Recent Progress on Optical Transmission Systems

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This paper briefly overview recent progress on ultra high capacity optical transmission systems and relevant technologies which make these cutting-edge results happen. Steadily increase of the number of FTTH service subscribers should be one of the driving forces for higher capacity back-bone network. Among various clients, Ethernet should play a dominant role so far and in the future. Currently, 1GbE and 10GbE has widely penetrated for computer networking applications. IEEE is now targeting 100GbE as the next step after 10GbE, and intends to standardize it by 2010. So, inevitably traffic demand for back-bone network should expand further to accept 100GbE. For the time being, 43G DWDM systems have already installed for commercial services. To meet the potential demand, we are trying to develop novel ultra high capacity transmission system which can transport 100GbE clients effectively. I will briefly present some latest results of the effort toward the direction.

Key Words: DQPSK, FEC, OTN

1. Introduction

Interface capacity of Use-Network Interface (UNI), namely client interface and Network-Network-Interface (NNI) are closely associated.

Fig. 1(a) shows a trend of broadband services subscribers in Japan. In contrast to saturation of ADSL subscribers, the number of FTTH subscribers is steadily getting larger. Moreover, highest UNI speed is now reached 10Gbit/s for the time being, since 10GbE cards have penetrated worldwide for conventional computer systems. To transport such high-speed traffic, NNI speed or back-bone network capacity should also evolve to support those emerging clients. Fig. 1(b) summarizes the evolution of transmission capacity of experimental and commercially deployed back-bone transmission systems in NTT laboratories or network categorized by corresponding multiplexing schemes such as Electronic Time-Division Multiplexing (ETDM). The similar trend for Ethernet is also shown for comparison in the figure, since Ethernet must be dominant clients for photonic network. The latest report presents over 20Tbit/s capacity transmission on a single fiber with the help of unprecedented modulation technique.[1] In Jan. 2007, the world highest line-rate 43G DWDM systems have been commercially deployed in NTT Communications network. There has been extensive research and development to expand total transmission capacity. Multi-level modulation namely lowered symbol rate encoding has been proposed to accommodate impairments caused by fiber chromatic dispersion and/or polarization mode dispersion. In addition to that, to ensure sufficient signal-to-noise ratio, coherent detection and forward-error-correction have been thought to be play a dominant role. Moreover, in IEEE 802.3 Higher Speed Study Group (HSSG), 40GbE and 100GbE standardization activity are now on-going and expected to consent until 2010. So the need for upgradability of back-bone network should be intensified in the near future. Accordingly, ITU-T G.709 standard Optical Transport Network (OTN) has now been extending its digital hierarchy to support 40GbE and 100GbE. In addition to this trend toward higher capacity and longer transmission distance, we are targeting to upgrade lambda-controllability of photonic network. Based on the above point-to-point transmission technologies, we are developing Reconfigurable Optical Add-Drop Multiplexer (ROADM) system and/or Optical Cross Connect (OXC) system which are expected to handle such large amount of traffic in a cost-effective and agile way. The paper also touches these topics.

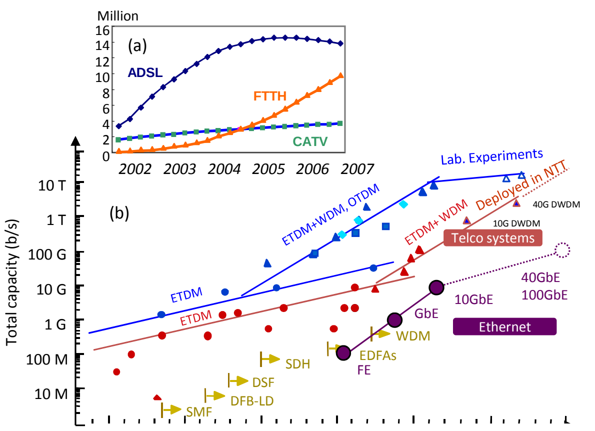

Fig. 1 (a) Broad and trend in Japan
(b) Evolution of transmission capacity

2. Transmission technologies

Optical fiber induced-impairments including Group Velocity Dispersion (GVD) and Polarization Mode Dispersion (PMD) are the main obstacles to extend optical reach of ultra-high capacity transmission systems. When we try to increase line-rate of transmission systems, these effects strongly limit the maximum distance. The effective way to overcome the deterioration, some novel modulation formats with decreased symbol rate must be promising. Differential Quad Phase Shift Keying (DQPSK) [1] and/or Orthogonal Frequency Division Multiplexing (OFDM) [2] are attracting much attention since they can provide lower symbol rate optical signal. These cutting edge modulation techniques actually yielded world record capacity of 20.4 Tbit/s with 111Gbit/s channel rate which can support 100GbE clients.

In parallel to the modulation technique, ultra wide optical amplification should also play an important role to extend transmission bandwidth and optical reach. Phosphorous co-doped silica fiber amplifiers (P-EDFA) [1] dramatically extended optical amplification bandwidth up to 7THz (1561-1620 nm) which fully covered entire L-band of optical fiber.

3. Toward upgrading lambda controllability

The transmission technologies described above are for photonic network with point-to-point network topology. It means optical paths are terminated in each network node.

