NEXT GENERATION SUBMARINE NETWORKS INTEGRATING TERRESTRIAL SYSTEMS

T3.5.4

Shu Yamamoto, Nobukazu Toda
KDD-SCS

Les Baxter, Kamal Raychaudhuri
Lucent Technologies

1. Abstract

The traditional global (i.e., submarine + terrestrial) network architecture needs to be revamped to meet contemporary needs. This paper deals with the validation of new global network concepts through a Test Bed, jointly provided by KDD-SCS and Lucent Technologies. This Test Bed consists of the latest products and technologies from the two companies, and is a unique and innovative collaboration between them.

2. Introduction

Present-day submarine networks have used SDH rings to provide TDM connectivity between cable landing stations with back-haul facilities to nearby major cities. In recent years, this architecture has been stressed due to increased bandwidth requirements, the need for packet-switched data connectivity, and the need for seamless wet and dry connections. A new view of global networks is emerging, consisting of a λ-centric mesh network which integrates the wet and dry networks.

3. Traditional Global Networks: Issues and Trends

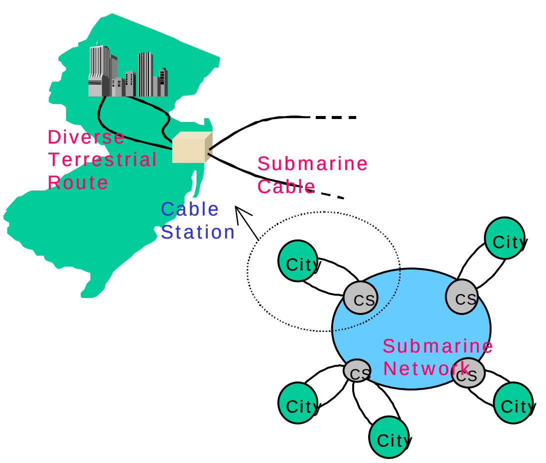

Figure 1. Traditional Global Network

Figure 1 shows a typical global network. Traffic is aggregated at a central office located in a metropolitan area, transported over SONET/SDH-based terrestrial back-haul systems to a cable landing station, where it is further aggregated on to submersible rings for transport to another landing station, where it is disaggregated and back-hauled to a metropolitan area.

Let us look at some key issues and trends associated with these networks.

OAM&P With today's system, the wet and dry networks are partitioned. While the wet-dry partitioning with its segregated OAM&P (Operations, Administration, Maintenance & Provisioning) domains has served us well for the past few decades, it is clear that the needs of the industry are changing. The recognition is that the OAM&P needs are best served by an integrated environment with smooth coupling between the wet and dry systems. In such an environment, greater automation and economies of scale should inevitably result.

Transmission Capacity Demand for higher bit-rates has driven the development of new technology to dramatically increase submarine transmission capacity (Figure 2).

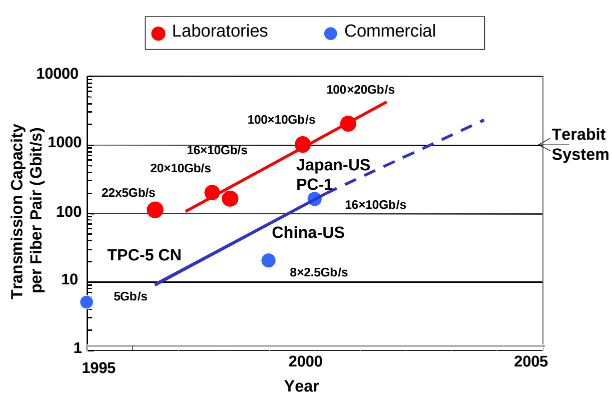

Figure 2. Progress in Submarine Transmission Capacity

Transoceanic terabit transmission capability was reported for the first time at ECOC'99 (European Conference On Optical Communication) in Nice[1]. Submarine cable systems that can carry Terabit capacities over trans-oceanic distances are being intensively developed by KDD-SCS. In such systems, hundreds of wavelengths are transmitted over a single fiber at rates of 10Gb/s or higher. The number of fiber pairs in the new submersible cable is also increased from the current value of four to eight in the new systems. Accordingly, at the cable landing station (Figure 3), thousands of wavelengths will be de-multiplexed and terminated by Submarine Line Terminal Equipment (SLTE). Landing station space and power requirements will increase by an order of magnitude.

In addition, for WDM submarine systems, the terminal cost will dominate the total system cost. The unit price of wet plant may increase somewhat, but it is not a strong function of the capacity of the system. The terminal equipment costs will increase in proportion to the number of wavelengths of the system. For a Terabit system, if the same network architecture continues to be used, the terminal equipment cost will significantly increase. As a result, the total system cost will skyrocket.

