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Flexible access technologies to upgrade PONs

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Abstract: Access technologies designed to provide the next generation services and their migration scenarios are described. There is a strong need for both a flexible architecture that can overlay or coexist with a large number of FTTH facilities and simple high-end technologies.

Issues in system migration: Broadband services have been steadily spreading in Japan, and the target is now set at 30 million FTTH subscribers by 2010. Most FTTH facilities are constructed using GE-PON, and this will continue to exist as a network platform for a long time. PON is well known to be the most economical access architecture for the first stage of FTTH penetration, however it will impose several constraints due to its unique architecture in the coming upgrade stage. For example, its lack of service flexibility, poor loss budget, very high-speed burst TDMA, and complex operation, administration, and maintenance (OAM) function should be carefully considered and overcome when developing new systems.

Upgrade scenarios and various technologies: The current GE-PON configuration is shown in Fig. 1. Thirty-two ONUs are slaved to one OLT through two-step optical power splitters. The system capacity of 1 Gbps is shared among all the ONUs. By adding a V-ONU and an OLT through an SCM-WDM at a wavelength of 1.55 μm, an optional RF-video distribution service can be provided to every user.

The upgrade scenario is shown in Fig. 2, where we simply assume three main branches. The first branch to appear indicates a partial upgrade when some users belonging to one PON require new services. The power splitter based WDM-PON is most suitable here as shown in Fig. 2(a). Each new ONU and OLT can exchange signals through an allotted wavelength filter whose wavelength can be chosen from a future band of the ITU-T G.983.3 grid. With this additional WDM method, we must smoothly install new ONUs on customer premises to maintain good OAM. We have been developing a PnP mechanism whereby an OLT automatically configures the IDs and wavelengths of newly connected ONUs, and colorless ONU technology [1]. In addition to the above WDM systems, a simplex downstream system of ~10 Gbps, although it might be transitional, is also very attractive since broadband distribution services such as IP-video can be easily achieved with almost the same architecture as the RF-video distribution mentioned above. (Fig. 2(b)).

The second branch shows an extension of the area to be covered. This is typically required in rural areas to overcome the digital divide. Bidirectional optical amplifiers used as repeaters can extend the transmission distance and increase the number of branches supported by the optical power splitters. Last year BT, Mitsubishi Electric and NTT proposed long-reach PON technologies that represent enhanced versions of GE-PON or G-PON. BT achieved 60 km transmission distances with a 128-way splitter [2]. SOA-based repeaters were employed for both upstream 1.49 μm and downstream 1.51 μm wavelengths. NTT also achieved a 40 km transmission with a 128-way splitter by using TDFA for 1.31 μm and PDFA for 1.49 μm wavelengths. Furthermore, a 60 km transmission with 256 branches (64-way and 4-way splitters) can be realized by two-step amplification [3]. The wavelength arrangement in our experiment is equivalent to that in current GE-PON. PONs with more than 32 branches are also expected to be used for large housing complexes in place of VDSL. Optical devices, in particular optical amplifiers, are still too expensive for access network use, and the cost efficiency should be improved in future.

The last scenario means replacement or overlay by new access systems in the next generation. This is similar to the case of greenfield installations. The TDM-based PON will become mainstream with bit rates of around 10 Gbps and TDM, WDM and OCDM hybrid methods will become candidates for applications beyond a few tens of Gbps. Although the simple 10 GbE has already been completed, 10G-PON cannot be fully achieved yet because of difficulties in obtaining burst signal processing devices with higher speeds and lower prices. This year, Mitsubishi Electric first announced that they had developed a 10 Gbps XFP transceiver module for PON [4]. NTT has also reported the burst-mode 3R receiver operating at 10.3125 Gbps using SiGe-BiCMOS monolithic ICs, which achieved the highest sensitivity of -18 dBm, the widest dynamic-range of 16.5 dBm and instantaneous responsivity of 75 ns [5]. The competition is sure to be accelerated further in one or two years from now. From the viewpoint of upgradeability, a double/multi-rate 10 Gbps system accommodating both 1 and 10 Gbps services will be required in the future.

A lot of research (hybrid multiplexing, multilevel transmission, etc) has been reported with the goal of attaining much larger capacity for the long term. NTT proposed a high-density FDM (equivalent to WDM) system with coherent detection to expand capacity to one digit or more. Customers can obtain the desired video signal from among a few hundred channels by optical frequency tuning. The application of coherent detection to conventional DWDM is expected to yield higher sensitivity and wavelength/frequency efficiency. We have reported a 1 Gbps×100 ch FDM transmission experiment with a simple ONU in which both the transmitter and local light source consist of a DFB-LD to lower the price [6].

