The Future Optical Network
(Invited)

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Abstract

Inefficiencies of current IP technologies will become pressing problems in creation of future video-centric networks. Extension of optical layer technologies and coordination with new transport protocols will be critical.

Summary

Broadband access including ADSL and FTTH is being rapidly adopted throughout the world and, as a result, traffic is continually increasing; around 50 % every year in North America and Japan. The number of FTTH subscribers exceeded thirteen million in Japan and three million in USA in 2008. In order to cope with the traffic increase, optical transmission and node technologies are being extensively developed. The maximum number of WDM wavelengths per fiber exceeds one hundred, and WDM transmission systems with a channel speed of 40 Gb/s are now being introduced in some countries. The key to enhancing node throughput while simultaneously reducing node cost is optical path technology [1,2] based on wavelength routing. Wavelength routing using ROADMs has recently been introduced, and large scale deployment is being conducted in North America and Japan. GMPLS controlled OXCs (Optical Cross-connects) have also been used to create nation-wide testbed networks [3].

Video technologies including IP TV and high-definition and ultra-high-definition TV (more than 33M pixels) are advancing [4] and they will induce further traffic expansion in the near future; future communication network services will become video-centric. More advanced video applications that include three-dimensional TV [5] and cutting-edge applications including e-science, all of which need enormous bandwidth, have also been conceived. The inefficiencies of the present TCP/IP protocol will become more tangible given the above service advances. The power consumption and throughput limitations of IP routers are expected to limit the scale of Internet expansion in terms of bandwidth and the number of users [6,7], and the approach of relying on only IP convergence will not be the best in creating future bandwidth abundant networks [8].

The bottlenecks of present IP network technologies include the scalability limitation of IP routers and the protocol bottleneck. It is shown that the one important approach that can resolve these problems is the enhancement of photonic networking capabilities [9]. The future optical networks need reconfigurability or agility. The networks must offer a greatly increased number of wavelength paths and hence optical node throughput. The enhancement of optical path benefits and the introduction of new protocols including fast optical circuit switching will play key roles.

In order to realize the future networks needed, wavebands (bundles of optical paths) and hierarchical optical path cross-connects (HOXCs) need to be adopted as the basic transport technologies. In a single layer optical path network, optical path establishment/tear-down requires node (optical cross-connect) by node optical switch setting. On the other hand, in a hierarchical optical path network, optical path establishment can be done utilizing one (direct) or multiple wavebands. This means that in the connection establishment/release phase, the number of nodes involved is greatly reduced and the connection set-up/release delay minimized. On the other hand, wavebands are usually established semi-permanently. This scheme requires bandwidth reservation even when the optical paths/circuits that can be accommodated within the waveband are not used, which results in reduced resource utilization. The relationship between the optical wavelength path cross-connect and the waveband cross-connect corresponds to that of the electrical switching system and the cross-connect system in POTS networks. In regard to connection establishment and signaling, centralized and distributed control schemes can be applied as demanded by service requirements.

Compared with single layer optical path networks, the introduction of wavebands can greatly reduce network cost. Evaluation results on the network cost reduction attained with introduction of waveband technologies are presented [10,11]. It is clear that when traffic is relatively large, the attained cost reduction is large. One important point to be emphasized is that the waveband is effective when traffic volume is rather small. This will multiply the effectiveness of waveband technologies in terms of network migration from single optical path networks.

In this presentation, recent advances in hierarchical optical path network realization technologies are explained. They include network design algorithms, network reliability enhancement with waveband and wavelength path protection, enhanced network control protocols, and some key component technologies for creating the HOXCs; a new waveband MUX/DEMUX, a waveband selective switch (WBSS) and hierarchical OXC architectures. The hierarchical optical path network will be implemented in the not so distant future when traffic volumes warrant it.

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