10G EPON- Unleashing the Bandwidth Potential

Talking to the Future

ZTE中兴

Product Type Technical Description

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1 Abstract

For the first time in history, we can now aim to live in “One World”, because the 21st century has ushered in a new era in man’s ongoing quest for a better life and a better world. Telco industry is passing through a phase of multiservice revolution, with a shift from legacy to next generation networks and the introduction of new and advanced services (e.g. 3DTV, HDTV, IPTV, VoIP, WiMAX, Mobile TV, etc.). More and more service providers are progressing to triple-play and even quad-play packages in order to provide a one-stop shopping service to customers. IP traffic is growing exponentially and networks evolve to include bandwidth hungry IP-based applications on voice, video and data. A discussion about broadband medium and speed is on everyone’s tongue. But still it is under discussion that “**how fast is fast enough**”. In fact, broadband is not just a speed it is defined as a potential medium that offers a wide variety of applications to users at their premises. This white paper provides a detailed tutorial overview of the **IEEE 802.3av 10Gbit/s Ethernet PON (10G EPON)** market trends that are driving the requirement of future last mile access networks, standardization advancements, technology infrastructure.

2 Introduction

The users thirst for higher capacity, versatile diversity and more personalization of services is keep on increasing at rapid pace. Video and bandwidth hungry applications drive the requirements for versatile access network and fiber to the last mile. Optical fibre is coming to the premises, in order to relieve the shortcomings of the copper network, and also able to outperform the power consumption of today’s electronic solutions. Moreover, by exploiting the wavelength domain; optical fibre is uniquely capable of integrating services with widely differing characteristics independent from each other into a single infrastructure. Time-division multiple access (TDMA) protocol, where functions can be readily implemented with digital electronics being used in BPON, up to 622 Mbit/s symmetrically, GPON (Gigabit PON, with speeds up to 2.5 Gbit/s, for ATM and also Ethernet packets plus native TDM), and EPON (Ethernet PON, optimized for variable-length Ethernet packets).Alternatively, one may consider Sub carrier Multiple Access (SCMA), requiring more costly RF electronics, or Optical Code Division Multiple Access (OCDMA), requiring more costly optical spectrum slicing filters. Gaining popularity is Wavelength Division Multiple Access (WDMA), where each user on the WDM-PON gets an individual pair of wavelengths for up- and downstream communication, thus in effect getting a P2P link (with its advantage of easy per-user upgrading) on a P2MP physical infrastructure. With so-called ‘colour-less’ optical network units (ONUs) at the user side

Both EPON and GPON, which belong to the same technology generation, can provide 1G / 2G

bandwidth. With the huge-stream broadband services like IPTV, HDTV, 3DTV and online game play, the bandwidth requirement of subscribers is predicted to increase in magnitude per five years and will accelerate at pace. Taking the middle and long-period development trend to analyze, the bandwidth requirement per subscriber will reach 50-100 Mbps. For current PON interfaces, of both EPON and GPON, the bandwidth bottlenecks appear. To solve this problem, IEEE put forward 10G EPON technologies, which can increase the up and downstream bandwidth as wide as 10G and can accomplish co-existence of 10G EPON ONU and 1G EPON ONU in one PON interface. This provides a smooth migration solution from 1G EPON to 10G EPON for carriers. Thus protects carriers' investment at the maximum. So, 10G EPON technology becomes the best solution for carriers to construct next generation optical access network.

3 IEEE 802.3av 10Gbit/s Ethernet-based PON (10G EPON)

The IEEE 802.3av PON standard was developed to increase the data rate of EPON systems from 1 Gbit/s to 10 Gbit/s, in keeping with the 10 Gbit/s Ethernet interface. Many protocols are shared between 10G EPON with EPON. An amalgamation of coarse wave division multiplexing (CWDM) and time division multiplexing (TDM) is used in order to allow EPON and 10G EPON systems to co-exist on the same PON. As with EPON, 10G EPON relies on VoIP for carrying voice traffic and circuit emulation service (CES) for carrying other TDM client requirements. Figure 1 shows the 10G EPON protocol stack.

