Large-Scale Network Field Trial Demonstrating the Evolution of 10G EPON to 50G PON Using Two-Generation Multi-PON Modules

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Abstract: We report the first large-scale network field trial demonstrating the evolution of 10G EPON to 50G PON using a newly two-generation multi-PON module, which validates the sustainable evolution for mass 10G EPON networks.

1. Background

Globally, operators have deployed optical access networks on a massive scale to provide high-speed Internet services to subscribers. In operators' deployments, the most widely adopted PON technologies are EPON, GPON, and 10G PON (including both 10G EPON and XG(S) PON) [1, 2]. The ITU-T has developed 50G PON standards (G.9804 family) for the evolution of access networks beyond 10G PON [3]. There have already been reports of lab trials of 50G PON prototypes [4] and announcements of 50G PON product releases [5].

In China, telecom operators have deployed more than 20 million 10G PON OLT ports and more than 38 million km of access network cables, with more than one billion fiber optic access (FTTH/O) ports [6]. With the backdrop of such a huge network scale, the evolution from 10G to 50G PON technology must consider key factors including how to reuse the deployed ODN facilities; how to realize the coexistence of 10G and 50G PON and upgrade on demand; how to reduce the project complexity and the failure rate during the upgrade process; and how to optimize the demand for scarce infrastructure resources such as equipment rooms and associated power supplies and so on. Large-scale field trials are an important tool for network operators to work through such issues.

The ITU-T G.9805 standard [7], provides multiple technical solutions for the coexistence of different generations of PON systems. Due to the sheer scale of China Telecom's optical access network, the multi-PON module (MPM) based PON coexistence solution in G.9805 is the preferred method. This is mainly because it miniaturizes the bulky external WDM devices that combine and split the upstream (US) and downstream (DS) signals at the different wavelengths of 10G EPON and 50G PON and builds them into the MPM. This enables the full reuse of deployed ODNs in the 10G EPON/50G PON coexistence scenario. Furthermore, the MPM solution greatly reduces the additional infrastructure investment requirements and the complexity of engineering and construction. Of course, the challenges of this solution are considerable and include optical miniaturization, complex packaging, and heat dissipation - all while ensuring PON standards compliance with the MPM.

In this paper, we report for the first time, the initiation of a large-scale network trial of 50G PON coexisting with 10G EPON using a two-generation MPM. Based on the 10G PON network deployed by China Telecom, we have fully verified the cross-vendor interworking of the MPM with already deployed 10G EPON gateways, the ultra-high-speed access capability provided by the 50G PON channel, and the ultra-high-bandwidth support capability for new services in different scenarios across multiple provinces in China.

2. 10G-EPON/50G-PON Multi-PON Module

To achieve a smooth upgrade, the 10G-EPON/50G-PON MPM (10GE/50G MPM) needs to integrate a 50G Tx, a 50G Rx, a 10G-EPON Tx, a 10G-EPON Rx, and the WDM multiplexer/demultiplexer into one optical module. What is more, the MPM also needs to be as compact as the previous 10G-EPON module it replaces otherwise, the OLT port density is reduced so it supports fewer ODNs, central office (CO) space is increased and fibre cabling in the CO needs reworking. All of which results in higher costs. Therefore, despite the number of internal components of the MPM increasing significantly, the size of the original optical module needs to be retained, which poses great challenges for the packaging and layout of the MPM.

Fig.1a illustrates the optical path layout of the MPM. On the rightmost part, the 50G-PON Tx and the 10G-EPON Tx signals are combined through thin film filter (TFF) 1, passing through the isolator, and entering the fibre ceramic ferrule through TFF2. The Rx signals of 50G-PON and 10G-EPON are incident from the left ceramic ferrule to the inclined TFF2 and reflected to separate the Tx and Rx optical signals. TFF3 separates the 10G-EPON

Rx signal from the 50G-PON Rx signal. 1286 nm is selected as the US wavelength for this MPM as it enables a common solution for both the ITU-T and IEEE PON upgrades.