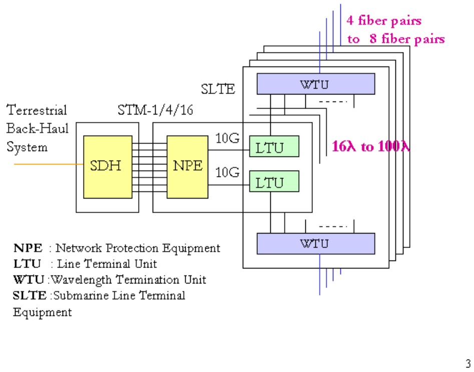

Figure 3. Cable Station Equipment Configuration

Traffic Characteristics It is forecast that the industry will shift significantly from voice-optimized, circuit-switched services to data-optimized, packet-switched services in a few years. As a consequence, the value of SONET/SDH as an intermediate multiplexing layer is diminishing. Most vendors are developing solutions designed to carry IP traffic directly over DWDM, and various standardization bodies are addressing the same problems. The industry trend is to bypass the need for SONET/SDH based networks and to develop technologies supporting optical networks capable of carrying any optical signal regardless of the signal format. It is expected that the signal format conversion, tributary aggregation, together with OAM&P relating to tributaries, get pushed out to the network edges.

Survivability and Topology Survivability, which is an essential ingredient in telecommunication networks, is achieved in present-day submarine networks through the well established automatic protection switching (APS) protocol of SONET/SDH rings. For undersea applications the Network Protection Equipment (NPE) supporting a 4-fiber ring network is required to comply to the transoceanic protocol described in ITU-T G.841, Annex A.

Ring-based protection tends to be faster than mesh restoration because it is simpler and uses a more constrained approach. However, as mesh methods close the performance gap, mesh networks are expected to gain acceptance in optical layer networking for several reasons. Mesh networks offer a more flexible topology than rings, and can adapt to changing traffic patterns more efficiently than ring networks.

Mesh networks use network protection and restoration capacity more efficiently than ring networks. This is because in the former there are generally multiple choices for the restoration path, whereas in the latter there is only one. For the same reason, mesh networks are also more forgiving under multiple failure scenarios.

4. λ-based Networks

The concept of intelligent optical (hereafter "λ-based") mesh networks in one fell swoop addresses all of the above issues.

First, it removes multiple transport and OAM&P infrastructures, since λ-based networks can accommodate different signal formats in a common network platform, and the core transport network architecture is simplified and minimized.

Next, a λ-based network eliminates the profusion of tributaries and SONET/SDH cross-connections. The role of SONET/SDH network equipment is taken over by the optical layer network equipment, whose footprint can be dramatically reduced thanks to the λ granularity. The minimization of network equipment will contribute to greatly diminish the system cost.

Third, different traffic types are accommodated transparently without the need to overhaul the λ-based network. In fact, the term "protocol agnostic" has been used to describe these networks to underscore this attribute.

Finally, by virtue of the mesh topology of λ-based networks as defined, the advantages of mesh restoration are inherently derived.

5. Enabling λ-based Networks

The key enabling technology for λ-based networks is the intelligent Optical Cross-Connect (OXC), which allows us to enter the new generation of global submarine networks integrating terrestrial systems. The OXC will provide the capability to automate the cross-connection of wavelength-based channels. Through the use of intelligent OXCs in conjunction with the DWDM technology, an intelligent optical transport layer is defined that allows the fiber infrastructure to be shared dynamically by allowing flexible provisioning of end-to-end wavelength channels.

The WaveStar LambdaRouter™, an advanced OXC product offered by Lucent Technologies, consists of a Micro-Electro Mechanical System (MEMS)-based single-stage free-space optical switching fabric. The LambdaRouter is pictured in Figure 4, along with one of its MicroStar™ mirrors and a MicroStar array.

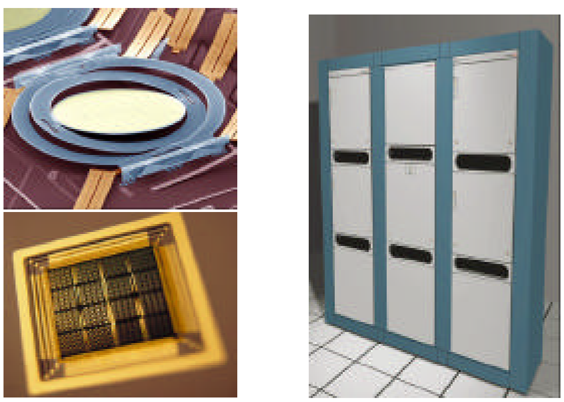

Figure 4. MicroStar Mirror, Array and WaveStar LamdaRouter

A 256x256 optical cross-connect fabric was first demonstrated by Lucent at Telecom '99 in Geneva. The optical fabric is scalable, initially by a factor of 4, and by another factor of 4 subsequently for a total of 16 times. The MEMS-based optical fabric provides a 100-fold reduction in power consumption over electronic fabrics. The optical ports are not subject to a bit-rate limitation, and have been tested at 40 gigabits per second.

A software platform known as Optical Services Manager (OSM) has also been developed by Lucent Technologies to manage wavelength paths in a network of LambdaRouters. This software platform can provide fast "point-and-click" provisioning of light-paths between given endpoints in an optical network, which is key for on-demand bandwidth allocation. It also provides network restoration capabilities by performing dynamic routing, computing the optimal path between any given points in the network based on the state of the network and the link information between LambdaRouters.