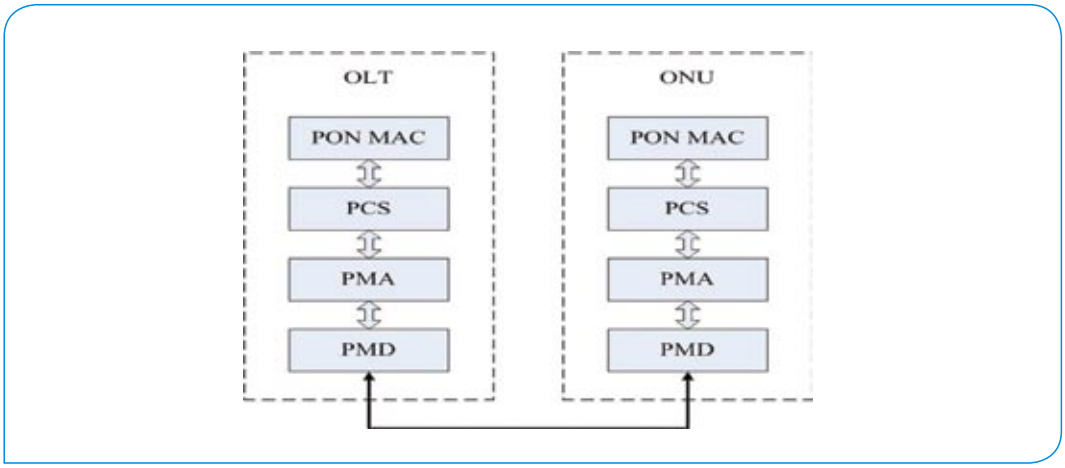

Figure 1 10G EPON protocol stack

IEEE802.3av defines two physical layer modes. One is Symmetric-**rate 10/10G-EPON** supports transmit and receive data paths operating at 10 Gb/s. The main driver for 10/10G-EPON is the necessity to provide adequate downstream and upstream bandwidth to support the MDU’ s. When deployment strategy is MDU configuration, one EPON ONU may be connected up to thousand subscribers.

And second is, **Asymmetric 10/1G-EPON** appear less challenging then the symmetric option, as this specification relies on fairly mature technology. The upstream transmission is identical to that of the existing 1G-EPON (as specified in IEEE Std. 802.3ah), and will rely on field-proven and mass deployed burst-mode optical transceivers. The downstream transmission, which uses continuous-mode optics, will rely on the maturity of 10 Gb/s point-to-point Ethernet devices.

As the service and technology develops, it will transfer to symmetrical mode. Figure 2 shows the 10G EPON protocol schedule.

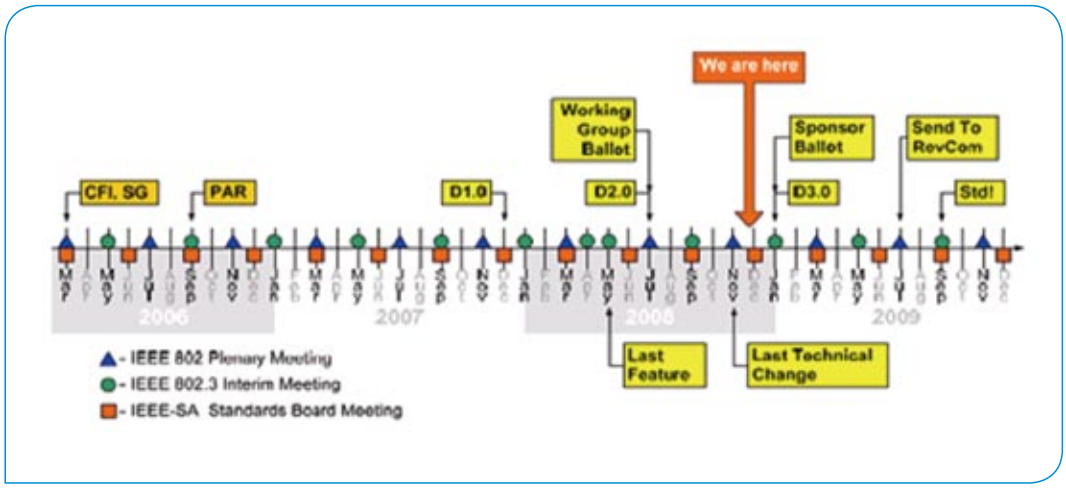

Figure 2 Shows the 10G EPON protocol schedule.

