Symmetric 10G-EPON ONU Burst-Mode Transceiver Employing Dynamic Power Save Control Circuit

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Abstract: Symmetric 10G-EPON ONU burst-mode transceiver employing dynamic power save control circuit was, for the first time, developed. Reduction of power consumption up to 37.7% was successfully achieved with shorter settling time of 736 ns.

OCIS codes: (060.4250) Networks; (060.4510) Optical communications

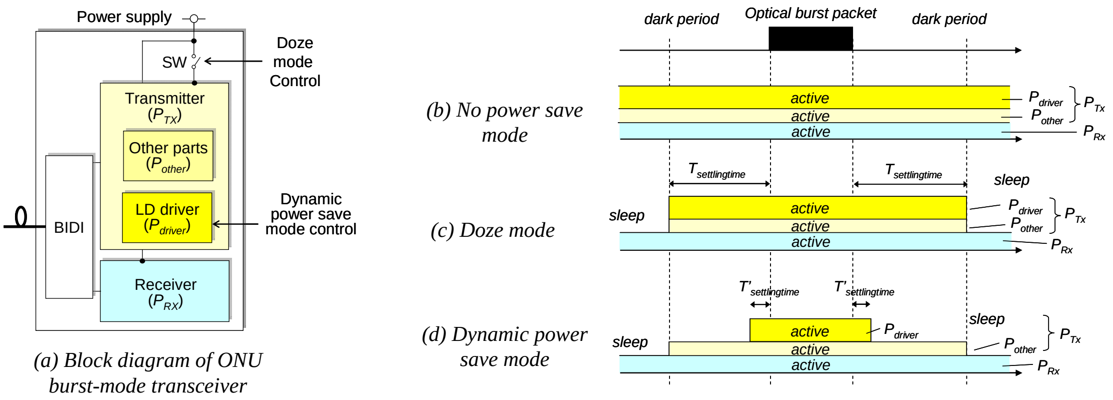
1. Introduction

The standardization of 10G-EPON (10 Gigabit Ethernet Passive Optical Network) has completed in September 2009 under IEEE802.3av [1]. 10G-EPON PR30 standards require full compatibility with the existing Gigabit EPON fiber plants which have been already installed in the field, thus the power budget of more than 30 dB is mandatory to provide smooth migration from 1Gb/s to 10Gb/s optical access systems. In order to meet such demand of large power budget at 10Gb/s, ONU (optical network unit) transceivers with high launch power and high received sensitivity were already reported [2]. On the other hand, the power save technologies have recently attracted a great deal of attention as a way to prevent the global warming. In PON systems, the power consumption of ONU located at the user's premises becomes the most serious issue, because the number of ONUs is rapidly growing all over the world. In order to address the issue, the power save protocols, which include Power shedding, Doze mode, Deep sleep, and Cyclic sleep are being investigated under ITU-T and IEEE standardization activities [3] and related works [4]. Among them, the Doze mode can become the most promising to realize both of the efficient power save and the simple protocol implementation by shutting down transmitter blocks only of ONU burst-mode transceivers.

In this paper, we have proposed, for the first time, the dynamic power save mechanism, which can switch the transceiver in shorter settling time of 736 ns than the Doze mode mechanism. A newly developed symmetric burst-mode 10G-EPON ONU transceiver employing a dynamic power save circuit successfully demonstrated its power save effectiveness of as high as 37.7 % even in the heavy PON upstream traffic condition.

2. Dynamic Power Saving Mechanism in 10G-EPON ONU transceiver

Figure 1 (a) shows high-level block diagrams of ONU burst-mode transceiver, which consists of a transmitter block including a LD driver block and a receiver block. Figures 1 (b) - (d) show four power save mode including our proposed dynamic power save technique. Fig.1 (b) shows the mechanism of the conventional transceiver with no power save mode, where all transceiver blocks shown in Fig.1 (a) are always active, thus there is no power save effectiveness. Figs.1 (c) and (d) correspond to the Doze mode and the proposed dynamic power save mode, respectively. In the Doze mode, the transmitter block only is periodically switched between active and sleep to

