Unified Wavelength Grid and Plan for 100G-EPON

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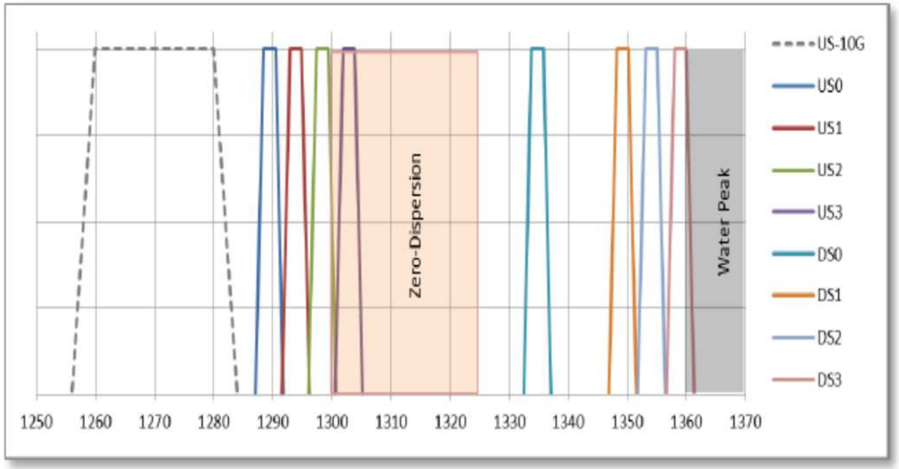
The Problem at Hand

There is an implementation difficulty in wavelength multiplexing/de-multiplexing for the wavelength plans of 100G-EPON that are currently under evaluation, e.g., Revised Plan A and Revised Plan B, because

- The wavelength channels may have different channel spacing values
- They may have different channel bandwidths
- They need to avoid the zero-dispersion window (1302nm~1322 nm)
- They need to avoid the water-absorption window (1360nm~1470nm)
- They need to be compatible with 10G-EPON upstream (1270±10nm)
- They need to be multiplexed and de-multiplexed in a cost-effective manner.

Revised Wavelength Plan A

In this wavelength plan, the wavelength channels may have different channel spacing values and different channel bandwidths, making it difficult for wavelength multiplexing and de-multiplexing for both downstream (DS) and upstream (US) channels.



Revised Plan A

- Shift US channels by +100GHz so US2 > 0.64nm from ZDF. Trade-off vs. smaller 10G/US0 gap.
- Increase DS0-DS1 spacing to 2.4 THz (12.4nm gap). Trade off vs. DS3 closer to 1360nm water peak region.

Reference: http://www.ieee802.org/3/ca/public/meeting_archive/2017/01/johnson_3ca_2_0117.pdf

Revised Wavelength Plan B

In this wavelength plan, the wavelength channels may have different channel spacing values and different channel bandwidths, making it difficult for wavelength multiplexing and de-multiplexing for both DS and US channels.

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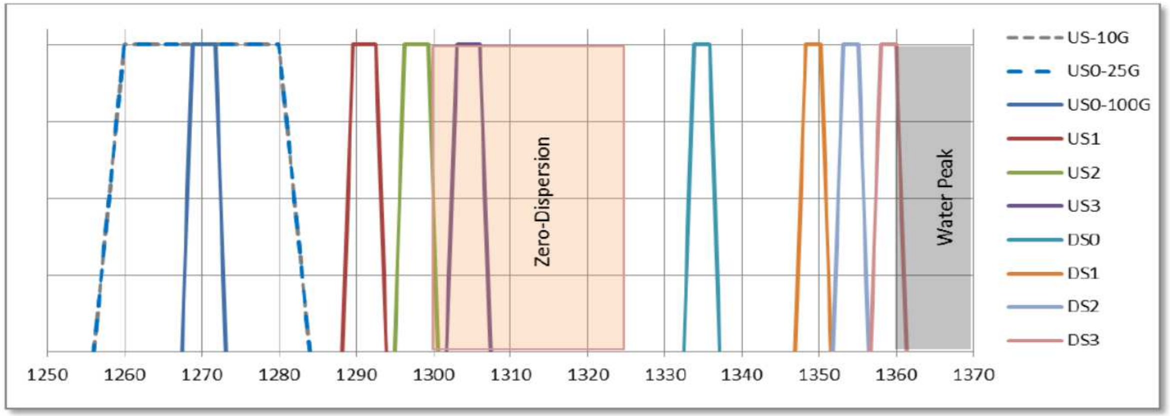
Details of revised Plan B channel plan