CDMA technique is also now receiving a lot of attention because it can be flexibly applied to networks of any topology and offers high frequency/wavelength efficiency. Several basic experiments have been reported. OKI Electric has reported a system capacity of 2 Gbps (62.5 Mbps×32 users) with 100 km-distance by coding in electronic domain [7]. As for Optical CDMA, a system of 320 Gbps (10 Gbps×32 users) with a sensitivity of 32 dBm has been realized by the

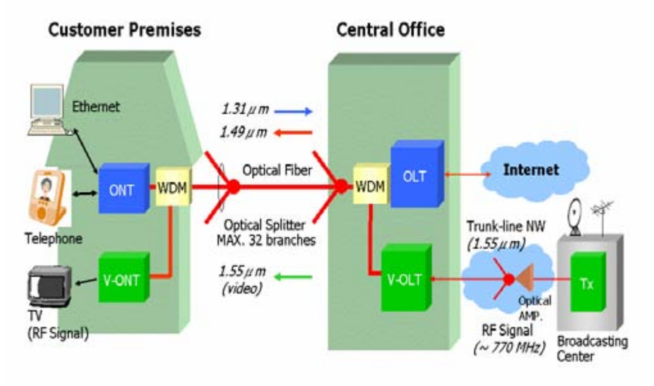

Fig. 1 Gigabit-Ethernet Passive Optical Network (GE-PON)

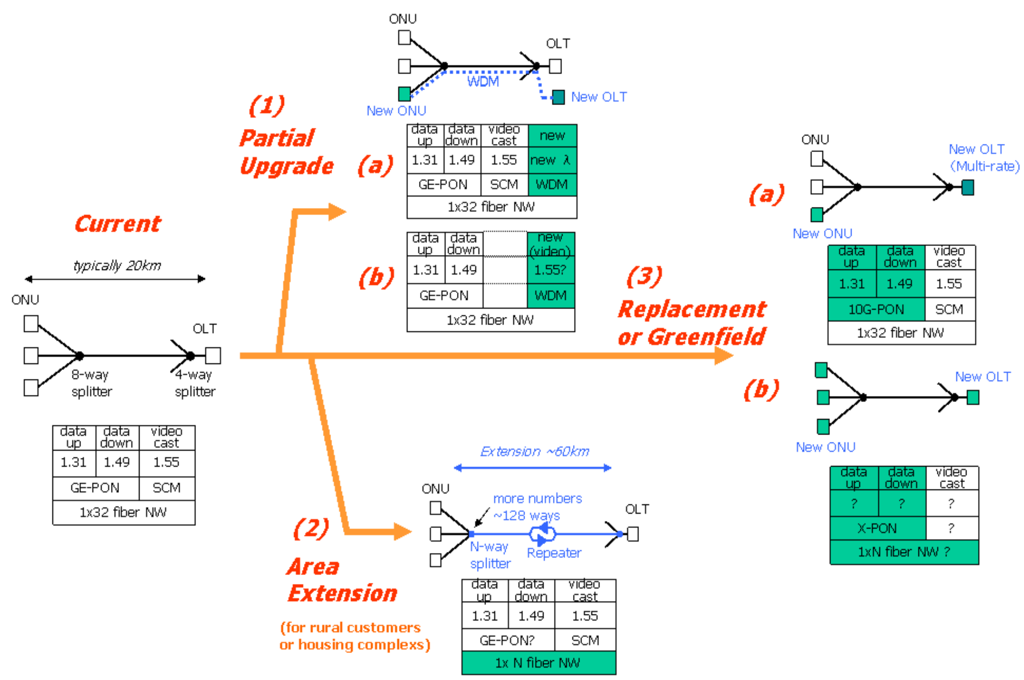

Fig. 2 PON Upgrade Scenarios

University of California [8]. NICT and Osaka University have also reported a system capacity of 300 Gb/s (3-WDM×10-OCDMA users×10.71 Gb/s) with a sensitivity of 30 dBm [9]. These OCDM experiments need highly accurate and large scale devices to support huge system capacities, therefore it may be important to ascertain OCDMA's applicability to actual access networks in the future.

Summary: I have described system migration scenarios and several access technologies. Smooth migration from legacy PONs is a key factor for the next generation access systems, and this makes it important to consider various approaches including partial and/or complete replacement of systems to allow services to evolve.

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