last week, continue to move forward in laying the foundation for the future of both networking and network-aware applications and services.

No product category exists in a vacuum these days; for operators, it is all about comprehensive solutions. We look forward to IIR's Carrier Ethernet World Congress in September.

We are not able to comment on everything at the conference in reasonable length, and had numerous off-site meetings - but what follows are some selected subjects and highlights of presentations organized by topic for quick scanning, which we thought might be of interest.

Key Themes and Trends

40G / 100G are hot topics today, given the driver of bandwidth demand. More complex modulation formats received considerable attention, and the results of early 100G trials. **Verizon** conducted trials with **Nokia Siemens Networks** and **Nortel**, **Deutsche Telekom** has performed field trials with **Alcatel-Lucent** and **Ericsson**, and **AT&T** has performed trials with **NEC**.

More complex modulation formats and coherent receiver detection appear to be gaining strong support, probably due to the interest and proof points **Nortel** helped generate in terms of DP-QPSK offering similar engineering rules to 10G without the need for external compensation techniques. Nortel has defined 100G requirements as including simple and cost efficient integration with 10G and 40G, support of a 50 GHz channel grid, avoidance of restrictions such as guard bands between channels or groups, optically transparent bypass, system reach of 1500 km, tolerance against PMD and CD comparable to 10G systems, and parallel transmission of 25G, 10G, 100G, 40G channels on a fiber while showing footprint and energy consumption equivalent to 40G. Despite its own solvency issues and uncertain future, Nortel has helped shape carrier thinking about what 100G could or should be and fueled some of the early interest in 100G so very evident at this conference.

40G has been slow to ramp, in part because of the unrealistic cost expectations of service operators. But we think it has a strong life left, and will continue to grow and enjoy good opportunities for the next 6 years. Interest in **100G** is strong, and there is an unusual degree of consensus this early in its life for how to get there, with new modulation formats likely to play a key role. The challenges in successfully commercializing 100G as well as overcoming the technical challenges are greatly underestimated, and we are surprised at the degree of optimism expressed by operators such as **AT&T** regarding its ability to deploy it widely in 2012 unless they are not worried about the price. Commercially, we think it will potentially take at least another 3 years after 2011 for 100G to fully "prove in" from the business case perspective.

ZTE predicted that when 100G arrives, DWDM/OTN system capacities of 9.6 Tbps will be required. But ZTE still sees the challenges of 100G including channel spacing, OSNR, chromatic dispersion, PMD and non-linear effects.

But it is early for the 100G market yet, and 100G trials to date have been very early experiments running well ahead of commercial viability. We think the technical hurdles of getting 100G to the point of commercial viability (vendor profitability at a competitive price to the carrier with respect to 40G) are still very significant, and will represent the major cause of delay in bringing 100G to market. And of course it's always nice from the vendor perspective to have the opportunity to pay back 40G development and reap some profitability before jumping to 100G - though some with less 40G market share will undoubtedly choose to do so.

40G sales have never ramped to a dominant market position because 40G has never met carrier's unrealistic cost objectives for the savings over 10G. But existent 40G sales have been driven nonetheless by the need for scalability on high traffic routes. From a practical standpoint, market-wide we expect 40G will have another 5-6 years of stronger opportunity than 100G, despite very aggressive statements about intentions to deploy from carriers like **AT&T**.

Access: **Ericsson** talked about how new media applications are causing broadband access needs to gravitate toward multi-stream, high definition, unicast requirements where 50 Mbps access and 10 Mbps of throughput and reduced levels of oversubscription and 1:5 to 1:1 aggregation are becoming more common than in the past, and how it is researching scalability for both copper (such as bonding and vectoring VDSL2 to achieve rates as high as 500 Mbps over six pairs) and fiber (10G GPON and WDM PON). **Deutsche Telekom** discussed the broadband strategy of the German government, which wants 50 Mbps access connectivity for 75% of German households by YE 2014, followed by eventual ubiquitous coverage. This will be achieved by a mix of fiber to the building, curb, and home. DT has considered both GPON and WDM PON, and has decided GPON is an interim technology with which reach can be extended using GPON Extender technology and by mapping GPON into OTN containers between the OLT and ONT and achieve range extension to 60 km today. However, the high bitrates and high split ratio of WDM-PON makes DT very interested in the use of this technology in future when it is more commercially viable.