Lane	Center Freq (THz)	Center WL (nm)
US0-25G	236.06	1270.00
US0-100G	236.00	1270.31
US1	232.20	1291.10
US2	231.00	1297.80
US3	229.80	1304.58
DS0	224.60	1334.78
DS1	222.20	1349.20
DS2	221.40	1354.08
DS3	220.60	1358.99

- Channel spacing: 800GHz (DS), 1200GHz (US)
- Laser accuracy: ±1nm (DS), ±1.5nm (100G US), ±10nm (25G US)
- DS-US gap (min): 53.8nm (25G), 27.7nm (100G)
- DS0-DS1 gap (min): 12.4nm
- US0-US1 gap (min): 9.6nm (uncooled US0)
- US2 to zero dispersion range (min): 0.7nm (124GHz)

Reference: http://www.ieee802.org/3/ca/public/meeting_archive/2017/01/johnson_3ca_2_0117.pdf

Plan A is currently more preferred

StrawPoll #4

Which of the following upstream wavelength plan (categories) could you live with?
(Choose which you like BEST, vote once):

1. Pure WDM co-existence plans, as described in harstead_3ca_3_0317, slide 2
2. Initial WDM co-existence plan that postpones TDM co-existence, as described in harstead_3ca_3_0317, slide 3
3. Pure TDM co-existence plans, as described in harstead_3ca_3_031, slide 4
4. Compromise plans: optionally support both WDM and TDM co-existence, as described in harstead_3ca_3_0317, slide 5

1:	7
2:	5
3:	4
4:	3
Abstain:	8

StrawPoll #5

Given all past contributions I would choose:

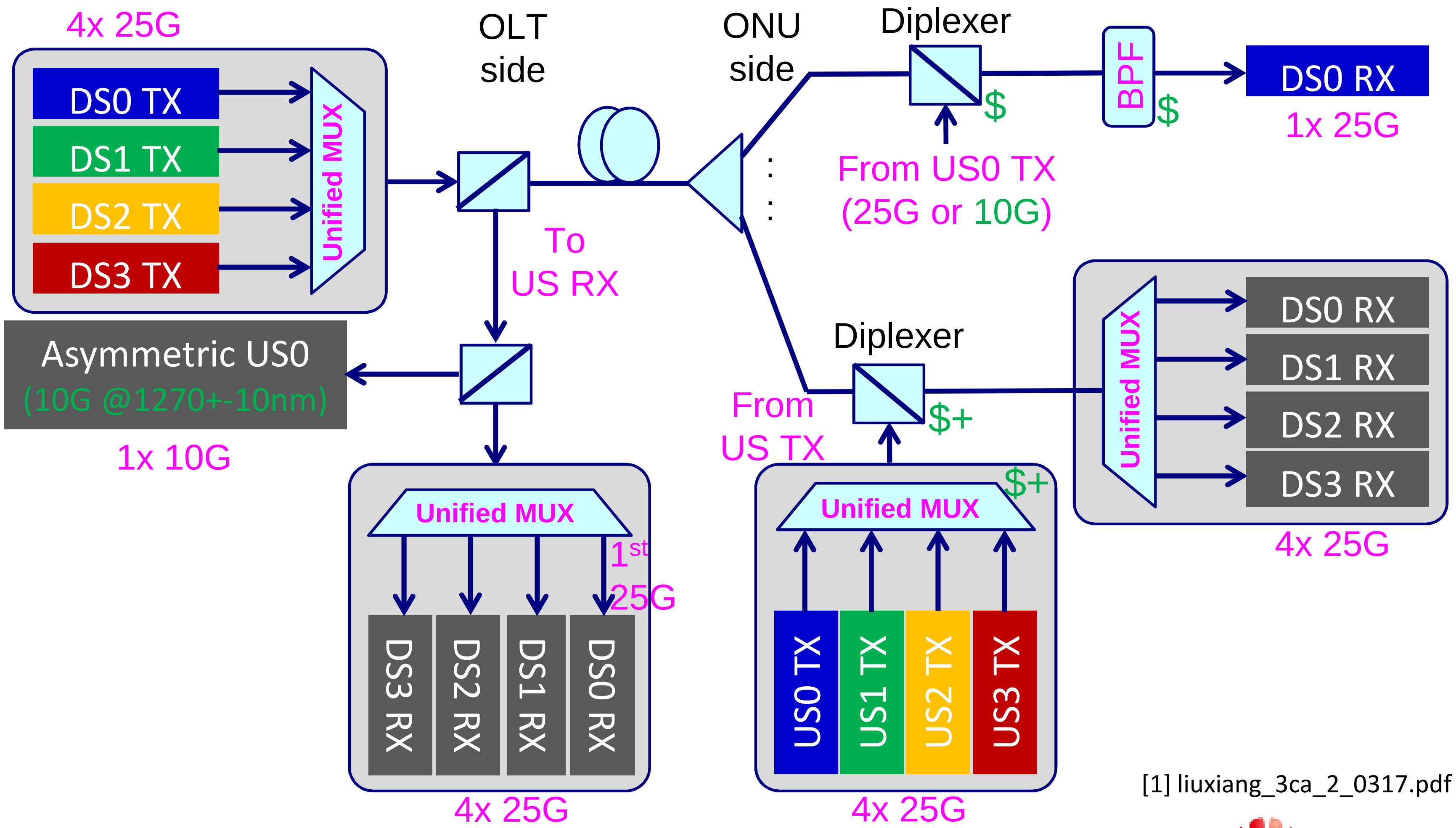
1. WDM coexistence with all four 25G US external to 1260-80nm
2. TDM coexistence
3. Don't Care
4. Don't know

