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IEEE 802.3ca 100G-EPON Task Force:
25G ONU Options to increase Network Capacity

Shawn M. Esser

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Whistler, British Columbia

Executive Summary

- Network Capacity (25G, 50G, 100G) and Max ONU Capacity (25G, 50G, 100G) can be independent

- With 50G and 100G Network Capacities, ONU's with 25Gb/s Max Capacity could be sufficient for vast majority of the premises in 1+3 architecture 1x32 split.

- Evaluated the cost of network deployment of 50G and 100G with two options for the 25G ONU's:
  1. 25G ONU's only available on Wavelength Pair 0
  2. 25G ONU's available on any Wavelength Pair (0, 1, 2, 3, 4?)

- When migrating to 100G Network Capacity with 1+3, Option 2 could save MSOs up to 62% in optics cost
  - More savings with 1+4 architecture and/or higher split ratios

- Lower optics cost will make it more likely MSOs will deploy 50G and 100G networks
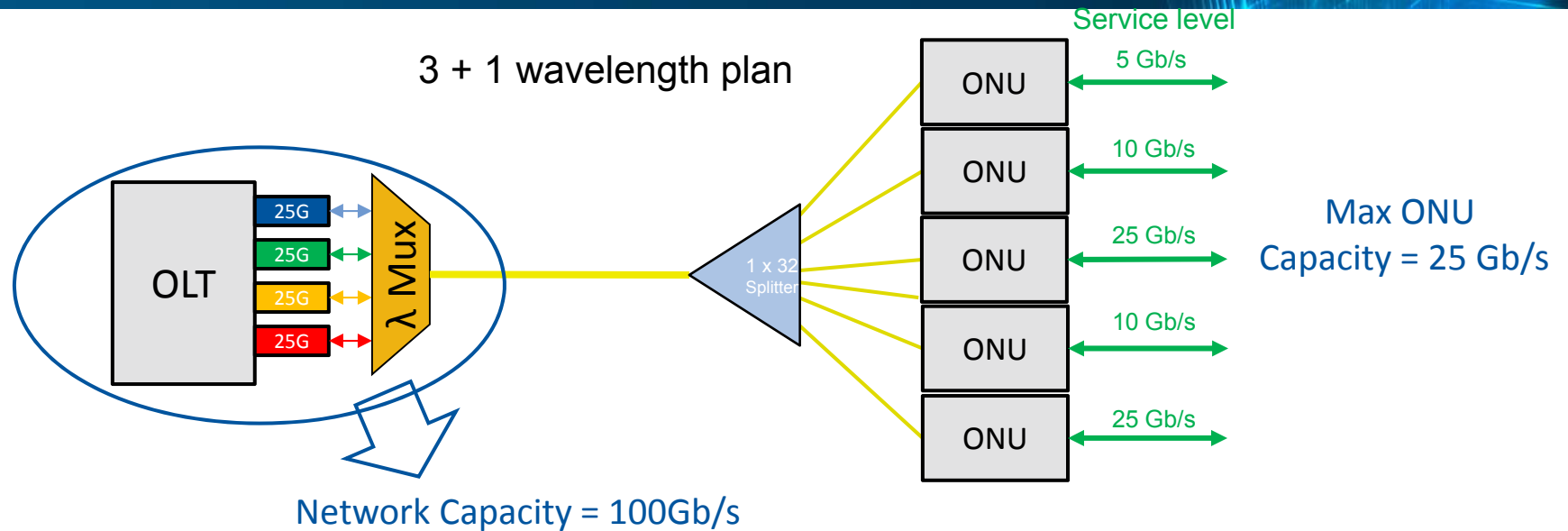
Network Capacity vs. Max ONU Capacity