Bandwidth Growth figures cited in presentations and by people we talked with at the conference ranged from about 40 - 130%, with 60-90% being the approximate norm. For instance, **Swisscom** indicated their traffic is doubling every 16 months. And **KPN** indicated their Internet traffic is doubling every 18 months and the Ethernet traffic generated by Customer Wholesale and Business customers is doubling every 18 months. The laptop and dongle have been a particularly strong driver of mobile bandwidth requirements.

Control Plane: **GMPLS** remains a complex topic more frequently debated than deployed. **Infinera** talked about how having electrical regeneration at every node as is the case with their DTN solution can help unlock the full value of GMPLS due to greater visibility of performance information. On the other hand, **Bouygues** evaluated the benefits of GMPLS and deemed it was not necessary as part of their network upgrade. **Airtel** was among those vendors that talked about the critical need for control plane multi-vendor interoperability. And **Ericsson** discussed the evolution of control plane technology, and the need for a standardized control plane for inter-working between vendors and its utility in supporting end-to-end client provisioning and control of connectivity set up and automatic network restoration in association with flexible ROADM technology and OTN.

Environmental: In some environments (like **Airtel** cell sites in India), there is really a strong need for innovative solutions from vendors as they have a lot of equipment failures due to environmental conditions (in this case, dust particles of smaller diameter than filters can trap). **Airtel** is also looking to greater use of renewable energy at more of their cell sites.

Fiber Quality: **Not all fibers, or operating conditions, are equal.** **Airtel** has real pain points here to deal with, citing their need to cope with frequent fiber failures. This is something they have to take into account in the network design.

Flexibility and control over transport. Tunable lasers for transmitters and receivers are key technologies enabling wavelength routing flexibility. The ROADM has gained a strong presence in the network now, including in EMEA where initial uptake was slow. Increasing carrier interest in ODU switching has been generated by **Huawei**, and we expect to see one or two others vendors respond.

Foreign wavelengths: Support for foreign wavelengths is a key requirement for many operators with multi-vendor networks, and installed base, and the option to integrate interfaces into core routers and other equipment.

IP/DWDM: Has to be more than just a simple router interface, as partners **NSN** and **Juniper** pointed out in their joint presentation.

Market share: Only 6 years ago at this same conference, operators were telling us they like **Huawei** primarily as a negotiating tool to force incumbent European vendor pricing down. Those days are long gone. Now even some of the more conservative operators like **Swisscom** are Huawei customers, and Huawei has significantly upgraded the quality and breadth of its portfolio. But this is a market in fast transition, one in which relatively new competitors from other regions that have a lower cost basis can have significant opportunity, and one in which vendors from any region with particularly strong experience on the services side can build greater financial strength through services complementing product.

Modulation formats: **Ericsson** discussed results of their 100G trial, indicating that polarization multiplexed DQPSK with fast polarization tracking is a viable option for 100G transmission - providing comparatively high fiber launch power, excellent long term stability in real world conditions, and a 5 dB margin over a 630 km field link.

Network Management System: **NSN** and **Juniper** suggested that a common management and provisioning platform for L1/2/3 is of potential benefit in the future, but that the push for this would have to come from operators. When **Swisscom** selected vendor **Huawei** one reason they did is that they liked having an end-to-end solution with OTN and SDH in which everything is managed under a single NMS.

OTN: Approval of the formal 100 GbE ODU-4 is on track for October of this year, and the new ODU-1 will finally provide the GbE-level OTN construct we have been hoping for over the past 2 years. ODU switching interest is on the rise, driven by **Huawei** - and expects to see more development of this capability relatively soon. **Ericsson** mentioned the value of OTN/ODU switching in one of its presentations on achieving a more flexible optical layer. **Transmode** suggests that native packet optical transport is better than OTN because it enables access to OAM bytes and service tags at intermediate nodes without the need to terminate the service to get it. **KPN** also shared some thoughts on its next-gen OTN architecture.

Packet/Optical Transport: **Swisscom** has decided not to integrate L0 and L1 after evaluating its needs for a new transport network, citing the need for separate systems to ensure less complexity. **Ciena** talked about the value of Packet/Optical Transport combining a programmable optical layer, OTN, and L2 Ethernet Transport for the enterprise - stating that convergence of the optical and packet layers can be expected to save 25 - 30%. **MRV** added its discussion of the definition of a packet optical transport system, claiming it as the best solution for fixed/mobile access that can extend to the network core and solve issues of synchronization and OAM - citing a case study of a North American MSO.