1:	12
2:	9
3:	1
4:	6

Reference: http://www.ieee802.org/3/ca/public/meeting_archive/2017/03/minutes_unapproved_3ca_0317.pdf

Unified Wavelength Multiplexing for Plan A

It is beneficial to use a unified wavelength multiplexer for downstream (DS) and upstream (US) wavelength multiplexing (MUX) and de-multiplexing (DMUX), to save cost and ease management [1]. The diagram below shows the case for Plan A (WDM coexistence with 10G-EPON).



[1] liuxiang_3ca_2_0317.pdf

Beneficially to Use IEEE 802.3ba LAN-WDM Frequency Grid & Wavelength Grid

TABLE 2. Optical Ethernet lanes

Lane	Center frequencies, THz	Center wavelengths, nm	Wavelength ranges, nm
L0	231.4	1295.56	1294.53–1296.59
L1	230.6	1300.05	1299.02–1301.09
L2	229.8	1304.58	1303.54–1305.63
L3	229.0	1309.14	1308.09–1310.19

Reference:
https://www.finisar.com/sites/default/files/resources/optical_ethernet_august_2009.pdf

Unified Wavelength Grid:
800GHz (LAN-WDM Compatible)

Channel center frequencies: f(n)=**236.20***-(n-1)*0.8 (THz), for n=1:20

4 Newly Standardized (IEEE 802.3bs) LAN-WDM Wavelengths (channels 2–5)

4 Standardized (IEEE 802.3ba) LAN-WDM Wavelengths (channels 7–10)

Wavelength Grid (nm)