3 + 1 wavelength plan
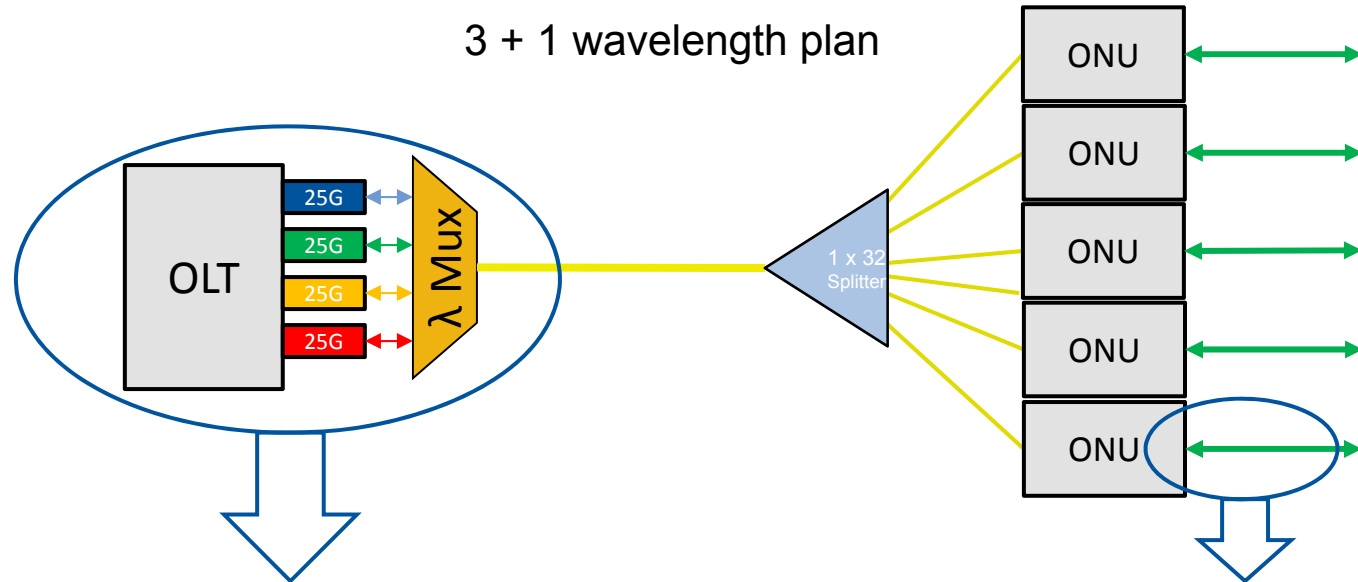
Network capacity

- The total bandwidth throughput on the PON segment
- Shared with up to 32 or 64 ONU's
- Dependent on # of λ:
  - λ_0 => 25Gb/s
  - λ_0, λ_1 => 50Gb/s
  - $\lambda_0, \lambda_1, \lambda_2, \lambda_3$ => 100Gb/s

Max ONU Capacity

- Hardware limit on the maximum amount of data output from an ONU (25G, 50G or 100G)
  - Number of sets of optics and ASIC determine max ONU capacity
  - Peak data service to individual consumer will be less because network capacity is shared

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Network Capacity vs. Max ONU Capacity

3 + 1 wavelength plan

OLT

25G
25G
25G
25G

λ Mux

1 x 32 Splitter

ONU — 5 Gb/s
ONU — 10 Gb/s
ONU — 25 Gb/s
ONU — 10 Gb/s
ONU — 25 Gb/s

Max ONU Capacity = 25 Gb/s

Network Capacity = 100Gb/s

Network capacity can be increased <u>without</u> increasing **Max ONU Capacity** (all ONU's may only need 25Gb/s max).

Why would you do this?

- ◆ Add more customers to the PON segment → 12 customers to 25 customers

- ◆ Increase service levels to customers (≤ 25Gb/s) → peak service levels from 5 Mb/s to 10 Gb/s

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Data Service Rates vs. Network Capacity

Network Capacity (Gb/s)	Flagship Peak Rate (Gb/s)	Billboard Peak Rate (Gb/s)	Network Capacity/ # of ONUs (Gb/s)
25G	8.3	12.5	0.8
50G	16.6	25	1.6
100G	33.3	50	3.1

- Flagship peak service rate is ⅓ of Network Capacity (per Jorge)
- Billboard peak service rate is ½ of Network Capacity (per Jorge)
- Network Capacity/# of ONUs
  - Assumes 32 ONUs on PON segment
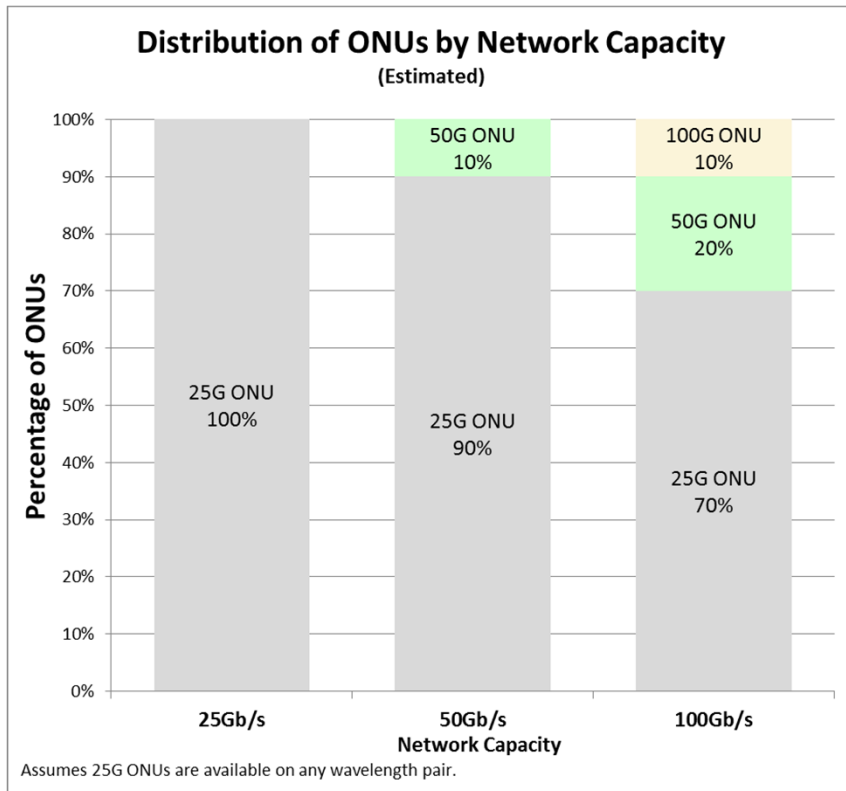 - Individual ONU service data levels will vary greatly