Passive Aggression: **Belnet** stated that the fundamental belief that passive optical solutions will always have a cost savings over active ones is simply not true, citing their experience with ROADM technology.

Profitability is sometimes talked about less openly at industry events than are sex, politics, or religion, but **JDSU** broke that barrier and pointed out that the current business model is not resulting in a healthy ecosystem of vendors or components providers - and needs to change.

ROADMS are a hot topic, having gained strong mindshare in Europe these past few years. Colorless, directionless ROADMs were a frequent topic of discussion - and additional degrees of flexibility will be rolled out in the next couple of years. But the cost of tunable filters remains relatively high for now.

Scalability is a must, ranging from GbE upward. For OTN, a new ODU-0 and the ODU-4 are on the way, supporting GbE and 100 Gbps respectively. The ODU-0 is a welcome and much needed addition. In long haul applications, 25 GHz channel spacing appears dead, and scalability with higher speed channels at 50 GHz appears the likely winner.

GbE will increasingly be the de facto base unit of transport in the metro, though in the short-term few Enterprises will actually need that much access bandwidth. 10G and then increasingly 40G for aggregation purposed will gradually increase in the metro over the next few years.

Shared infrastructure: Challenging economic conditions in the form of relatively low average wages and restrictive government tariffs in India are leading **Airtel** to consider innovative business models like sharing of cell towers, cell sites, cabling, and *even managed services partners*.

Single Fiber Working: Single fiber working solutions offer more valuable savings than in the past as they have continued to scale in terms of the number of wavelengths they support. **Ekinops** is one vendor now offering a single fiber working solution - now scalable to 72 wavelengths. **France Telecom's Orange Labs** is considering a mono fiber architecture, that allows to share resources and increase the fiber bandwidth with a bidirectional architecture and the use of C/DWDM, agnostic grooming and transparent protocols for delivering services like Ethernet, SONET/SDH/POS, SAN, PDH, 3G/4G and PON for Triple Play.

SONET/SDH is being EOL'd at last - but just because the end is finally in sight does not mean that it will be quick. For **KPN**, for instance, SDH still carries about 70 percent of its revenues - and the transition off of SDH is not expected to be complete before 2015. SONET/SDH has been a stalwart technology; operators have not wanted to get off of it until vendors could make Carrier Ethernet more like it - and even then it is a major undertaking that will take considerable time to achieve.

Carriers

Belnet, the Belgian National Research and Education Network (NREN), reviewed the process it went through in order to select equipment for its optical and IP network concluded in 2008 that encompasses 1650km of Optical Fiber. The RFP required a full ROADM solution; **Alcatel-Lucent** was selected for its 1696 ROADM and **Juniper** was selected for its M120 and T1600 router. Belnet asserts that the idea that passive networks are inherently cheap while ROADM-based networks are inherently expensive is simply not true. Belnet cites the Wavelength Tracker technology of Alcatel-Lucent as offering strong operations value in an all optical environment, and the ROADM technology as enabling large OPEX savings.

As drawbacks, the company is concerned by the evolution of 1696 ROADM platform that will be replaced with 1830PSS family as the interworking today is possible only via additional 1830PSS drop shelf. But the replacement will have a limited impact as the same Wavelength Tracker technology and NMS is used.

Bharti Airtel examined the current network status and discussed problems of the India WDM backbone network. Humidity and dust contribute to an unusually high failure rate for equipments in Airtel's network, and frequent fiber cuts are common. Airtel needs custom solutions from vendors to cope with challenging environmental conditions, and it is looking to extend the in-service life of equipment.

Airtel gave its vision of network transformation: from ring based OEO network to Mesh based, from flat network to layered network, from TDM to packet/IP and OTN based network, from Layer1 only protection to L0+L1+L2, from Single service to service differentiation, from Manual provisioning to Control Plane based, and from Manual planning to Automated planning tool.

The operator is not satisfied with its current core network, which is suitable only for TDM voice applications for regional network, and plans to evolve towards 40G/100G rates in its National Expressway connecting major cities with mesh based, multi-path protection, 99.999% uptime, OTN based service agnostic platform, and Packet Transport based network designs.

Boygues Telecom presented the transport evolution of its mobile network in the Access & Aggregation and Core parts. In Access & Aggregation, following the emergence of Ethernet ports on 3G RAN the company has adopted PTN technology to support Eth NodeB & eNodeB to build a scalable and LTE proof network and has supported the evolution to fiber to complement SDH Mw rings.

