White Paper: 3G Via Optical Core Networking

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The explosive growth anticipated for the 3G wireless data applications and multimedia services is a major concern to wireless operators at the moment. The convergence of voice, data, and video services and the close integration with the fixed networks is raising issues of network inter-working, interoperability, mobility management and the provision of dynamic and flexible bandwidth in the core network. The crucial factor is being able to meet the ever changing demand with a scalable network infrastructure and flexible transport technology. A flexible transport architecture is needed that is internet protocol friendly, provides efficient bandwidth on demand, and is easily reconfigurable to meet the demands of mobile users. This new transport infrastructure should be flexible to allow the rapid introduction of new services and be managed with minimal complexity.

Core Network - A Key Investment

For 3G network deployments, the core network is a key investment that operators must make in order to secure a superior competitive position by allowing them to offer an extensive variety of services. Customers will measure their wireless operator on both the ease and flexibility of the access to this expanding variety of services. The core network should ideally be based on an architecture that is independent of the type of access technology in order to allow interoperability with existing and future access technologies.

Most of the current models proposed for core networks consist of four layers: IP and other content-bearing traffic, ATM for traffic engineering, the SONET/SDH transport network, and dense wave division multiplexing (DWDM) for fiber capacity . Such models involving mixing and matching of numerous technologies can ultimately suffer from functional overlaps, conflicting performance tuning among its layers, and unnecessary complexity. This approach is ineffective in utilizing the evolving optical transport and switching technologies.

The numerous data and multimedia services in the 3G networks, and the scaling of the core network, can make the traffic between pairs of backbone routers reach a single optical carrier OC-48c/OC-192c volume, making the ATM's virtual path equivalent to a wavelength. Hence, while the benefits of ATM's fine virtual path granularity, including QOS, make it eminently suitable for the access network, it becomes irrelevant in the optical core, where the appropriate switching granularity becomes the wavelength. In addition, effective management of these large and numerous virtual paths depends on the widespread introduction of the private network-to-network interface (PNNI), which is ATM's dynamic virtual path provisioning and restoration protocol. Even then, PNNI's restoration times will be in seconds to minutes, far inferior to the 50-ms benchmark set by the SONET/SDH ring. As a result, ATM switches do not offer compelling value for the long term inclusion in the optical core. In addition, the availability of IP routers capable of operation at the wirespeed of 10 Gb/s will make the SONET/SDH grooming function unnecessary.

Other Bottlenecks - Current Architectures

A further drawback in the four layer architecture is in the provisioning of multigigabit bandwidth across a pair of routers located in two cities. This will require the availability of bandwidth across all Sonet/SDH rings along the connection route, and the manual intervention at the ring junctions. Furthermore, the optical ring interconnects can result in increased worse case network delays by the failure initiated re-routing mechanisms used in the ring architecture. A second drawback is the fact that the layers are unaware of each other, resulting in increased overhead and duplication of their services. Error correction may be performed twice, or flow control may be performed both at the ATM, and the TCP windowing level, potentially resulting in conflicting actions.

With all said considerations, the future optical core network is envisioned to be based on the transport of IP over WDM using the evolving wavelength switching and optical cross connect (OCX) technologies. With intermediate SONET/SDH and ATM switches eliminated, only two switching elements---the Wavelength Router and the IP router---are needed in the long-haul optical infrastructure with dense wavelength division multiplexing (DWDM) elements. The IP routers placed at the edge of the optical meshed network groom packets from DS-1, DS-3, OC-3, and OC-12 flows to OC-48c or OC-192c streams. The Wavelength Router maps these streams to wavelengths for end-to-end transport across the network. The SONET/SDH ADMs, and ATM switches may still be used at the edge of the network, in addition to the IP routers, for the grooming and transport of circuit switched traffic such as voice, signalling, and video through the multigigabit transport network.

Provisions for Success

The success of IP over WDM will depend of course on whether the IP layer can support the necessary QOS mechanisms, and whether the WDM can provide survivability as robust as SONET and SDH. The efforts at the IETF for the provisioning of effective QOS at the IP layer has led to the creation of the multiprotocol label switching (MPLS) standard. MPLS combines the intelligence of IP routing and the fast switching of ATM and thereby introduces the notion of connection-oriented forwarding to IP networks. When packets from a particular session enter the network, they are sent along the same path by giving them all the same initial label by the edge router. Each intermediate node on the path uses the packets label as an index into a lookup table to find the next hop for the packet and a new outgoing label, hence the term label switching. At the WDM layer, the label switching concept of MPLS is extended to include wavelength -routed and switched lightpaths. Hence, MPLS takes the name multiprotocol wavelength switching (MPlS). As the name implies, in MPlS , the wavelength of the light serves as its own label. In MPlS, IP packets from one or multiple sessions are mapped to a wavelength by the edge IP routers which are then routed through a mesh of wavelength switching optical cross connect (OXC) nodes.
Currently, there are OXC technologies available (for instance from Ciena, and Sycamore) which allow the network operator to rapidly configure optical paths between any pairs of routers. The routers placed at the edge of the network are connected through a mesh of the optical cross connect wavelength switching elements. The paths configuration within the optical meshed interconnect is done through a rather simple point and click process. These available technologies can be used advantageously in the migration process to the future models of optical transport and routing.

In the longer run, the provisioning of optical paths will be made automatically through real time signalling exchanges between the edge IP routers and the optical wavelength routers. Most likely, this realization will take place initially by having the signaling exchange performed through an optical cross connect controller (OCC) entity using separate signalling interfaces. The OCC uses the topology and resource availability information it maintains on the optical transport network to provide circuit switched services to IP and other higher layer protocols. As the standards for addressing and signalling for a unified control plane are resolved and worked out, the border routers and the optical cross-connects will be able to directly exchange signalling and routing information. This model will distribute the route determination and paths set up process and result in a scalable network control infrastructure. Also, the use of standardized protocols and mechanisms for the exchange of signalling and routing information will allow for the mixing of equipment from different vendors and open up competition for the equipment markets.

The network operators will be able to take advantage of the evolving optical networking technologies both in the short and the long run to provide scalable high capacity core networks. This will allow the support of a diverse range of services with different bandwidth and QOS requirements through a single core infrastructure with the advantages of simplified management, operation and maintenance.