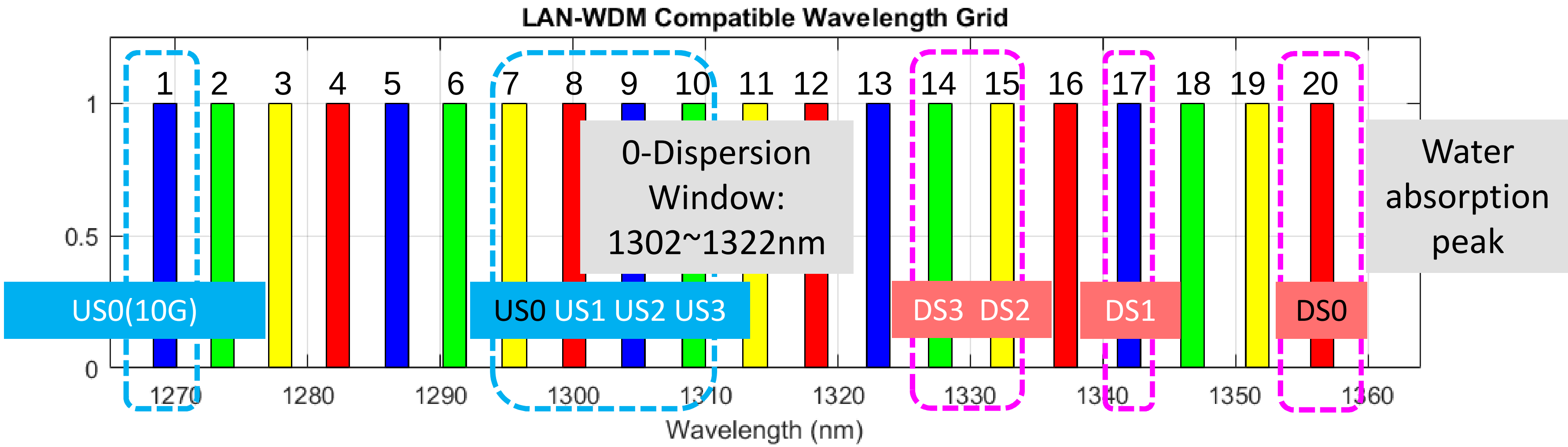
1	2	3	4	5	6	7	8	9	10
1269.23	1273.54	1277.89	1282.26	1286.66	1291.10	1295.56	1300.05	1304.58	1309.14
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1313.73	1318.35	1323.00	1327.69	1332.41	1337.17	1341.95	1346.78	1351.63	1356.53

Frequency Grid (THz)

1	2	3	4	5	6	7	8	9	10
236.2	235.4	234.6	233.8	233.0	232.2	231.4	230.6	229.8	229.0
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
228.2	227.4	226.6	225.8	225.0	224.2	223.4	222.6	221.8	221.0

100G-EPON Wavelengths: Plan A1

– LAN-WDM Fully Reused & GPON Co-Existence



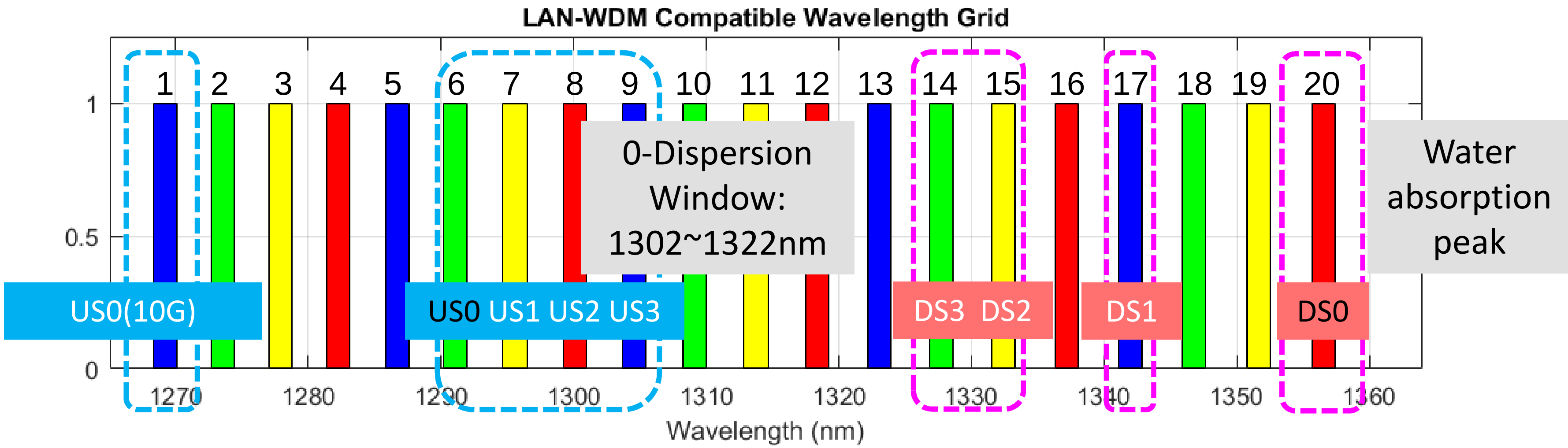
- ✓ US0~3 fully reuse the four wavelengths of LAN-WDM (L0-3) ➔sharing the industry chain
- ✓ US0 and DS0 coexist with GPON via WDM
- ✓ US0 and DS0 have >45nm gap ➔allowing for low-cost focused-beam diplexers [1]
- ✓ DS0 and DS1 have >12.4nm gap ➔allowing for low-cost focused-beam 25G BPF [2]
- ? FWM penalty among the US channels ➔ Polarization Control is needed*

