ADVANCED ENHANCEMENTS OF THE SAM-1 SUBMARINE CABLE SYSTEM

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Abstract: Telefonica's South America I (SAm-1) is a 1.92 Tb/s submarine cable that connects all major cities in Latin America with the United States. This paper describes the evolution of SAm-1 from a pure SDH/SONET network to an IP over the WDM layer. Other optimizations on the ring included the modification of the original design to build direct express ultra long-haul all optical links to major cities in the region and the introduction of new generation of optical cross-connect equipment to add flexibility to traditional SDH/SONET circuits. In the last part, the paper reviews the extensions of the SAm-1 cable to Colombia and Ecuador to be operational by the end of 2007.

1 SAM-1 NETWORK CONFIGURATION

TIWS network consists of approximately 23,000 kilometer ring that connects to 12 landing stations in six countries: Argentina, Brazil, Chile, Guatemala, Peru and the United States (Puerto Rico and Boca Raton, Florida). The network also includes approximately 1,600 kilometers of backhaul networks between the landing stations and major metropolitan areas in Latin America and in the US, including Buenos Aires, Guatemala City, Lima, Miami, Rio de Janeiro, Santiago and Sao Paulo. By the end of 2007, SAm-1 will also include landings in Ecuador and Colombia. Figure 1 below shows the geographic locations interconnected by the SAm-1 network and the location of the Network Operation Center (NOC), the principal NOC in Lima, Peru. The backup NOC is located in Madrid, Spain.

The undersea plant was engineered to accommodate the total of 48 wavelengths at 10 Gb/s per wavelength on each of the four fiber pairs, i.e., a total capacity of 1.92 Tb/s. Therefore, successive upgrades of the system could be achieved by simply adding transponders and SDH or wavelength add/drop equipment in each cable station. The system uses the Tyco's TeraWave SL-17L cable series which is designed and constructed for transoceanic undersea fiber optic systems. Depending on the characteristics of the sea bottom, several types of armored cables are included in the system, varying from the Lightweight (LW) cable for the benign, sandy bottom, to the most extreme cases of a rocky terrain with high risk of abrasion and crushing, the Rock Armor (RA) cable. Additional protection to the cable was included at the shore end of it to minimize the effect of fishing, marine activities and rough environmental conditions. SAm-1 uses Tyco's state-of-the-art optical amplifier technology for the undersea repeaters to achieve high performance and reliability in the transmission of multiple wavelength channels on multiple fiber pairs.

Figure 2 shows the network connectivity for the system in which the four fiber pairs are arranged in a two-ring topology. The outer ring that links all the cable stations with the exception of Salvador and Rio de Janeiro in Brazil and the inner ring that connects to these two cities to the rest of the ring via the branching units. The initial 40 Gb/s cross-sectional capacity was equipped with SDH/SONET, including the MS-SPring protection scheme, with half of the total capacity dedicated for working traffic, and the other half allocated for protect traffic, complying with the ITU G.841 Annex A recommendation for transoceanic systems such as SAm-1. The cable stations were all initially equipped with Nortel Networks' OPTera DX which provides Add/Drop functions for the System. This ADM (Add&Drop Multiplexer) supports STM-64 high speed interfaces and add/drops of low speed at the STM-16, STM-4 and STM-1 levels. Additionally, Frame Relay, ATM and IP services were also added to the network by using subtended equipment over the SDH/SONET layer.

2 OPTIMIZING THE NETWORK

2.1 IP Over the Optical Layer

Based on the rapid growth of the IP services in the region, it was necessary to redesign the network architecture to make better use of the bandwidth and the installed fibers and undersea infrastructure. For this reason, large capacity routers were deployed directly on the WDM layer using the Tyco's HPOE transponders as interfaces. This configuration was also extended to the Telefonica's city PoPs via the WDM based backhauls which are integral part of the SAm-1 Network. This was accomplished by connecting the HPOEs back to back to the transponders of the terrestrial networks for each of the wavelength pairs. In addition to eliminating completely the SDH/SONET equipment for these wavelengths, the final true bandwidth utilization was also increased effectively to 10Gbps per wavelength since overhead bits, normally used for management and signaling of SDH and SONET circuits, were not necessary under the IP protocols. Furthermore, the network configuration moved from a rigid ring MS-SPRing protection scheme of point-to-point circuits to a more flexible model based on the optimization of a mesh network topology adapted to the dynamics of the traffic patterns. Figure 3 illustrates the mesh topology of the IP network with diverse routes providing IP connectivity and diversity between any two nodes depending on the traffic and content needs of the customers. For simplicity, only few of the total routes are shown in this diagram. Depending on the customers' requirements, legacy IP traffic, originally riding on the SDH/SONET layer, was moved to the IP wavelengths, making space for dedicated TDM circuits with the standard protection features. All the additional 40Gbps upgraded cross-sectional capacity of the system was fully configured in this way with the added benefit of a significant cost reduction of capital investment and operations and maintenance cost associated to the SDH/SONET equipment and management systems.