4 Standardization Timeline

In March 2006, IEEE 802.3 working group held call for interest (CFI) for 10 GB/s EPON study group. According to the CFI materials, representatives from various worldwide vendors and operators supported the formation of the study group such as: Advance/Newhouse Communications, Broadcom, Centillium Communications, China Netcom, China Telecom, Chunghwa Telecom, Cisco Systems, ClariPhy Communications etc. Below mentioned in table 1 are the major milestones in 10 Gb/s EPON study group:

Table 1 Major Milestones in 10G EPON Study Group

Date	Milestone
September 2006	IEEE 802.3av task force is formed. First task force meeting in Knoxville, TN.
December 2007	Draft D1.0 is produced
July 2008	Draft D2.0 is produced. Working Group balloting begins.
November 2008	Cut-off date for last technical change
January 2009	Draft D3.0 is produced. Sponsor balloting begins.
September 2009 (projected)	Standard approval

ZTE actively participates in various standards, including the editorial board that sets the IEEE 802.3av 10G EPON standard. It spends significant amount of time to contribute in the formulation and improvement of 10G EPON standards. Meanwhile, early this year, Glen Kramer, Chairman of the IEEE "10G EPON" Working Group, announced that the 10G EPON draft for the EPON next-generation standard has been completed. It is expected to be formulated in 2009 and officially released by middle of the year. According to a White Paper on 10G EPON published by the Ethernet Alliance, both IEEE and ITU-T are committed to conduct more research on next-generation optical access systems.

4.1 10 G EPON Co-existence with 1G EPON

The 802.3av task force places significant emphasis on enabling simultaneous operation of 1 Gb/s and 10 Gb/s EPON systems on the same outside ODN plant. In the downstream direction, the 1 Gb/s and 10 Gb/s channels are separated in the wavelength domain, with 1 Gb/s transmission limited to 1480-1500 nm band and 10Gb/s transmission using 1575-1580 nm band.

In the upstream direction, the 1 Gb/s and 10 Gb/s bands overlap. 1 Gb/s band spreads from 1260 to 1360 nm; 10 Gb/s band uses 1260 to 1280 nm band. This allows both upstream channels to share spectrum region characterized by low chromatic dispersion, but requires the 1 Gb/s and 10 Gb/s channels to be separated in time domain. Since burst transmissions from different ONUs now may have different line rates, this method is termed dual-rate TDMA. Figure 3 illustrates a network where an OLT supports a mix of EPON ONUs, ONUs with 10Gbit/s downstream and 1Gbit/s upstream, and ONUs 10Gbit/s upstream and downstream. Note that WDM technique is used to separate the 1Gbit/s and 10Gbit/s traffic in the downstream direction and combination of WDM and TDM is used in the upstream direction. The discovery and other protocol extensions to support the co-existence

of EPON and 10G EPON ONUs are discussed in the appropriate sections below. The key features of the 10GE EPON architecture is that it allows 10G EPON to operate on the same ODN backbone that is already being used for 1G EPON. Following are some of the benefits associated to this one platform feature are:

- Using cost efficient ONU for the required desired service
- No disruption of the services and network operations during the upgrade of the network
- Migration from EPON to 10G EPON by upgrading the OLT then migrating the ONUs as needed
- Reduced OpEx and CapEx cost associated with this migration of network.
- Innovative improvement on device, enhanced network capability and optimization synergy
- Same OAM for stronger end to end monitoring will be used intensively.

