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Introduction

- To meet the demand of the increasing traffic in future optical access network, next generation passive optical network (NG-PON) technique is emerged as one of the most competitive technologies
- the utilization of capacity in NG-PON cannot be fully utilized by all the ONUs due to the certain power budgets for the good links are wasted.
- the concepts of power domain multiplexing (PDM) and power domain access (PDA) scheme in terms of non-orthogonal multiple access (NOMA), the well known hierarchical modulation (HM) and non-uniform PAM have been defined demonstrated
- this paper first summarizes the status quo of above key PDM/PDA techniques with the advanced modulation formats in NG-PON

Summary of the Status Quo

Table 1 Literature demonstrations of optical power domain techniques

Technique	Scenari	Rate	Distance	Comments
NOMA-PON[2]	OFDM-	2Gbaud	25	The power margin and BER are increased by 2.5-dB and one order-
NOMA-PON[3]	Single	3.3Gbaud	20	The optimum power allocation ratio is about 0.42 in the case of four
NOMA-PON[4]	DD-OFDM	26.71Gb/s	25	Signal transmission capacity is improved by 28.6%
NOMA-PON[5]	CAP	50-90 Gb/s	BTB	Sensitivities better than -5.5(0.5) dB at 50(90) Gb/s
NOMA-PON[6]	CAP	50Gb/s	23.6 and	Optical power budgets are 28.2 dB and
PDM[7]	DD-OFDM	2.5Gb/s	25	The system spectral efficiency is doubled
HM[8]	OFDMA-	1Gb/s	30	The sensitivity performance is improved by 2.5 dB
HM[9]	OFDMA-	5Gb/s	51/80	The power margin is improved by 2.7 dB
HM-PAM[10]	TDM-PON	25Gb/s	40	Power budget increase of up to 3.5 dB
Non-uniform PAM[11]	TDM-PON	10Gb/s	BTB/40	Network throughput is improved.
Non-uniform PAM[12]	TDM-PON	10Gb/s	20	An improvement on received optical power
Non-uniform PAM[13]	TDM-PON	50Gb/s	20	Rx sensitivities are improved for different Rxs
HM-PAM-4[14]	TDM-PON	20Gb/s	70,80,100	Power margin is improved
HM-PAM-4[15]	TDM-PON	20Gb/s	60-100	Flexible power ratio with advanced DSPs are demonstrated
NOMA-PON[16]	DD-OFDM	40Gb/s	20,30,40	The average BER can be reduced

So far, the flexible HM already provided in the literatures focuses on the following two aspects. Firstly, HM can achieve the coexistence between current on-off keying (OOK) system and digital signal processing (DSP) based NG-PON. Secondly, HM QAM has achieved higher power budget and data rates in OFDM/TDM-PON. The present statuses of typical power domain techniques in different scenarios are shown in Table 1.

Open Research Topics

A. Advanced DSP design with PDM/PDA PON

To address the impairments effect, many equalization schemes based on DSP have been applied at both the Tx side and Rx side. However, the channel estimation error of the DSP causes residual interference, which may result in decoding error at the destination ONUs. Thus, in response to provide the better performance, the key power-related parameters should be well designed with advanced DSPs to make fully optimized NG-PON system.

B. Advanced bit and power loading with PDM/PDA PON

To date, none of the bit loading algorithm considers the bit priority. Thus, the current bit and power loading should be considered with the PDM/PDA NG-PON system. In particular, some implemented sub-bands can use low order modulation formats and/or higher power level on the first priority layer. The idear of the UEP bit-loading schemes proposed in wireless network can be referred and extend to the PDM/PDA NG-PON.

C. Advanced network coding (NC) with PDM/PDA PON

Recently, with the exchange of the localized traffic, inter-ONUs communication via a single-OLT is to be developed. In this case, NC has been proposed to improve the network capacity, efficiency and security for NG-PON. Note that the NC in NG-PON is similar with the two-way relay channel in wireless network where integrates the two aspects of HM and NC scheme. Thus, the joint HM and NC scheme can be also used in PDM/PDA PON.

D. Advanced low complexity transceiver with PDM/PDA PON

Considering the PDM/PDA-PON operation, the Rx should be mainly concerned for the inter-layer interference. Therefore, the costs paid and the decoding complexity is high. Due to the low power consumption and low cost of the NG-PON, how to provide a new and low complexity symbol-to-bit de-mapping and decoding algorithm is the key achievement in future.

E. Advanced pairing and resources allocation

To utilize the PDM/PDA technique and share the same time or spectrum in advance, OLT should decide which ONUs are to be paired. In addition, the resource allocation/ scheduling scheme plays an important role in the overall system's throughput or capacity. Moreover, cross-layer optimization is important to maximize the SE, energy efficiency, and quality of service criterion.

Conclusion

- This paper provides a literature review of the full benefits of power domain schemes in terms of NOMA, HM and non-uniform PAM in the reported NG-PON system.
- This paper analyzes the issues and challenging tasks in future.