Fig. 2 shows our strategy for photonic networking R&D. The lambda controllability means how dynamically we can manage lambdas. We had developed and commercially deployed point-to-point (P-P) 10Gbit/s and 40Gbit/s DWDM systems in NTT Communications network. The optical signal transmitted from a sender of these systems will be amplified by some intermediate optical amplifiers and then received by an optical receiver. It means all the optical signal is terminated in the receiver, and electrically regenerated, then transmitted again in the next link. However, it could be the case where most of the optical paths should not be terminated but skipped over to the next node. Therefore, it could cause higher cost and much power consumption of a number of transmitter/receivers.

To upgrade lambda controllability, we are developing ROADM system [3]. Each ROADM node does not terminate all the optical paths, but only the ones needed to be terminated there. We can anticipate reducing cost and power consumption of above-mentioned transmitter/receiver equipments and simplifying operation of the network system. Consequently, we can reduce CAPEX and OPEX of overall network service.

In addition to that, we are trying to develop OXC systems [4] which can support multiple degree of optical switching beyond two degree of ROADM systems. OXC systems are a promising candidate which could realize agile photonic network with arbitrary network topology with lowest CAPEX and OPEX.

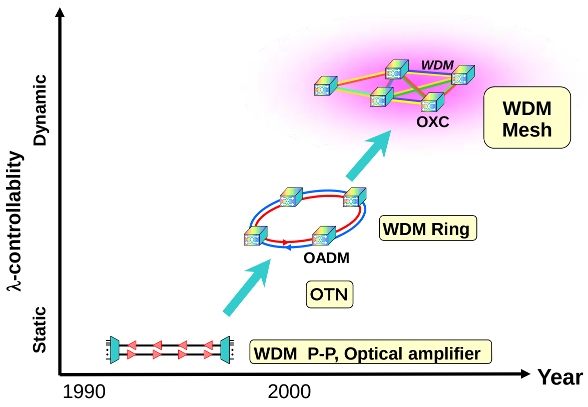

Fig. 2 Lambda controllability

4. Standardization activities

4.1 40GbE and 100GbE

IEEE 802.3 HSSG is responsible for standardizing high-speed Ethernet. 40GbE and 100GbE are scheduled to be consented by 2010 in the working group. 40GbE and 100GbE are expected to be deployed in data centre applications and future back-bone network, respectively. As for 40GbE, it will have two types of PHYs, cupper cable and optical fiber. The optical reach of 40GbE will be limited below 100m. On the other hand, 100GbE will reach 40km of distance for wide area network applications. There have been two approaches to achieve 100Gbit/s capacity, parallel and serial. As the initial step toward 100Gbit/s, the study group plans to consent parallel approach based on matured 10GbE technologies. 10 parallel 10GbEs is a promising candidate. When it is the case, 10 x 10GbE channels will be aggregated to provide 100Gbit/s fat pipe in the first version of 100GbE standard which is planned to be consented by 2010. 100GbE serial version will be discussed after the parallel version.

4.2 ITU-T standard OTN for 100GbE

In line with the activity in IEEE 802.3, ITU-T also started to revise a standard digital hierarchy to support such large capacity Ethernet clients. ITU-T is responsible for developing standard of telecommunication networks. ITU-T SG15 has already recommended G.709 Optical Transport Network (OTN) to support various kind of client traffic including telephone, Ethernet and so on. With the help of Forward Error Correction (FEC), OTN can provide reliable transport these clients. Of course, 10GbE could be transported via network equipments which are compliant to G.709. For the time being, ITU-T is developing new digital hierarchy which can accept 40GbE and 100GbE clients.

5. Conclusion

The paper briefly overviewed recent progress on optical transmission technologies. Transport technologies which ensure to accept 100GbE clients are one of the main interests. Cutting edge modulation technique in combination with extended bandwidth optical amplification techniques achieved 20Tbit/s transport in a single strand of fiber. ITU-T standard OTN with the help of FEC are expected to ensure interoperability and reliability of these optical transport systems. Moreover, we have provided some prospect for future photonic network where higher lambda controllability will be reserved to yield agile and cost-effective network services.

References

1) H. Masuda, A. Sano, T. Kobayashi, E. Yoshida, Y. Miyamoto, Y. Hibino, K. Hagimoto, T. Yamada, T. Furuta, and H. Fukuyama: *OFC2007* (2007) PDP20.
2) A. Sano, H. Masuda, E. Yoshida, T. Kobayashi, E. Yamada, Y. Miyamoto, F. Inuduka, Y. .Hibino, Y. Takatori, K. Hagimoto, T. Yamada, and Y. Sakamaki: *ECOC2007* (2007) PD 1.7.
3) T. Takahashi: Proc. of APOC 2006, SPIE, **6354** (2006) 63540E.
4) Y. Tsukishima, A. Hirano, N. Nagatsu, T. Ohara, W. Imajuku, M. Jinno, Y. Takigawa, K. Hagimoto, L. Renambot, B. Jeong, J. Leigh, T. DeFanti, A. Verlo, and L. Winkler: *OFC2006* (2006) PDP48.