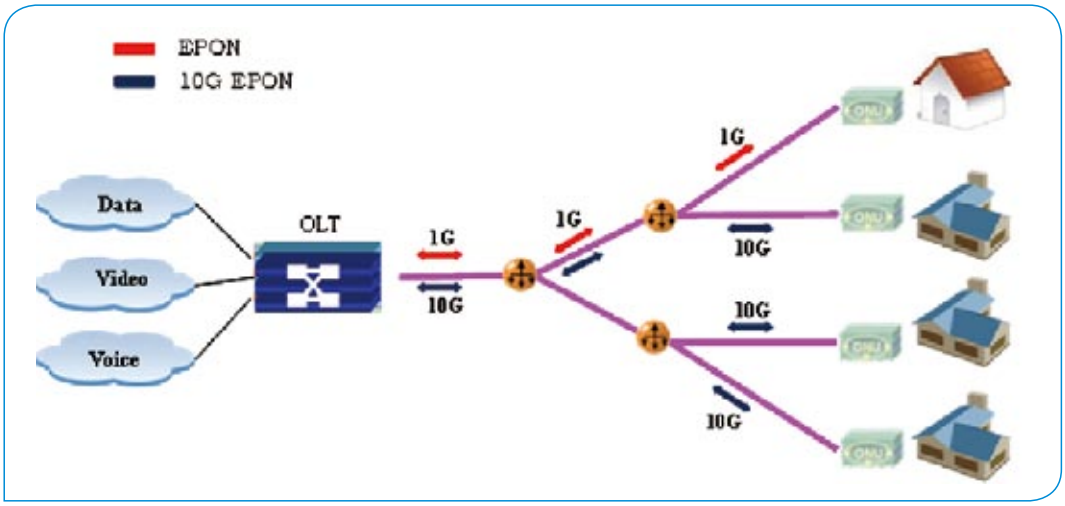

Figure 3 10G and 1G EPON co-existence

5 Power Budget

The 802.3av defines several power budgets, denoted either PR or PRX. PRX power budget describes asymmetric–rate PHY for PON operating at 10 Gb/s downstream and 1 Gb/s upstream. PR power budget describes symmetric–rate PHY for PON operating at 10 Gb/s downstream and 10 Gb/s upstream. Each power budget is further identified with a numeric representation of its class, where value of 10 represents low power budget, value of 20 represents medium power budget, and value of 30 represents high power budget. To increase optical power budget, it is regulated that 10G EPON technology must be able to achieve FEC which uses RS (255, 223) coding. 10G EPON currently standardize three types of power budget: PR10/PRX10， PR20/PRX20 and PR30/PRX30. Table 2 lists power budget information. 10G EPON Power Budget

Table 2 Power Budget Explanation

Description	Low Power Budget		Medium Power Budget		High Power Budget		Units
	PRX10	PR10	PRX20	PR20	PRX30	PR30	
Maximum Channel insertion loss	20		24		29		dB
Minimum Channel insertion loss	5		10		15		dB

6 10G EPON Optical Spectrum Allocation

PMD layer is used to represent the 10G EPON wavelength allocation and optical power budget Figure 3 shows the IEEE802.3av wavelength allocation spectrum. For downstream data transmission, it adopts 1575 – 1580 nm bands. For upstream, the band is 1260 – 1280 nm which is lapped over 1G EPON. The wavelength allocation enables 10G upstream wavelength to overlap 1G upstream wavelength. So 1G ONU and 10G ONU must use wavelength division multiplexing mode to transmit upstream data. In downstream direction, 10G wavelength and 1G wavelength are separated. This guarantees the downstream data to enjoy broad bandwidth.

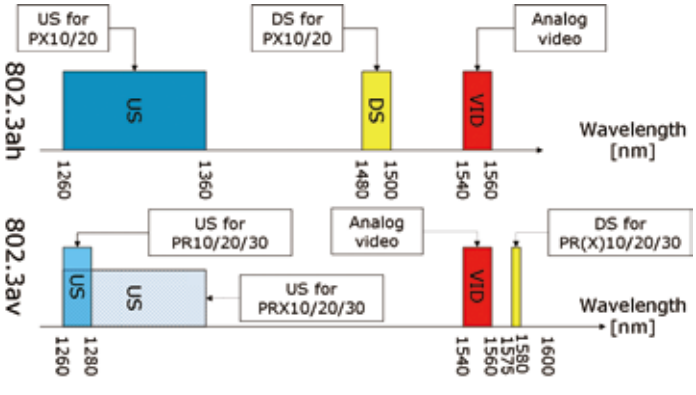

Figure 4 10G EPON Wavelength Allocation Chart

7 Forward Error Correction (FEC)

The 10G-EPON system use Reed Solomon (255, 223) forward error correction (FEC) mechanism. The FEC is mandatory for all channels operating at 10 Gb/s rate, i.e., both downstream and upstream channels in symmetric 10 Gb/s EPON and the downstream channel in the 10/1 Gb/s asymmetric EPON. (Upstream channel in the asymmetric EPON is the same as in 1 Gb/s EPON, i.e., optional frame-based FEC using RS (255, 239).). The 10G-EPON task force also focuses on defining a new physical layer, keeping the MAC architecture. This means that users of 10G-EPON can expect backward compatibility of network management system (NMS), PON-layer operations, administrations, and maintenance (OAM) system, DBA and scheduling.

