change its configuration more frequently than the XC path network that is operated in a conventional way. Statistical multiplex gain is expected in use of wavelength resources between a pair of OPSWs. Therefore, it is important for efficient network operation to implement the OPSWs with taking a tradeoff between the statistical multiplex gain and cost for interconnection and operation of the OPSWs into account.

A SW path that consists of multiple XC paths is managed by multiple pairs of OPSWs as shown in Figure 5. Since each pair of OPSWs operates a XC path independently, it is not ensured that all the XC paths necessary for a SW path can be established simultaneously. The target of this path management is transmission of burst traffic that requests wide bandwidth during a very short time period, such as high-speed download of hot content and aggregated traffic of individual streams that are apt to be highly concentrated. Furthermore, when the initial paths are established as a point-to-multipoint connection set and traffic is broadcasted via the paths, the additional path management mechanism of the SLAMNet can be simply applied for broadcasting the traffic.

IV. Harmonization with Wavelength Label Switching

The SLAMNet is applicable to a network that employs GMPLS function and can afford to work with the function in a harmonization scenario. In the scenario, initial paths and XC paths of the SLAMNet are managed as LSPs (Label Switched Paths) with signaling protocol by the GMPLS function. Based on the LSPs, additional paths are dynamically set up and released as SW paths by the signaling-free path management of the SLAMNet. Figure 6 illustrates a configuration of a node to support both the GMPLS function and the path management mechanism of the SLAMNet. In this scheme, a GMPLS router needs additional functions to set a cross-connect for the XC paths to be used in the additional paths according to setting of the initial paths and to control forwarding packets in output buffer of a packet switch with observing the volume of traffic. Furthermore, it is necessary for the GMPLS router to set a guard time before transmission of traffic through a newly established additional path and also to interwork with the OPSW in order to keep consistency of correspondence between the initial and additional paths.

V. Test System

For the purpose of demonstrating performance of the SLAMNet, a test system is developed as shown in Figure 7. This test system emulates the case where four router pairs share four or fewer OCh paths as additional paths on a best-effort basis. The additional paths are dynamically set up and released by a pair of OXCs representing OPSWs. Two routers in each side of the OXCs emulate four routers that share the additional paths. The router directly connected with hubs gives a tag to such the IP packet that overflows the capacity of an initial path and the other router distributes the traffic between the initial and additional paths according to the tags. A PC connected with the OXC works for monitor of traffic volume and control of the cross-connect. In a trial of this hardware, it is confirmed that the additional paths are dynamically managed in the cycle less than 28 milliseconds [6]. The cycle is expected to shorten in the further trials.

VI. Conclusions

The concept of SLAMNet is applicable to specific parts of the network, such as dense areas and bottleneck sections, and allows reduction of the necessary wavelength resources only in such portions. Thus, the architecture and path management mechanism can be introduced to conventional WDM networks in a step-by-step manner according to their usage status and operation plans. Furthermore, the SLAMNet has the possibility to shorten the cycle of additional path switching to the order of transmission time of a burst in an optical burst switching network. Based on the SLAMNet, the short cycle operation is also pursued for optical burst switching.

References


FR5 (Invited) 11:30 AM

Core Mesh Optical Networks: A European Carrier’s Perspective

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Experiences with mesh restoration in a former SDH network are presented. Results of mesh core networks design studies are given with respect to opaque and transparent scenarios and problems of inter-working of mesh restoration domains are discussed.

FR6 (Invited) 12:00 AM

A National Mesh Network Using Optical Cross-Connect Switches

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This paper presents Dynegy’s long-haul national network utilizing intelligent optical switches. This network offers end-to-end point-and-click provisioning, shared mesh restoration, re-provisioning of connections and network re-optimization.

Networks that transport optical connections using Wavelength Division Multiplexed (WDM) systems and route these connections using intelligent optical cross-connects (OXCs) are firmly established as the core constituent of next generation long-haul networks. In such networks, preventing and restoring link and node failures is increasingly becoming one of the most important network features [1-4]. Dynegy’s network implements shared mesh restoration using intelligent optical switches to protect against single link and node failures. In shared mesh restoration (Figure 1), backup paths can share capacity if the corresponding primary paths are mutually diverse. Diversity of routes in Dynegy’s optical network is defined using the notion of Shared Risk Groups [5]. A set of optical channels that have the same risk of failure is called a Shared Risk Group (SRG). SRGs are configured by Dynegy’s network operators with the knowledge of the physical fiber plant of the optical network. Compared to dedicated protection, this scheme allows considerable savings in terms of capacity required [5,6]. In addition, the backup resources can be utilized for lower priority preemptible traffic in normal network operating mode. However, recovery is slowed down in some cases, yet still within the realm of SONET restoration times, essentially because it involves signaling and path-setup procedures to establish the backup path. In particular, the restoration time will be proportional to the length of the backup path and the number of hops, and if recovery latency is an issue this length must be kept under acceptable limits. Furthermore, this constraint may increase the cost of the solutions, as it is sometimes more cost-effective to use longer paths with available shareable capacity than shorter paths where shared capacity must be reserved. This tradeoff can be handled by an appropriate cost model in the route computation algorithm [7-8]. For routing purposes, the algorithms utilized by the intelligent optical switches use a cost model that assigns costs to links in the network. The policy used for assigning costs to the links is different for primary and backup paths. The weight of a link for a primary path is the real cost of using that link in the path. This is a user-defined cost that reflects the real cost of using a channel on that fiber. The weight of a link for a backup path is a function of the primary path [7-9]. Backup link e is assigned: (1) Infinite weight if it intersects with an SRG of the primary path. (2) Weight w_e if new capacity is required on the backup path. (3) Weight w_e if the existing backup capacity is not sufficient for the backup path.

Mesh Restoration

Provisioning of shared mesh restored lightpaths in Dynegy’s live network that utilizes Tellium’s intelligent Aurora Optical Switches, was achieved by calculating the working and backup paths using the weight assignment as described above. Dynegy’s network is on the order of 45 nodes and 75 trunks, and is carrying shared mesh restored

Figure 1: Shared Mesh Restoration: (a) Network connections before a failure occurs (b) Network connections after a failure occurs.