*: please refer to our another presentation on FWM suppression via Polarization Control.

[1] Funada_3ca_1_0117; [2] johnson_3ca_2_0117

100G-EPON Wavelengths: Plan A2

– LAN-WDM Partially (L1&L2&L3) Reused & GPON Co-Existence

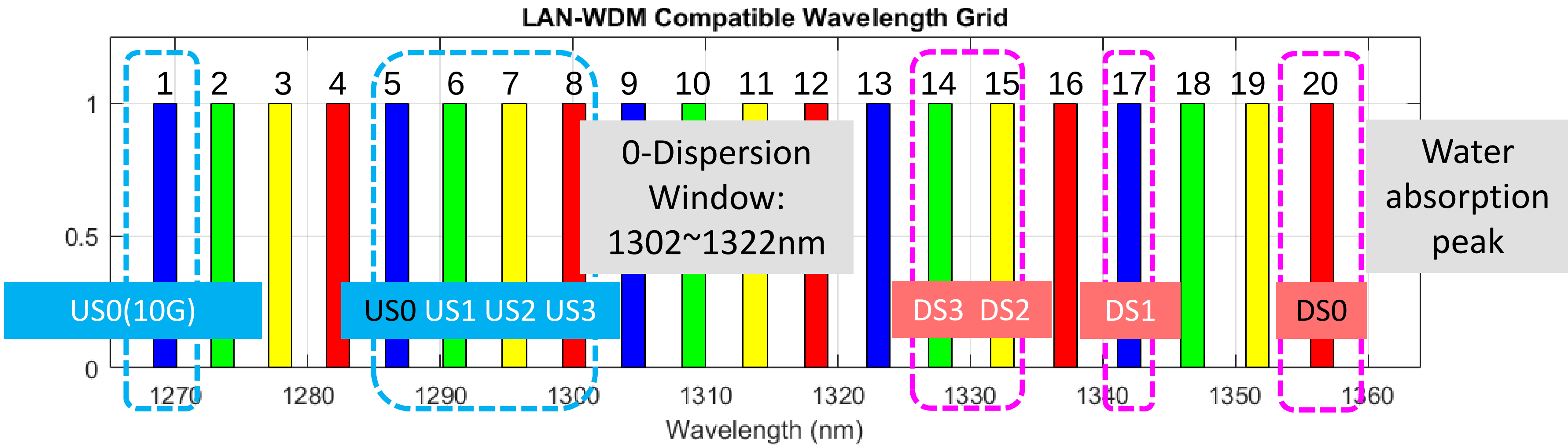


- ✓ US1~3 reuse the 3 wavelengths of LAN-WDM ➔sharing the industry chain
- ✓ US0 and DS0 coexist with GPON via WDM
- ✓ US0 and DS0 have >45nm gap ➔allowing for low-cost focused-beam diplexers
- ✓ DS0 and DS1 have >12.4nm gap ➔allowing for low-cost focused-beam 25G BPF
- ? FWM penalty among the US channels ➔ Polarization Control is needed*

*: please refer to our another presentation on FWM (when one channel is inside ZDW).

