Architecture Analysis of Hybrid TDM/WDM PON

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OUTLINE

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Motivation

- TDM-PON has been proven to be cost–effective, flexibility and versatile
  - TDM can be used to share a single OLT port among multiple subscribers; Initial CAPEX can be shared by connecting large number of customers
  - Flexibility of dynamic bandwidth can achieve statistical multiplexing gain
  - 1G-EPON , 10G-EPON are used for FTTH, FTTB, cellular backhaul. Already deployed for millions of customers with different QoS and for different services.
- WDM is considered as the most practical technology for PON capacity expansion
  - Achieving 10+Gbps per wavelength faces great challenges i.e. high device cost, fiber dispersion limitation, decreased power budget.
  - 10G-EPON optical and electrical devices are mature, but 10Gbps per ONU supported by pure WDM PON is too excessive for next 10 years.
- What is needed is an approach to combine the benefit of TDM PON and WDM, by simply stacking TDM PON on top of a WDM structure
  - There are many ways to approach a combined TDM/WDM PON. Which is to be preferred?

ODN architectures of hybrid TDM/WDM PON

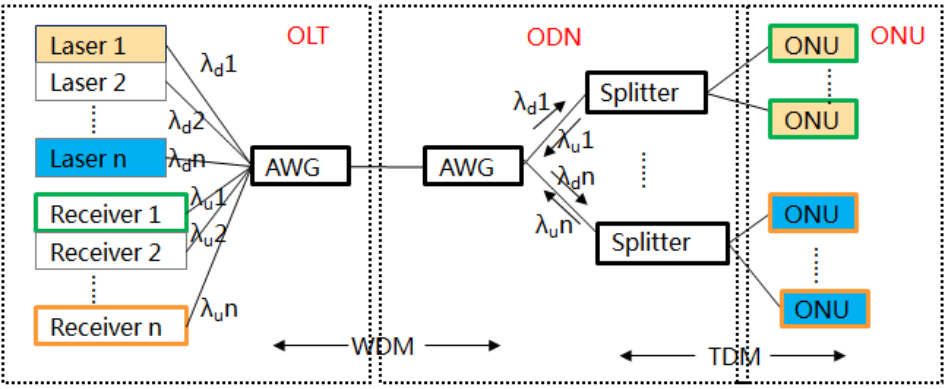


Fig.1 Wavelength routed ODN

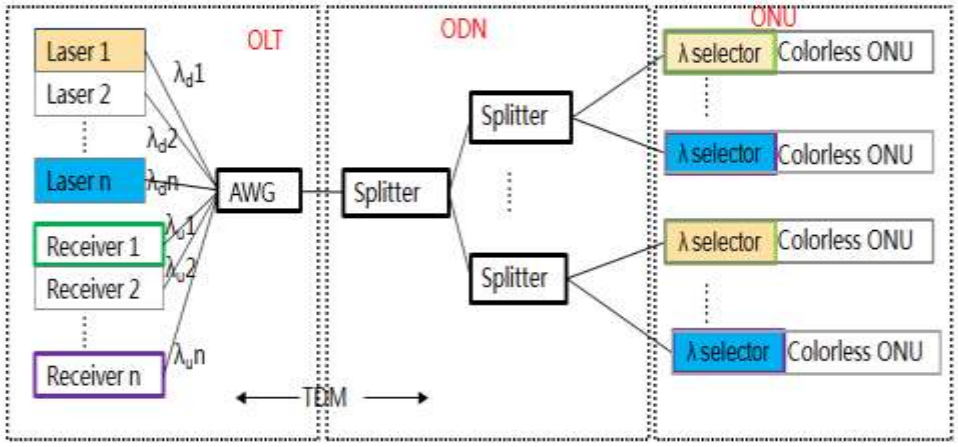
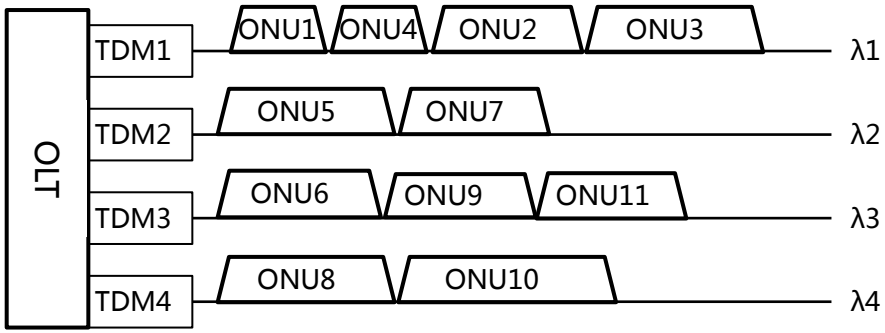


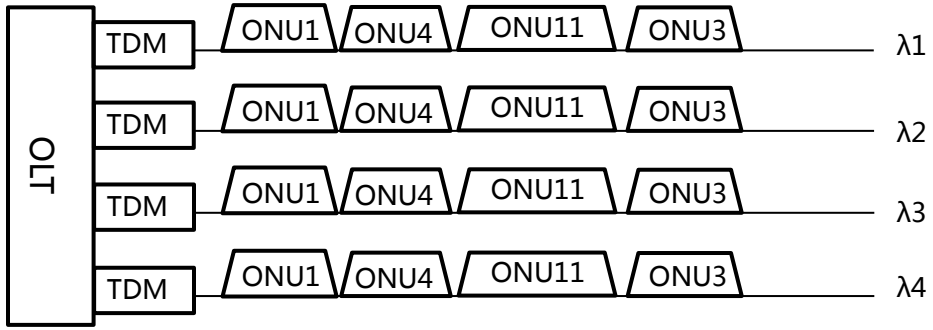
Fig.2 Wavelength selected ODN

- Two types of ODN(Fig.1 and Fig.2) for hybrid TDM/WDM PON have been discussed
- Wavelength routed topology would require changes to deployed ODNs and violate the no ODN changes requirement
- Wavelength selected topology can reuse deployed ODNs by combining a turning band pass optical filter in the optical receiver
- The following classes of hybrid TDM/WDM PON discussed are realized based on Wavelength routed topology