For management of large-scale OXC-based mesh networks, the capability to perform node and link auto-discovery is essential to facilitate autonomous switching and routing functions. To enable such functions, a system known as the Optical Network Navigation System (ONNS), which embodies an extension of MPLS protocol to the optical layer [2], is being developed by Lucent Technologies. These will work with the network link and node state data contained in the distributed database systems within the LambdaRouters.

In the advanced phase, an optical network managed by OSM/ONNS is a network that has capabilities to reconfigure itself in real time based on service levels set by the end customer. Such a network will auto-discover new routes when new nodes are added. These functions will create a new paradigm of an intelligent optical network.

6. Future Network Services

Major global carriers provide city-to-city connectivity in their global data networks. In order to differentiate itself from competitors, a successful global carrier needs to be able to provision broadband capacity in granularity increments of at least STM-16 in a fast and economical way. To enable transparent λ connection throughout the entire network of integrated submarine and terrestrial systems to support this kind of service is a central objective of the optical layer technology .

The deployment of data networks to connect data centers across global submarine networks is an increasingly important telecommunication service. λ connectivity can simplify the network architecture. A data center is usually located in a metropolitan area and can be connected to another data centers though a direct λ connection. This is a major simplification in comparison to the present mode of operation where the data traffic is transported with many hops through multiple IP routers and multiple facilities. The direct optical end-to-end connection enables "One Hop" routing and improves the performance of the packet transport as well as the system economy. The advantage of the optical layer networking will be enhanced as the service capacity increases.

With optical layer networks, new business models can be envisioned. The proposed system supports the implementation of the services needed for these new businesses. Such businesses would include on-demand λ provisioning services, λ-based capacity wholesale business, optical virtual private network services, and so on.

7. Global Networking Test Bed

To validate the concepts discussed above, KDD-SCS and Lucent Technologies have jointly established a Next Generation Global Networking Test Bed (Figure 5) which will provide a setting to demonstrate concept evolution and application of the intelligent submarine and terrestrial integrated optical networks.

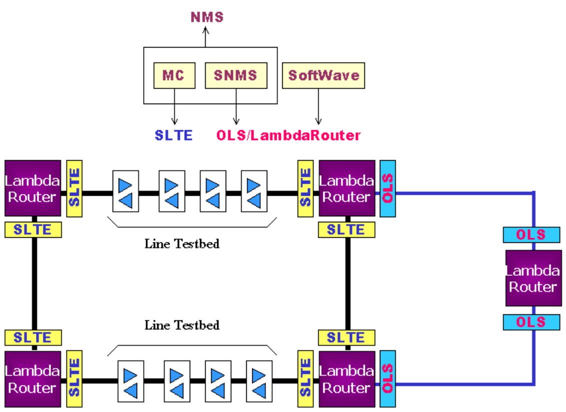

Figure 5. KDD-SCS/Lucent Technologies Next Generation Submarine Networking Test Bed

The Test Bed combines the value of KDD-SCS's submarine technology and Lucent Technologies' terrestrial optical networking technology. The main components are:

- The KDD-SCS OS-W SLTE system which provides submarine 10Gb/s networking together with new enhanced FEC functionality.
- The KDD-SCS Line Testbed facilities to simulate the optically amplifier submersible transmission
- The Lucent Technologies WaveStar® LambdaRouter, which provides OXC capabilities.
- The Lucent Technologies WaveStar Optical Line System which provides terrestrial 10Gb/s DWDM transport
- Management systems associated with the above.

Key to enabling the seamless networking between submarine and terrestrial systems is the implementation of proper translation between the proprietary network signaling systems together with the reconciliation of the equipment interface specifications. The interworking between SLTEs and LambdaRouters is one of the major efforts to provide new lambda services. At the same time, this seamless network connectivity between KDD-SCS's and Lucent Technologies' equipment can reflect on the creation of the unified global network management systems.

The Global Networking Test Bed will demonstrate and prove the following key concepts:

- Automatic end-to-end provisioning of wavelength paths
- Automatic network reconfiguration in response to failure or overload conditions
- Automatic adjustment when service level parameters are modified by the end user
- Unified network management throughout the entire network.

The KDD-SCS/Lucent Technologies Global Networking Test Bed is under development and will be constructed by 2nd Quarter, 2001. The proposed network functionalities will be enhanced and tested throughout 2001. The test result will reflect on the new concept submarine networks beyond 2001, which seamlessly integrate submarine and terrestrial networks based on the optical routing technologies.

8. Conclusion

Convergence of land and sea technologies in all-optical mesh networks is seen as a promising direction in global network evolution. In this fast-evolving landscape, it is important for global carriers to keep pace with the evolution, and all the more important for equipment providers to stay ahead of the game. The KDD-SCS/Lucent Technologies collaboration described in this paper blends the former's state-of-the-art submarine technology with the latter's cutting-edge optical networking technology to provide global carriers a unique and integrated solution to their network needs.

REFERENCES

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[2] D.Awduche, Y.Rekhter, J.Drake, R.Coltun, "Multiple-Protocol Lambda Switching: Combining MPLS Traffic Engineering Control with Optical Crossconnects", IETF *Internet Draft*