

## Tutorial

### The future of optical networks

Ken-ichi Sato

Nagoya University; Furo-Cho, Chikusa-Ku, Nagoya, 464-8603 JAPAN  
sato@nuee.nagoya-u.ac.jp

#### Abstract

*The transport network paradigm is moving toward NGN (Next Generations Networks) which aims at IP convergence, while architectures and technologies are diversifying. Video technologies including ultra-high-definition TV (more than 33M pixels) continue to advance and future communication networks will become video-centric. The inefficiencies of current IP technologies, in particular the energy consumption and throughput limitations of IP routers, will become pressing problems. Harnessing the full power of light will resolve these problems and spur the creation of future video-centric networks. Extension of optical layer technologies and coordination with new transport protocols will be critical, and are discussed in detail.*

#### Ken-ichi Sato



Ken-ichi Sato is currently a professor at the graduate school of Engineering, Nagoya University. Before joining the university in April 2004, he was an executive manager of the Photonic Transport Network Laboratory at NTT. His R&D activities cover future transport network architectures, network design, OA&M (operation administration and maintenance) systems, photonic network systems including optical cross-connect/ADM and photonic IP routers, and optical transmission technologies. He has authored/co-authored more than 200 research publications in international journals and conferences and fourteen books. He holds 35 granted patents and more than 100 pending patents. He is an NTT R&D Fellow, a Fellow of the IEICE of JAPAN, and a Fellow of the IEEE.

#### **Extended Abstract**

Until ten years ago, we looked at N-ISDN and SONET/SDH as the next step technologies on which to base the development of access and core networks, respectively; agreement was universal. The next step, IP convergence, is supported by the advent and penetration of IP, new technical developments including WDM and photonic network technologies, rapid advances in access technologies, and the emergence of IP-based control protocols such as MPLS and GMPLS; all provide powerful tools for creating the next generation networks. While IP convergence is well recognized among carriers and vendors, the key issues that they must consider include the divergence of architectures and technologies. The technology alternatives are extremely varied and this allows us to develop optimized networks that match each country's or region's and/or carrier's situation.

Broadband access including ADSL and FTTH is now 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 ten million in Japan and two million in USA in 2007. 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 enabling technology that enhances node throughput while simultaneously reducing node cost, is the optical path technology that exploits wavelength routing. Wavelength routing using ROADMs has recently been introduced, and a 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.

Video technologies including IP TV and high-definition and ultra-high-definition TV (more than 33M pixels) are advancing and further traffic expansion is expected in the near future. Future communication networks will become video-centric. Recent advances in video technologies, which include three-dimensional TV, are described. Cutting-edge applications including e-science, all of which need enormous bandwidth, have also been conceived. The inefficiencies of the TCP/IP protocol will become more and more tangible. 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, and the approach of using only IP convergence will not be the best to creating future bandwidth abundant networks. The details, including the limits of IP routers and protocol bottleneck, are discussed from various viewpoints.

One important direction that can resolve these problems is the enhancement of photonic networking technologies. In future networks the number of wavelength paths and hence optical node throughput must be greatly increased. The enhancement of optical path capabilities and the introduction of new protocols including fast optical circuit switching will play key roles. In realizing the networks needed, wavebands (bundles of optical paths) and hierarchical optical path cross-connects (HOXCs) will become basic technologies.

The presentation will elucidate the merits and issues of introducing higher order optical paths. The introduction of wavebands will substantially reduce optical switch size at cross-connects, which mitigates one of the major barriers to the implementation of large throughput optical cross-connect systems. One of the obstacles, network design complexity, will be shown to be effectively resolved by a new optical path network design that introduces a traffic demand expression in a Cartesian product space. Some of the key component technologies of the HOXCs, a new waveband MUX/DEMUX, and a waveband selective switch (WBSS) have been developed. The hierarchical optical path network will be implemented in the not so distant future when traffic volumes warrant it.