The evolution in the Core Network has taken into account the merge of the WDM fixed network with the mobile network, an increased capacity to 40 Gb or 100 Gb and the optimization of sites by means of ROADM. G-MPLS has not been considered as necessary.

Deutsche Telekom Deutsche Telekom talked about the requirements and implementation scenarios of 100 Gbit/s systems for incumbent network operators. Server cluster and storage arrays are already connected via multiple parallel 10 GbE links and growing bandwidth demands drive the need for increasing line capacities and ISPs have announced the need for 100GbE inter-switch links

The realization of 100 Gbps Transmission can be performed in three ways: with Multiple Fibers in intra-office or short haul applications, through WDM for Metro, high PMD, early 100G realization and through Serial Interface for High spectral efficiency and ULH transmission

The Serial transmission vs. Parallel Transmission has the advantages to reduce complexity for planning, to require less space and energy consumption, low effort for spare parts storage and handling, high

spectral efficiency and efficient fiber usage and reduced waste of ROADM ports. On the other side, it increases signal degradation with increasing data rate, requires compensators or complex modulation formats to support tolerances against transmission impairments comparable to 10 Gbps systems, and higher volume for 10x10 means lower prices compared to serial transmitted 1x100Gbps

Today PMD and CD are still limiting transmission distance: the requirement of 8 ps PMD has to be met for existing fiber infrastructure as 100 Gbaud cannot be transported on more than 50% of national DT routes without adaptive PMD compensation or mitigation. Chromatic Dispersion changes with temperature, so that adaptive CD compensation is needed at 100G. Concerning the modulation choice, highest CD and PMD tolerance can be achieved with the PM QPSK format. The 3 ASK DPSK modulation format provides good tolerance with medium complexity for both CD and PMD.

Deutsche Telekom performed field trials with Alcatel-Lucent and Ericsson. With **Alcatel-Lucent** the transmission was around 100 Gbps channel data rates, with a total capacity of 800 Gbps, in a commercial network, 100 GHz channel spacing, spectral efficiency of 1 Bit/Hz/s using NRZ VSB modulation format over 500 km of buried fiber, resulting in a transmission quality for all eight channels is above the BER Limit. After error correction the transmitted data have been received error free. The **Ericsson** trial was performed on 630 km field fiber using direct detected RZ DQPSK signals, high spectral efficiency of 2 Bit/Hz/s, mixed transmission with 10G and 40G caused performance penalties which have to be considered for the system design and potential upgrade scenarios at 50 GHz spacing.

The two field trials have shown that 100 Gbit/s transmission is possible over national distances in Germany. The first installations are expected after approval of the 100 GbE standards beginning or 2011.

France Telecom presented an interesting study case concerning a solution **Orange Labs** is considering. For the access, FT wants to offer services like Ethernet, SONET/SDH/POS, SAN, PDH, 3G/4G and PON for Triple Play, and believes these services can be provided with a mono fiber architecture, that allows sharing resources and increasing the fiber bandwidth with bidirectional architecture and the use of C/DWDM, agnostic grooming and transparent protocols. L2 Ethernet services will be used for business services and will offer policing/QoS/CoS.

In the Core, FT wants to offer services like Ethernet, OTN, SONET/SDH/POS, SAN, and Alien wavelengths; guaranteeing flexibility in term of protection, bandwidth optimization, scalability and high capacity. The transparency is a strong requirement at the OTN/ λ level, offering service integrity and reducing back to back regeneration. Simplicity is required in term of easy operation and maintenance; minimize on-site intervention and autonomous and fast provisioning. In the LH and ULH part of the network, FT wants to offer services like Ethernet, OTN, SONET/SDH/POS, and Alien wavelengths; guaranteeing performance in term of reach (OSNR tolerance, PMD, CD, NL effects) and in term of capacity (high λ rate up to 100G and high λ density up to 200 λ). Flexibility, transparency and simplicity are also required.

In term of features required to achieve those aspects, FT lists: SFP/SFP+/XFP, ROADM colorless and multi-degree directionless for meshed network, sub- λ switch capabilities in term of OTN that complements ROADM to transport Ethernet services, Control plane, 40G and 100G transport to support traffic intensification: metro networks will rapidly need for 40Gbit/s interfaces, in particular in intra-city context and DP-QPSK revealed efficient in term of costs and very robust to PMD. 100G DP-QPSK will be firstly implemented and in a second step, OFDM technology could open interesting perspectives for 100 GbE networking.