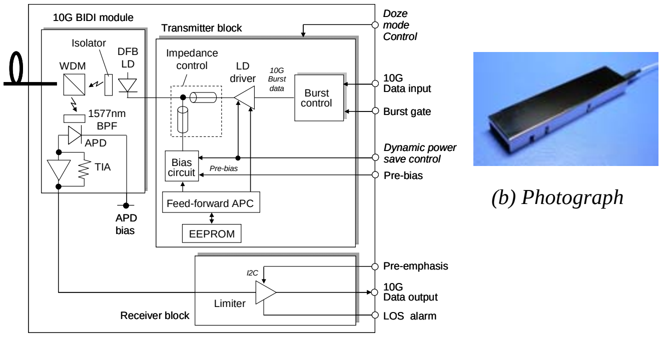


(a) Block diagram of ONU burst-mode transceiver

Fig.1 Power save modes in 10G-EPON ONU burst-mode transceiver reduce the power consumption during the dark period between upstream optical burst packets. However, the settling time, $T_{settlingtime}$, of as long as 1 ms – 100ms for the transitions between active and sleep is necessary in the conventional transceivers, thus the power save becomes less effective in the short dark period condition, that is the heavy PON upstream traffic condition. To improve the power save effect in the heavy traffic condition, we have proposed the *dynamic power save* mechanism as shown in Fig.1(d), where the LD driver block is switched between active and sleep in shorter settling time, $T'_{settlingtime}$, less than 1μs synchronized with optical burst packets and dark periods. The other blocks follow the power save mechanisms of the Doze mode. The LD driving block consumes the large portion of whole currents of the transceiver, thus the high power save efficiency can be achieved even in heavy traffic condition.

3. Configuration of ONU transceiver with dynamic power save

Figure 2 (a) shows the block diagram of a developed burst-mode ONU transceiver employing the control circuits for the dynamic power save mode and the Doze mode. The ONU transceiver consists of a BIDI (Bi- Directional optical module) [5], 10Gburst-mode transmitter block and 10G receiver block. The transmitter block comprises a burst control circuit, a LD driver, and a pre-bias timing control circuit using feed-forward automatic power control (APC). A DC-coupled transmission line with impedance control between the BIDI and the LD driver is adapted in order to realize the rapid burst-mode operation [2,6]. The power supply of the transmitter block is shut down controlled by the Doze mode signal. Both of the pre-bias control circuit and the LD driver are switched by the control signal to realize the dynamic power save mode. For ONU receiver side, a wider 40 μm diameter APD is applied to achieve the high received sensitivity. The ONU transceiver has a XFP compatible size of 78.0 mm x 18.3 mm x 8.5 mm, and its photograph is also shown in Fig.2 (b). The power consumptions (+3.3 V, +5 V) of three power savemodes are summarized in Table 1.



(b) Photograph

(a) Block diagram

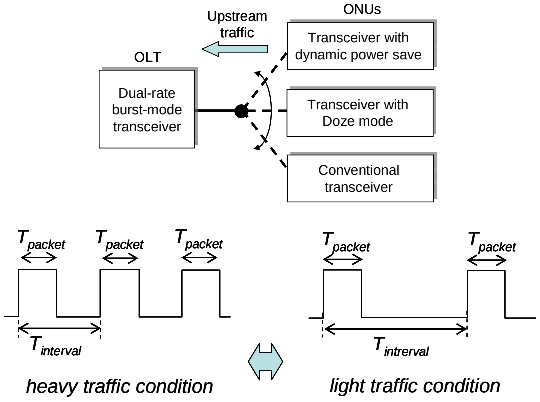
Fig.2 Block diagram of 10G-EPON ONU burst-mode transceiver employing the dynamic power save