8 Dynamic Bandwidth Allocation (DBA)

10GEPON system is the ability to overcome system bottlenecks and log jams via adjustments in the EPON DBA algorithm. The DBA cycle length and bandwidth allocation per ONU can be adjusted and as a result total OLT upstream transmission going into the switch will be "smoother", less bursty in nature, allowing carriers to overcome blocking elements in their network topology (e.g. assigning more bandwidth to the OLT ports then the uplink ports in the switch connected to the OLT to save CAPEX).

9 10G Convergence

Figure 5 shows the convergence need of EPON and GPON systems that currently use different physical layers structures, which leads to incompatible chips, hardware and optical modules. ITU and IEEE are discussing a plan for convergence of their specifications at the physical layer in 10G that would allow for the shared and convergence of the chips, optics and hardware platforms, thus driving costs reductions. Carriers would still have a choice of technologies in 10G PON, but would have the advantages of a single physical layer. That converged system is possible feasible in which only differences will be left at higher level. And as a result convergence brings unified OAM, ODN and service models.

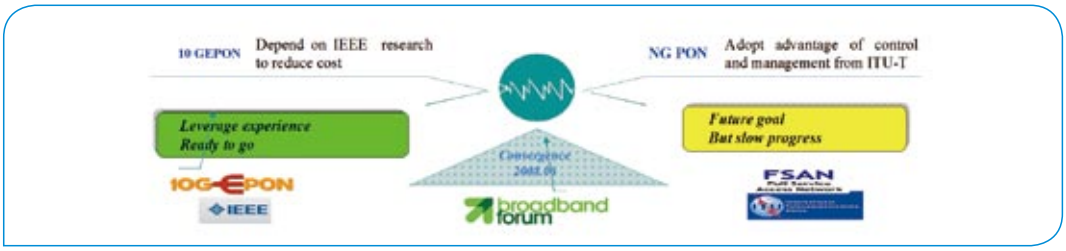

Figure 5 Convergences at 10G

10 10G EPON Industrial Chain

Hardware manufacturers who have invested in 10G EPON technology mainly include optical module manufacturers, chip manufacturers and equipment manufacturers. Recently, Vitesse, the IC solution supplier, announced to supply a whole set of PMD related chips for 10G EPON use. This set of chips complies with IEEE802.3av/ D3.0 protocol. For 10G EPON optical module, as early as the first half year of 2008, there were suppliers to provide asymmetrical optical modules. And now, the supplier is able to provide XFP asymmetrical optical modules in batches. And from the 4th quarter of 2008 on, they can also provide symmetrical optical modules. Japan's company Mitsubishi announced it researched and developed successfully 10G EPON sample equipment and 10G EPON optical module at FSAN conference in September of 2008. As to chip manufacturers, company PMC-Sierra played a leading role in demonstrating 10G EPON technology in July of 2008. The demonstration used PMC-Sierra complete 10G EPON reference design including 10G OLT) PAS8001 and 10G ONU PAS9001. This system had been launched at Optical Network Forum of China, Beijing from May 28 to 29. TKNOVUS company also announced its 10G EPON EVB fully complied with IEEE802.3av 10G EPON protocol. This set of EVB system included OLT and ONU equipment and integrated development tools. As to telecommunication equipment manufacturers, ZTE firstly brought forward 10G EPON sample equipment in the industry at International Information and Communication Expo of China on October 22nd, 2008 and performed system service demonstration. The displayed sample equipment includes xPON CO equipment, which supports EPON, GPON, 10G EPON and 10G GPON integrated platform, and MDU equipment. The demonstration covers 10G EPON broadband performance and perfect compatibility of 10G and 1G EPON. The series of equipment evolutes based on current xPON equipment smooth migration and enable to improve the capability of system access bandwidth enlargement and service access.

11 Conclusion

In nutshell, from the above brief analysis, we can conclude that 10G EPON protocol develops very fast. The requirements to deploy networks that service these new data intensive and bandwidth hungry video applications will spur demand for systems that supplement and evolve, rather than replace, existing equipment in the infrastructure. This migration and acceptability of new standard protocols is a great source of TCO Optimization and cost reductions. These networks will move from systems based on a variety of protocols to systems based primarily on Ethernet technologies. And the formal protocol is to be published in the 3rd quarter of 2009. 10G EPON can not only inherit EPON large-scale deployment experiences but also co-exist with GEPON without changing existing ODN network, thus saves a lot of cost for carriers.

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