KPN discussed the challenges of keeping up with bandwidth demand and their current OTN architecture, and that the very different skills required to operate an optical network vs. a packet network create advantages for keeping separate optical and packet platforms. KPN pointed out that the NMS, Control plane, and IT as well as hardware should be able to manage the OTN in order to reduce delivery time, manage available capacity, get point and click network with zero touch process, do it right first time, and deal with SDH legacy network (interfaces, XC, and clock sync) while dealing with the packet network functionalities and interworking.

A second presentation from KPN dealt with the Migration from a traditional DWDM network towards an automated Optical Transport Network. A next generation OTN is needed in KPN's view, as the Optical Transport Network is the carrier of all KPN's services and all existing means (HW, NMS, IT & process) are insufficient to deal with the increasing market demand.

In term of plans for the new KPN network, E2E fully transparent optical path using ROADM is KPN new OTN connectivity model, electrical grooming for sub lambda connections using OTN XC will be performed, and due to the migration in the coming years from TDM toward IP, the SDH network will be phased out guaranteeing the quality and the continuity of the running SDH services and platform. OTN will play an important role in maintaining those factors by integrating the SDH functionalities (STM1/4, E1 and clock synchronization) in the optical platform.

KPN is aware that the optical network requires different technical skills/knowledge than the packet network and that a separation of platforms guarantees the transparency and developments in terms of the releases of services at each network layer. KPN final opinion is that cost efficiency can be achieved by bypassing packet nodes via the optical network

Ntl:Telewest Business explained how to use Next Generation Networks to deliver High Capacity Services for "out of town" Data Centers. There are several aspects that are driving the Data Centers out of town: Economics for cost effective locations, Regulatory for distance separation requirements that are affecting greater number of verticals, Logistics for real estate availability and accessibility in preparation for the London 2012 Olympics.

In this frame, there are challenges to install green field Data Centers: in term of Network Access as the DC must be installed near existing fiber infrastructure, in term of Connectivity as direct routes must be available to major cities, and in term of Service Performance required: Very low latency, Deterministic transmission and resilience

The connectivity needs are key for Data Centers, and requirements in term of offers from the service provider are different whether we talk about Customer Managed Service, Provider Managed Service, Outsourced Managed Service or Utility Managed Service. The key to drive down price is getting connected with the right provider and having multiple providers will encourage "healthy competition" and give customers the best choice: the right provider must have product portfolio mix to support all the connectivity requirements for customers

Orange talked about the fixed-mobile infrastructure convergence at the optical layer. Orange UK owns an initial 'core' network with traditional TDM infrastructure that runs TDM Services and protected SDH services and a second and parallel 'core' network (OCN) with high capacity optical infrastructure that runs Transmission Services without SDH protection. As overlay of the OCN network, Orange UK installed a Gigabit Router Network with infrastructure from **Juniper** that provides high availability architecture and

features through a converged MPLS Network. This network supports Mobile & Residential Broadband Internet and Mobile and Residential Voice.

Showing examples of network traffic flows, Orange wants to underline that the optical layer offers a cost effective solution for FMC: For example, high capacity is required between BRAS & GGSN nodes in regional PoP sites and the Internet, and there are no benefits of routing the traffic at intermediate core nodes. The service provider needs a very scalable network that decouple capacity from cost, with simple capacity planning and delivery, reduced risk of HSI impact on critical infrastructure services and direct 10GE Express links with minimal O-E-O. The combination of Ethernet optimized edge routers, high speed core routers and optimized optical infrastructure ensure a cost-optimized transport network evolution.

Swisscom discussed the evaluation performed for its new transport network replacing legacy SDH and WDM equipment and the pros and cons it saw in the potential integration of L1 and L2 equipments. Though Swisscom recognizes the cost synergies of having one box, system complexity, and interoperability across multiple networks, loss of ability to select best of breed and upgrade each layer over the life cycle caused Swisscom to decide not to integrate L1 and L2. Swisscom selected **Huawei** OTN and SDH platforms, and cited the ability to manage both under one management system as a key factor.

Telefonica gave a Wholesale Networks Perspective: the company underlines that IP Optical Integration reduces CAPEX in IP networks and cost reduction is a main driver for integration as IP Router hardware cost in final Internet product cost has gone up dramatically as the speed of the interfaces increased.