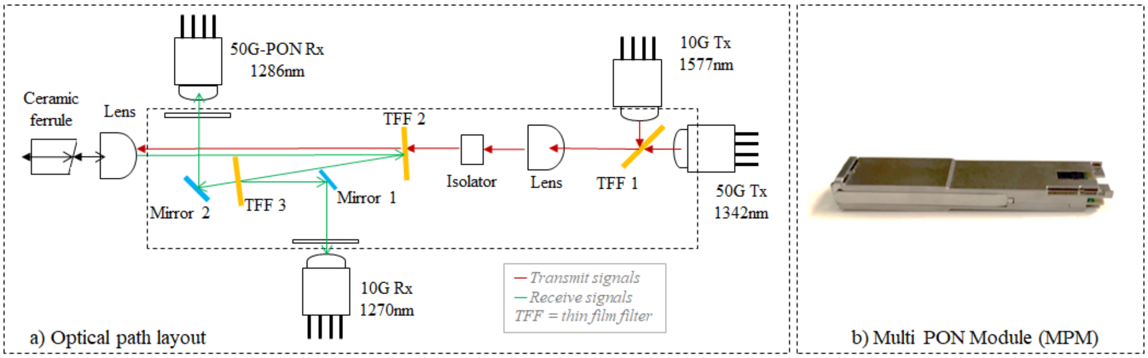

Figure 1 10G-EPON/50G EPON MPM (a) Optical path layout of the; (b) MPM

As the US Rx wavelength of the 10G-EPON is 1270±10 nm, the wavelength gap between the 10G-EPON and the 50G-PON Rx wavelength bands is only 4 nm. To effectively separate the Rx signal of the 10G-EPON and 50G-PON and reduce the size of the optical component, Mirror 1 and Mirror 2 are used to further extend the optical path of the Rx signals of the 50G-PON and 10G-PON. Through this novel layout, the two Rx optical signals can be well isolated, and the space inside the module is fully utilized. With this compact design, the 10GE/50G MPM was packaged into a Quad Small Form Factor Pluggable (QSFP) module for this initial proof of concept. In the future, we expect to approach the original SFP+10G-EPON module size and therefore support the same port density in each line card. Fig.1b shows the 10GE/50G MPM itself.

3. Experimental Setup and Results

The 10GE/50G MPM needs to support a high-power budget to be compatible with the ODN in the deployed network. The 50G Tx in the MPM uses a 50G EML with a center wavelength of 1342.8 nm, in compliance with [3]. Fig.2a shows the eye diagram of the 50G-PON Tx. At the modulation rate of 49.7664Gb/s, the extinction ratio is 8.3dB, the transmitter eye closure (TEC) is 2.3dB, and the eye passes the ITU-T mask with a 10.8% margin. To achieve a high-power budget, an SOA is integrated with the EML chip, which boosts the output power to +10.6 dBm, hence meeting the C+ class defined in ITU-T G.9804.3 [3].

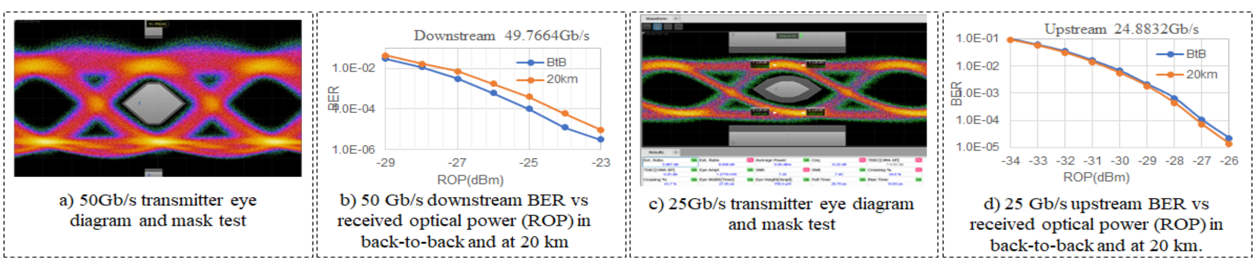

Figure 2 50Gb/s transmission performance in downstream and 25Gb/s transmission performance in upstream

Fig. 2b shows the DS BER curve measured for back-to-back (BtB) and 20 km fibre transmission. With a 50G Rx using a 25G APD with DSP-based equalization, the BtB and 20 km 1e-2 BER sensitivity is measured as -28 dBm and -27.4 dBm respectively, giving a 0.6 dB dispersion penalty after 20 km. For 50G-PON in the US, a 25G DML is used for the ONU Tx with 1287.2 nm wavelength and 6.0 dB extinction ratio at 24.88 Gb/s. The eye diagram is shown in Fig. 2c and it passes the ITU-T eye mask with a 34% margin. At the OLT side, a burst mode 25G APD Rx is used. The measured BtB sensitivity is -30.4dBm at 1e-2 BER and, due to negative fibre dispersion, the sensitivity after 20 km is 0.2dB better than BtB, at -30.6dBm. The BER curve for 25G US is shown in Fig. 2d.