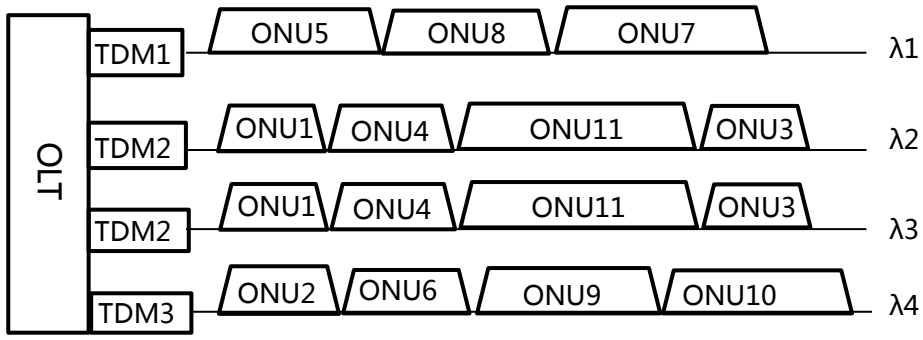
Three Classes of Hybrid TDM/WDM PON



TWDM



WTDM



Flexible Approach

- Hybrid TDM/WDM PON is further classified into:
  - TWDM-PON, each λ is an independent TDM domain
  - WTDM-PON, all λs are combined to create one big TDM domain
- Recently, it was proposed to use a flexible approach where selected λs are combined to create a TDM domain, but there is more than one TDM domain on OLT

Requirements for Optical Devices

➢Optical Devices for WTDM-PON

	Down		Up	
	Tx(laser)	Rx(filter)	Tx(laser)	Rx(filter)
Multi-channels down Multi-channel up	1. Each ONU would receive data transmitted across all channels at the same time. 2. Tunable optics aren't necessary .		1. OLT would receive data from a ONU transmitted across all channels at the same time. 2. Tunable optics aren't necessary .	
Multi-channels down Single channel up	1. Each ONU would receive data transmitted across all channels at the same time. 2.Tunable optics aren't necessary .		Fixed wavelength laser and fixed wavelength band pass filter .	

Optical Devices for TWDM-PON

	Down		Up	
	Tx(laser)	Rx(filter)	Tx(laser)	Rx(filter)
Multi-channels down Multi-channels up	1. Fixed wavelength laser is ok. 2 . Tunable laser can avoid inventory issues but increase cost.	Tunable receiver is necessary to avoid receiver arrays and colored ONU .	Tunable laser is necessary for flexible dynamic bandwidth allocation and colorless ONU .	ALL channels' Rx have to work at the same time. (Fixed is Ok, it isn't necessary to be tunable.)
Multi-channels down Single channel up	1. Fixed wavelength laser is ok. 2. Tunable laser can avoid inventory issues but increase cost.	Tunable receiver is necessary to avoid receiver arrays and colored ONU .	Fixed wavelength laser	Fixed band pass optical filter

Optical Devices for Flexible approach

	Down		up	
	Tx(laser)	Rx(filter)	Tx(laser)	Rx(filter)
Multi-channels down Multi-channels up	In order to obtain the maximum flexibility, each ONU would receive data transmitted across any channel combination at the same time. ONU must have Rx of each channel. Tunable optics aren't necessary .		OLT would receive data from a ONU transmitted across any channel combination at the same time. Tunable optics aren't necessary .	ALL channels' Rx have to work at the same time. (Fixed is Ok, it isn't necessary to be tunable)
Multi-channels down Single channel up	The same as above.		Fixed wavelength laser	Fixed band pass optical filter

Comparison of three types of hybrid TDM/WDM PON

	WTDM	TWDM	Flexible approach
Flexibility	Minimal Flexibility Dynamic bandwidth allocation is achieved only by TDM .	1. ONU can be independently assorted by registering in different channels. 2. Dynamic bandwidth allocation is achieved by TDM and WDM .	1. ONU can be independently assorted by registering in different channels. 2. Dynamic bandwidth allocation is achieved by TDM and WDM. 3. The peak rate per ONU will be several times of TWDM peak rate .
Extendibility	Channel number and PON capacity is fixed and define by initial assembly .	1. Capacity expansion can be achieve by increasing channels . 2. Channel numbers is based on customer demand (Pay as you grow).	1. Capacity expansion can be achieve by increasing channels . 2. Channel numbers are based on customer demand (Pay as you grow).
Cost	Optical device cost will be multiplying growth per ONU .	Receiver arrays aren't necessary . It is the lowest cost.	Many optical receivers per ONU increase the cost .

Conclusion

- WTDM-PON has less flexibility and extendibility than the other types. The most important is that receiver arrays increase the optics cost and higher aggregation data handle.

- The flexibility approach has the same flexibility as that of TWDM-PON, except it allows increasing the peak rate per ONU in the PON, but it also increases the optical device cost per ONU.

- TWDM –PON is the best trade-off solution in flexibility, extendibility and cost-effectiveness.

THANK YOU VERY MUCH !