There are today three simple steps towards integration:

- Transition from IP/SONET/SDH to IP over Ethernet cards.
- Move from L3 pure boxes to integrated L2/L3 for aggregation.
- Design IP Networks with a mix of 1+1 and 1+0 wavelengths instead of non-protected optical services that forces doubling IP interfaces.

As general solution, Telefonica recommends to use no complex re-engineering for protection or restorations on ultra-long haul paths, a network and service links automatic discovery, restoration in meshed topologies, and maybe GMPLS IP-Optical in the future. Coordination between IP and Transport designs can result in important CAPEX Savings and higher OPEX efficiencies.

Telekom Austria has been evolving its legacy TDM and WDM networks toward its IP based AllMediaNet. They have already implemented 5-degree ROADMs, deployed multi-rate 10G transponders, and implemented optical pass-through. They cited the need for VDSL2 or more fiber to address bandwidth demand, the problem of 2nd-mile capacity demand growing faster than the roll out of new Ethernet aggregation could be cost justified, and how complexities in OSS/BSS make it difficult to roll out services that involve different networks and service layers. For next steps, they will be analyzing the benefits of GMPLS and IP/WDM.

Vendors

Alcatel-Lucent discussed its 100G field trial of November 2007 for **Verizon**, which was designed to also carry both 10G and 40G. Alcatel-Lucent indicated that at 100G, severe fiber propagation effects (dispersion, PMD, single channel nonlinearities) require the use of more complex modulation formats such as polarization division multiplexing and QPSK, plus receiver architectures including coherent detection and digital post processing. This decreases the required baud rate, while digital post processing can also allow for ultra fast transmission optimization after a photonic restoration. Alcatel-Lucent also discussed how 40G PDM-QPSK is not suitable for mixing with 10G NRZ channels due to non-linear effects. Alcatel-Lucent was also involved in 100G field trials at **Deutsche Telekom** (*see Deutsche Telekom in the Operators section*).

BTI discussed new approaches to next-gen service aggregation, and discussed how packet optical edge networking architectures leveraging distributed add/drop capabilities enables dynamic cross connecting of client signals between any sites over a single shared wavelength. They also discussed the advantages of a converged WDM + Carrier Ethernet approach, including simplification of the network and reduced network elements, reduced sparing requirements, single management platform for the service and transport layer, and CapEx savings compared to Carrier Ethernet switch overlays

Ciena discussed Enterprise needs for metro optical and how that can drive revenue. Arguing that what the Enterprise needs is consolidation, simplification, and cost reduction and a solution enabling greater bandwidth in a high performance network that can support an increasing number of differentiated applications and provide faster provisioning and greater network control. Ciena advocated leveraging service-oriented packet/optical transport systems with multi-service OTN, carrier Ethernet, and Agile WDM - and discussed how the latency, jitter, and transparency offered by optical transport will make the optical capabilities of a packet/optical transport system valuable for applications involving digital video and storage.

Corning discussed how various types of optical fiber can influence the design of an advanced long haul network, and compared the dispersion curves of various fiber types. Their conclusion was that low dispersion G.655 fibers can lower the cost and complexity of high speed optical networks by reducing the need for DCMs, that ultra-low attenuation fibers can improve span reach and overall system reach while reducing a limiting factor to coherent systems, and that although large A_{eff} fibers have been used in submarine applications to good effect for years, their use in terrestrial applications remains a challenge.

Ekinops discussed how reducing TCO in optical networks is now all about choosing low cost fiber, using less of that fiber, minimizing the total number of required wavelengths, and eliminating amplifier sites or even the need for amplifiers altogether. They also talked about the cost and operational advantages they believe bonding lower rate carriers over a native 40G modulation scheme can provide, such as no interference from adjacent 10G wavelengths, having the same PMD and chromatic dispersion as at 10G, and compatibility with 3rd party line systems as a foreign wavelength. They suggested that bonding lower rate carriers over a native 40G modulation scheme provides the first truly "market-ready" 40G.

Ericsson discussed the benefits of having a more flexible optical layer, the market drivers making one advisable, approaches that could be used to attain this objective for operators, and some of the technical evolution making it all possible. Citing the growth of IPTV and consumer Internet video as key drivers,

Ericsson discussed using the optical layer to achieve scalable capacity and transparency, the use of ROADMs in an optical switching layer to enable flexible routing of traffic over various ring, chain or mesh topologies, the addition of an electrical layer offering sub lambda granularity, selective regeneration and wavelength translation, and management for optical performance monitoring and control.