100G-EPON Wavelengths: Plan A3

– LAN-WDM Partially (L0&L2&3) Reused & GPON Co-Existence

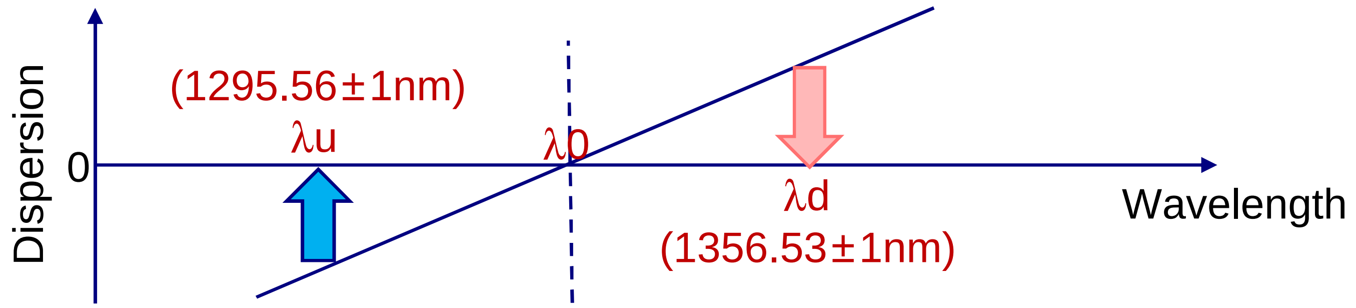


- ✓ US0&2&3 reuse the 3 wavelengths of LAN-WDM ➔sharing the industry chain
- ✓ US0 and DS0 coexist with GPON via WDM
- ✓ US0 and DS0 have >45nm gap ➔allowing for low-cost focused-beam diplexers
- ✓ DS0 and DS1 have >12.4nm gap ➔allowing for low-cost focused-beam 25G BPF
- ✓ No FWM issue* *(Polarization control is optional)*

*: please refer to our another presentation on FWM (when one channel is inside ZDW).

Worst-case US/DS fiber latency difference

For Wavelength Plans A1/2/3, the worst-case US/DS fiber latency difference occurs for the first pair of UD/DS channels, as the 1st DS channel is most far away from the ZDW.



Upstream wavelength (λu): 1295.56±1nm; (CH#7)

Downstream wavelength (λd): 1356.53nm±1nm (CH#20);

We have the worst-case DS/US latency differences [1]:

(i) $20km*0.09ps/(nm^2 \cdot km) *[(1357.53-1302)^2 - (1296.56-1302)^2]/2 \ nm^2 \approx +2.75ns$

(ii) $20km*0.09ps/(nm^2 \cdot km) *[(1355.53-1322)^2 - (1294.56-1322)^2]/2 \ nm^2 \approx -0.33ns$

So, the measurement error of To is about ±1.375 ns, which is a small fraction (~11%) of the desired overall synchronization error (±12.5 ns).

Thus, the choice of the 100G-EPON wavelengths can meet the stringent synchronization requirement of future mobile fronthaul applications [1].

[1] liuxiang_3ca_1_0317.pdf

Comparison

Wavelength Plan	Features	Pros*	Cons
A1	US0/1/2/3@CH7/8/9/10 DS0/1/2/3@CH20/17/15/14	US fully reuses 4 LAN-WDM channels	FWM suppression needed (e.g., via polarization control)
A2	US0/1/2/3@CH6/7/8/9 DS0/1/2/3@CH20/17/15/14	US reuses 3 LAN-WDM channels	FWM suppression needed (e.g., via polarization control)
A3	US0/1/2/3@CH5/6/7/8 DS0/1/2/3@CH20/17/15/14	US reuses 3 LAN-WDM channels	FWM suppression not required

*: Common pros:

- ✓ US reuses at least 3 wavelengths of LAN-WDM ➔sharing the industry chain
- ✓ US0 and DS0 coexist with GPON via WDM
- ✓ US0 and DS0 have >45nm gap ➔allowing for low-cost focused-beam diplexers
- ✓ DS0 and DS1 have >12.4nm gap ➔allowing for low-cost focused-beam 25G BPF
- ✓ Small US/DS fiber delay difference.

Proposed Motion

- The P802.3ca standard specifies a unified wavelength grid or frequency grid that is compatible with the IEEE 802.3ba LAN-WDM wavelengths, i.e., it has a 800-GHz channel spacing and is anchored by the LAN-WDM frequencies.

Thank you

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