Concerning the 10G-EPON elements of the system, all are IEEE 802.3av compliant [8]. The measured 1e-3 BER ONU sensitivity is -31.6 dBm whereas the OLT sensitivity is -29.2 dBm (both at 10.3125 Gb/s). The penalty after 20km is negligible at this line rate. With the configuration shown in Fig.3a, system throughput tests were carried out (following IETF RFC2544). As shown in Fig.3b, the 50G-PON system based on this newly developed MPM can achieve a throughput of up to 41.94 Gbps in the DS direction and 17.10 Gbps in the US direction, which is in line with expectations considering the system overheads from framing, FEC, etc.

4. Scale Field Trial

In a world-first field trial, China Telecom has validated the technical capability of the optical access network of the EPON system to evolve to 50G PON. The 50G PON prototype systems based on the 10GE/50G MPM described above have been deployed in the live PON networks of five provinces i.e. Jiangsu, Shanghai, Sichuan, Hubei, and Fujian. Initial evaluations of the service-bearing capability have been carried out in Jiangsu province and we share below these very first field trial test results. In the trial environment, 50G PON OLT equipment based on the 10GE/50G MPM is deployed. A variety of different 10G EPON ONUs have been deployed in the real network and are connected to the system at the same time as the 50G PON ONU equipment to verify that 10G EPON and 50G PON are supported simultaneously by the system and demonstrate their co-existence capability.

Figure 4 shows the trial network architecture. OLTs are uplinked through the metro-area network and connected to the speed measurement platform. To mimic a high-end user scenario, two PCs capable of 10GE download/upload are attached to the 50G PON ONUs to verify the service capability of the end-to-end metro-access network. In the pilot test, by accessing asymmetric 10G EPON home gateway units (HGU) and carrying services such as cloud gaming and HD VoD, the concurrent service carrying capacity of 10G EPON and 50G PON was verified.

The access bandwidth test server to PC link throughput was measured and the results show that the aggregate PC throughput can reach 13.048Gbps in the uplink and 12.728Gbps in the downlink. While this throughput was ultimately limited by the PC processing speed, the measured single ONU performance exceeds the access total bandwidth capacity of the existing 10GE PON network. At the same time, the asymmetric 10G EPON HGU can simultaneously carry services such as OTT video, thus demonstrating the coexistence of two PON generations from different standards bodies within a unified PON port. We verified the complexity of the engineering operation in the trial. The upgrade operation was completed by replacing the original 10G EPON card with a new card equipped with the 10GE/50G MPM in the same OLT frame, and the overall time taken was just minutes, before successful operation. This greatly simplifies the complexity of future network scale upgrades.

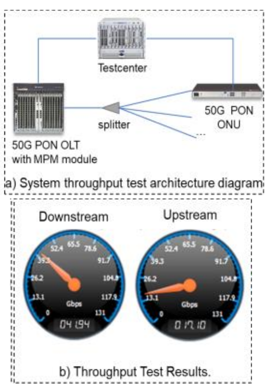

Figure 3 System throughput test

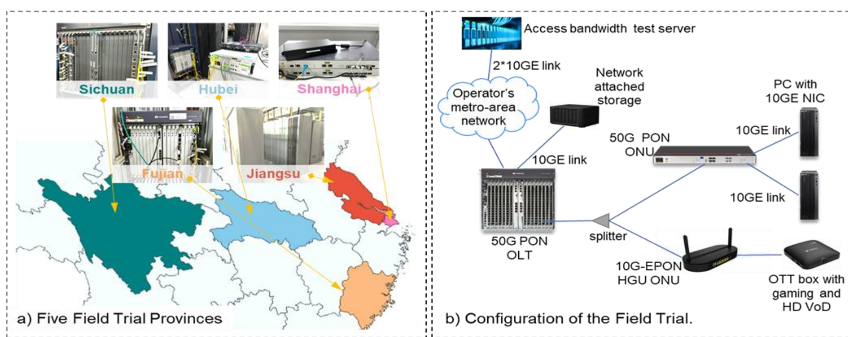

Figure 4 Trial provinces map and schematic diagram of the field trial

5. Conclusion

Facing the evolution of mass 10G EPON networks to 50G PON, we have developed, analyzed, and validated the key 10G EPON/50G PON MPM technology, and initiated the world's first and the largest multi-generation PON coexistence field trial to date. Results of lab tests and field trials show that the 10G EPON/50G PON MPM technology can ensure the sustainable evolution of the deployed 10G EPON optical access network to 50G PON.

6. References

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