2.2 Ultra Long Haul Links

The original topology of SAm-1 was based on a straight forward design with an homogenous traffic distribution, and basically determined by the maximum long haul span between landing points that could be achieved with a no-regeneration, and with the state-of-the-art technology at the end of 1999. There was only one exception to the symmetry followed for all the fibers, and this is the trunk and branching configuration in Rio de Janeiro and Salvador de Bahia in Brazil. All the rest of the nodes in the system were designed with the four fiber pairs in a festoon configuration. The design objective set by Tyco for the original system was to have 1.0 dB end-of-life margin on the 48x10 Gb/s WDM optical links for each segment throughout the ring. The undersea optical amplifiers were spaced between 50 to 60 km, providing sufficient gain to cope with all sources of signal degradation or impairments during the life of the system. The magnitude of the impairments was estimated by Tyco from a combination of analysis, computer simulations and direct measurements on test-beds.

One of the key component that impacts the final required transmission performance of the network is the Tyco's transponder, or HPOE (High Performance Optical Equipment). The HPOE provides the interface between the undersea line segment and the terrestrial telecommunications equipment. Some of the features of the HPOE include the Forward Error Correction (FEC) and the special wavelength signal grooming that enables transmission over the submerged system segment. The FEC is the coding technique used to detect and correct digital transmission errors improving the signal to noise ratio in several dBs. The original design of SAm-1 cable was based on Tyco Generation 1 (G1) HPOEs with an FEC of 7% and a line signal of 10.7 Gb/s. Since then, Tyco has developed Generation 2 (G2) and Generation 3 (G3) HPOEs which have significantly improved the performance and reliability of the FECs to 20.7% and also achieved a signal bandwidth of 12 Gb/s. With the use of these new HPOEs it is now possible to compensate for much larger signal degradation in ultra long-haul links than those encountered on earlier Tyco's system designs with G1 HPOE versions.

Taken advantage of the improved features of the FEC and the high density of the number of submerge optical repeaters on each segment, Telefonica decided to reconfigure the festoon based on the two fiber pairs that contains no branching units in the Atlantic. The original three segment link between Boca Raton and Santos was converted into a single ultra long-haul segment of 10,752 km, the longest fiber optic link in the world with no regeneration. The calculations and simulations, plus test-bed measurements, showed an end-of-life margin of 1dB for 6 wavelengths equipped with G2s and 42 wavelengths equipped with G3s HPOEs on each of these two fiber pairs. Presently, a total of six wavelengths per fiber pair have been activated providing 120Gb/s of express capacity between Santos and Boca Raton. Two additional wavelengths per fiber pair, based on G1 technology, are also active on the trunk-and-branch link between the same end points, with stops in Puerto Rico, Fortaleza, Rio and Santos. Overall, there is then 160Gb/s of capacity between Boca Raton and Santos.

Similarly, a two fiber pair link has been configured between Boca Raton and Lurin, Peru, by considering G3 HPOEs for all 48 wavelengths to the system end-of-life. In this case, additional optical amplifiers units were included in the terrestrial route across Guatemala. There are very significant cost savings of equipment and in operation and maintenance as well by introducing these ultra long-haul links to the original design over the life time of the system. In summary, the current total cross-sectional capacity of SAm-1 is of 160Gb/s around the ring, with express traffic to major IP growing markets in Latin America.

2.3 Flexibilizing the New SDH/SONET Layer

The areas of improvements mentioned in the sections above have a direct impact on the performance of IP based networks that have been deployed on this new infrastructure making use of very flexible routing and protection schemes. However, traditional TDM circuits are still preferred by a significant number of international carriers in the region and there is certainly space for further network improvement and optimization in SAm-1 cable. Dynamic market conditions, increasing competition and the need for dramatic improvements in network efficiency have motivated Telefonica to introduce a new breed of optical switching platform based on the Nortel HDX equipment. This platform offers automated end-to-end provisioning functions for superior connection management, differentiated Classes of Services (CoS) and carrier-grade mesh protection and restoration options. The mesh protection and restoration capabilities allow carriers to provide a differentiated CoS ranging from linear point-to-point, ring protected and mesh protected circuits that can be programmed for multiple failure scenarios. The first set of HDX equipment is schedule to be in service during the second half of 2007 on the express fiber pairs.