Huawei discussed the road to 100G, and compared the suitability of various modulation schemes. Cautioning for implementation of the right technology at the right time, Huawei predicted commercial launch of 100G products in the latter half of 2011, with operators beginning to make commercial use of them in 2012. Of the transmission formats it evaluated, Huawei has centered in on ePDM-QPSK, which it characterized as being very powerful but complex - offering the advantages of 50 GHz channel spacing, transmission distances of over 1000 km, and the ability to overcome chromatic and polarization mode dispersion. Huawei stated it believes that opto-electronic components are approaching maturity, but that there are still challenges to overcome in terms of ASIC/DSP manufacture, since there is no real verification possible prior to manufacture, resulting in high risk.

Infinera discussed how the GMPLS control plane remains on the roadmap for most ROADM vendors, and the value of achieving the benefits of service engineering and design automation, dynamic service activation, automated and accurate real-time inventory, routing optimization, and enhanced protection and restoration leveraging multiple protection schemes.

Infinera went on to discuss how integrated sub lambda switching and grooming per node helps unlock the economic benefits of an intelligent optical control plane and pointing out how this is available at each node with their DTN solution.

JDSU discussed new tools and approaches in optical components for next generation optical networks, citing key trends in optical networking including directionless, colorless wavelength switches that support dynamic provisioning and restoration applications, low cost high performance tunable sources that are full band tunable, front panel pluggable, remotely configurable and have reduced power consumption, and flexible, low cost amplification thanks to photonic integrated amplification while reducing labor-intensive splicing and mounting. JDSU also discussed the market timing for 40/100G. Stating that it is the Internet exchanges and content providers that need 100G today, JDSU identified supercomputer interconnectivity, storage area networking, IPTV and HDTV, long haul transmission, and the limitations of 802.3ad/1ax with respect to 10 GbE links.

NSN and Juniper made a co-presentation stressing the benefits of IP/DWDM in terms of providing the ability to manage the entire router to router link as a single entity, as well as eliminating the need for separate DWDM transponder cards and giving the advantage of fewer components to manage or fail.

These partners stressed that the router interface in IP/DWDM must become an integral part of the DWDM system, integrated into planning and design tools, the DWDM system EMS and NMS, and having common control plane mechanisms. An integrated IP/DWDM solution also provides the choice of L1 protection (OTN APS), mesh restoration at the optical layer and use of L3 mechanisms like MPLS Fast Reroute.

NSN and Juniper plan development of 10G/40G/100G IP/DWDM solutions with management integration and GMPLS Control Plane Interworking as part of their recently expanded partnership. Farther in future, they suggested common management and provisioning platform for L1/L2/L3 will be needed.

Nortel discussed its baseline tenets underlying 100G design: the ability to reuse 10G engineering rules at 40G and 100G, elimination of the need for dispersion compensation units, and enabling agile photonic infrastructure. Nortel discussed the performance characteristics of DP QPSK and coherent receiver detection, and shared projections for adoption of 100G indicating 23% deployment in 2010/2011 and another 33% of operators deploying in 2013.

Transmode discussed the drivers and requirements of building a next-gen optical network, making a case for the argument that native packet optical transport is preferable to OTN because when OTN was developed, it was not created with a view as to Ethernet services being a predominant service type. By contrast with OTN, Transmode suggests that native packet optical transport can carry Ethernet LAN frames with much simpler overhead - providing access to OAM bytes and service tags at intermediate nodes without the requirement of terminating the service there to get it.

ZTE discussed the advantages of going with a Dynamic Switch with Optical Level ROADM, Electrical Level ODUK, and a connection-oriented packet switch under the control of WSON/NMS. ZTE indicated that the IP bearer network of the future will need to be high capacity, support multiservice access, and provide a mesh topology and flat infrastructure in support of converged fixed and mobile networks.

Recommending a WDM/OTN platform for the core transport network, ZTE noted the need for dynamic switching, support for meshed topology, transport distances of 2 to 3 thousand km, a mix of 10G, 40G, and 100G services, and significant capacity. When 100G arrives, ZTE predicted that DWDM/OTN system capacities of 9.6 Tbps will be required. But ZTE still sees the challenges of 100G including channel spacing, OSNR, chromatic dispersion, and PMD>

Question, Comments?

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