Table 1 Power consumption of three power save modes

No power save	Doze mode	Dynamic power save mode
2.1W	0.7W	1.3W

4. Performance of proposed dynamic power save mechanism

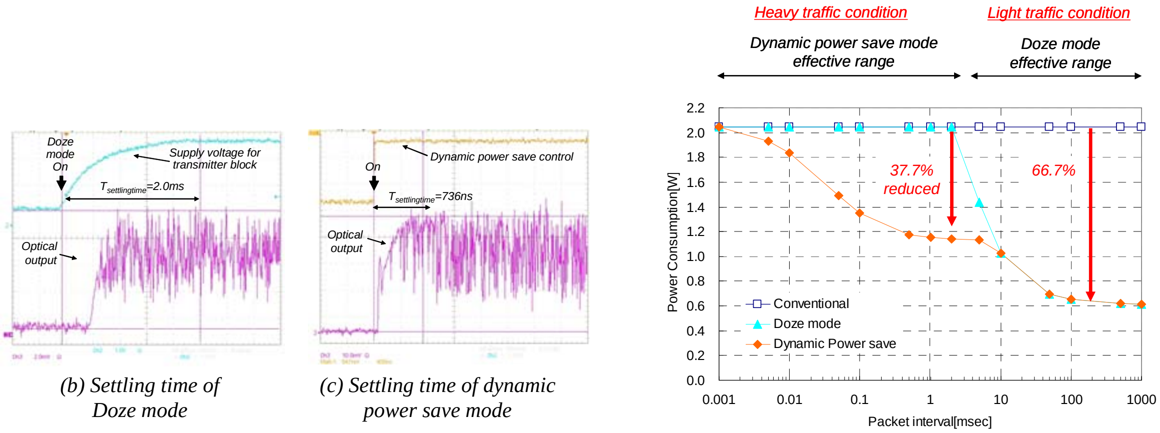
Figure 3 (a) shows the experimental setup to evaluate the effectiveness of the dynamic power save mode. In the experimental setup, the OLT dual-rate burst-mode transceiver [7] was used, accommodating one of the developed ONU transceiver with the dynamic power save mode, a transceiver with the Doze mode, or a conventional one [2]. The optical burst packet size, T_{packet}, was fixed to be 31.25 μs, which was derived from the condition of 32 split ratio and a grant cycle of 1 ms. The packet interval, $T_{interval}$, was varied from to 1 μs (0.001ms) to 1000 ms to emulate the various traffic conditions. First, we evaluated the settling times, $T_{settlingtime}$ and $T'_{settlingtime}$ for the Doze mode and the dynamic power save mode. The measured results were shown in Fig.3 (b) and (c), respectively. Figs.3 (c) show that the short settling time of 736 ns was obtained for the dynamic power save mode, compared to 2.0 ms for the Doze mode as shown in Fig.3(b). The developed dynamic power save control circuit could drastically reduce its settling time, comparing to the Doze mode. The measurement results of the power consumption versus the packet interval of the transceiver with the dynamic power save and with no power save were shown in Fig.3 (d). The



(a) Experimental setup

Fig.3 Measured power save effect

calculated results of the Doze mode were also shown in Fig.3 (d). As expected from the measured results of the settling time, the Doze mode was effective in the range of the packet interval more than 2.0 ms, and its power save effectiveness was up to 66.7%. However, no power save effect was obtained in the range of the interval less than 3 ms. On the other hand, the dynamic power save mode could successfully achieve superb power save effectiveness of 37.7% even in the range of the interval between 1 µs (0.001 ms) and 2.0 ms due to its short settling time. Such packet interval was the most possible traffic condition in PON systems, thus the effectiveness of the proposed dynamic power save mechanism could be confirmed even in the heavy traffic condition of PON systems.



(b) Settling time of Doze mode

(c) Settling time of dynamic power save mode

(d)Measured and calculated power consumption

Fig.3 Measured power save effect

Figure 4 shows the transmitted optical waveforms after the 4th order Bessel-Thomson filter at case temperatures Tc = 25 °C of the develop transceiver with the dynamic power save. The pattern length was PRBS 2^{31}-1. The clear eye-pening with mask margins more than 34% over the IEEE802.3av PR30 standards were obtained. Figure 5 shows the measured LD turn-on and turn-off optical waveforms for temperatures of 25 °C under the dynamic power save operation. The pre-bias timing control technique was well optimized, and the fast LD turn-on time less than 15ns and turn-off time less than 1ns were achieved, and no degradation was observed due to the dynamic power save circuits. Other basic performances of the transceiver were summarized in Table 2, which completely met the IEEE802.3av PR30 standards.

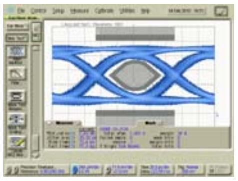


Fig.4 Optical waveforms with the 4th order Bessel-Thomson filter

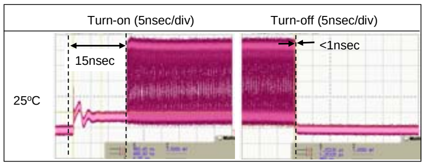


Fig.5 Measured LD turn-on/off waveforms

Table 2 Performance summary (Tc=0 - +75°C)

Item	IEE802.3av	Results
Wavelength	1260-1280nm	1265-1273nm
Output power	4-9dBm	>+7dBm
Mask margin	————	>26%
Extinction ratio	>6dB	>7dB
Overload	>-10dBm	>-4dBm
Receiver sensitivity @BER=1E-3	<-28.5dBm	<-32.4dBm

5. Conclusions

We have developed, for the first time, the symmetric 10G-EPON ONU burst-mode transceiver employing the dynamic power save control circuit. The dynamic power save circuit integrated together with pre-bias timing control technique successfully achieved both of the power save effect as high as 37.7% with less than the settling time of 736 ns and the fast LD turn-on time less than 15 ns and turn-off time less than 1 ns. In addition, the high output power of +7.0 dBm, the extinction ratio of 7.0 dB, and the high receiver sensitivity of -32.4 dBm (@ BER = 1E-3) were obtained over a temperature range of 0 to 75 °C, respectively.

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