3 EXTENSIONS OF SAM-1 TO COLOMBIA AND ECUADOR

Based on Telefonica's interest on the Colombia market and more specifically with the participation on Colombia Telecom, a decision was made to extend the connectivity of SAm-1 from Puerto Rico to Barranquilla, Colombia. This extension, which is expected to be completed by the fourth quarter of 2007, is based on two fiber pair repeatered segment of approximately 1,500km. Tyco's design of the wet plant for this segment will support a maximum capacity of 48 wavelengths at 10 Gb/s per wavelength on each of the two fiber pairs. Initially, several wavelengths will be activated and terminated in Puerto Rico and others will be connected to the ring to reach any other location of the SAm-1 cable. Another extension of the network that will be added also during 2007 is the branch to Ecuador. This segment utilizes the existing branching unit (BU) installed near the Galapagos Islands in the Pacific Ocean located on the segment between Puerto San Jose, Guatemala and Lurin, Peru. Only one fiber pair equipped with undersea repeaters will be actually extended 800 km from the BU to Punta Carnero, Ecuador. One fiber pair will provide direct connectivity to Guatemala and the second fiber pair will be connected directly to Peru. The design of the wet plant for this extension will support a maximum capacity of 48 wavelengths at 10 Gb/s per wavelength on each fiber pair.

4 CONCLUSIONS

In this paper we have presented the SAm-1 cable system that has evolved since the beginning of operations in 2001. In the past few years, several upgrades have been implemented on the network to increase the capacity required by Telefonica's customers in the region. Simultaneously to this upgrades, and responding to the competitive environment and more flexible services been demanded by the customers, recently developed IP and SDH/SONET equipment and associated management systems have been deployed into the network. The network has also evolved to an IP based configuration directly over the optical WDM layer, improving performance, and reducing investment and maintenance costs. By introducing last generation HPOE technology developed by Tyco, it was also possible to redesign some of the links to conform ultra long-haul segments reaching one of the longest submarine segment built and deployed in the world today. This is a significant undertaken and allows for an excellent optimization of the infrastructure and further cost reductions on upgrades and regular maintenance of the system. The paper also addressed the deployment of two additional submarine segments to SAm-1 ring, to Colombia and Ecuador, increasing in this way the footprint of a very reliable and diverse undersea network that Telefonica can offers to its customers in the region.

5 FIGURES

FIGURE 1 GEOGRAPHIC FOOTPRINT OF SAM-1

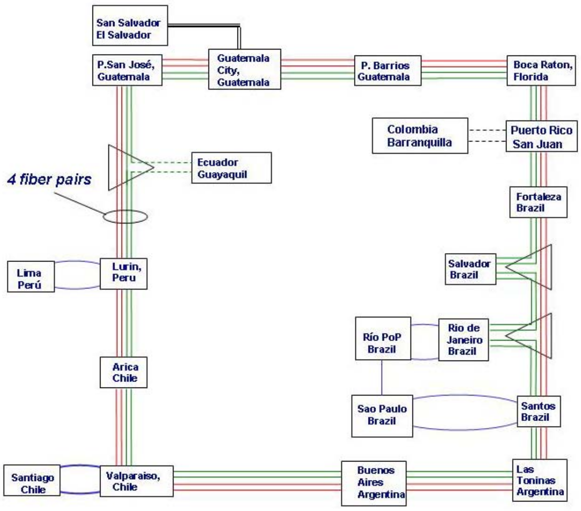


FIGURE 2 SAM-1 NETWORK CONFIGURATION

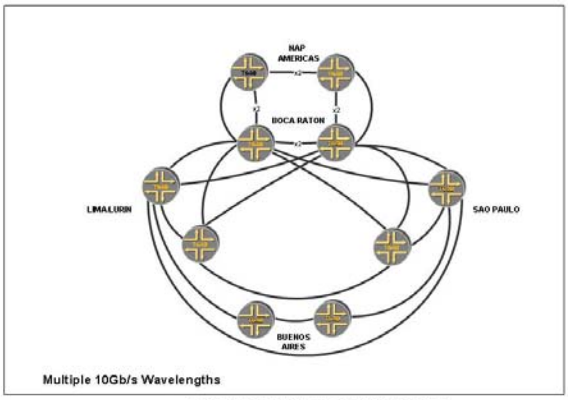
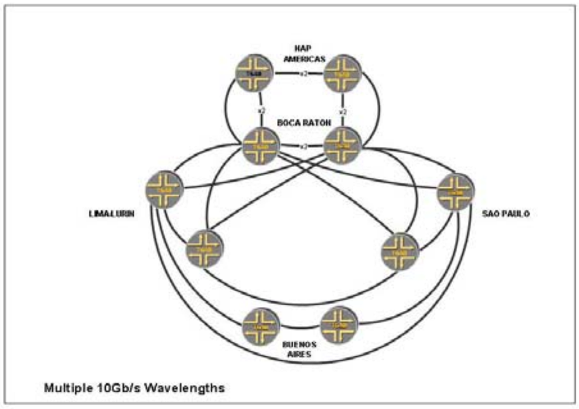


FIGURE 3 IP NETWORK OVER WDM LAYER



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