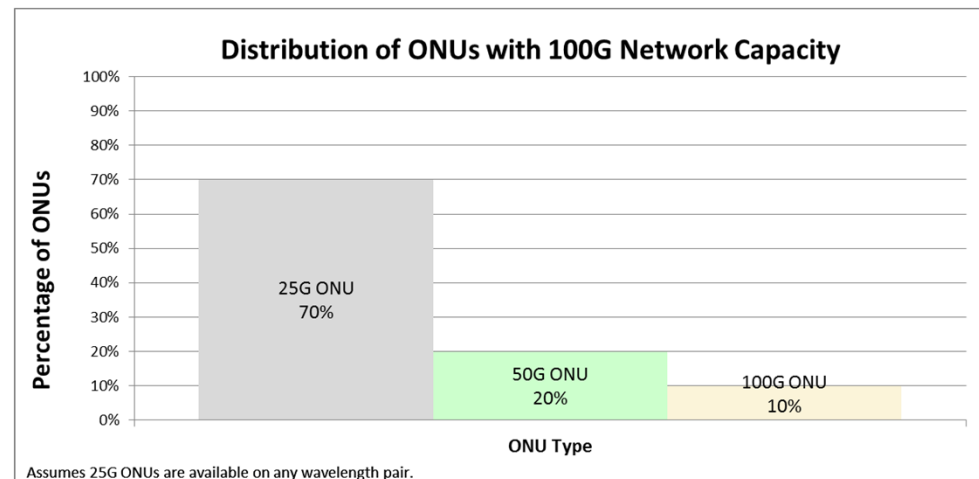Can be served by ONU with 25G ASIC
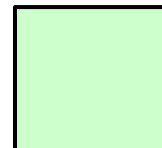
Can be served by ONU with 50G ASIC

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Hypotheses on ONU Distribution vs Network Capacity

Distribution of ONUs by Network Capacity (Estimated)

- ◆ **With 50G Network Capacity:**
  - ▪ Almost all of the premises can be served by ONUs with 25G ASIC

- ◆ **With 100G Network Capacity:**
  - ▪ A majority of the premises can be served by ONUs with 25G ASIC
  - ▪ Most of the remaining premises can be served by ONUs with 50G ASIC
  - ▪ Rarely will premises require ONUs with 100G ASIC
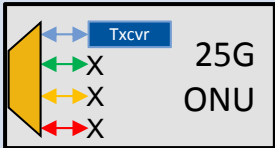
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Conclusions from the Hypotheses
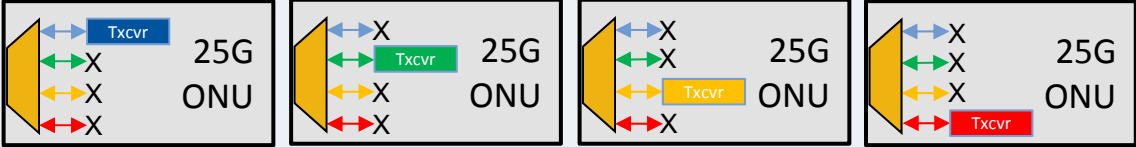
- ONUs with 25G capacity (25G ASIC) would be sufficient for most premises

- Some ONUs with 50G capacity (50G ASIC) would be needed

- Only rarely would ONUs with 100G capacity be needed

- Since optics will be the significant portion of ONU cost, should optics in ONUs that only need 25G capacity be optimized for cost?

Distribution of ONUs with 100G Network Capacity

25G ONU 70%

50G ONU 20%

100G ONU 10%

Percentage of ONUs

ONU Type

Assumes 25G ONUs are available on any wavelength pair.

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25G ONU Options to increase Network Capacity

Option	25G ONU λ Plan	How to expand Network Capacity to 50G & 100G?	Number of ONU variations	Pros/Cons
1	Fixed, λ_0 Only	1. Add 50G ONUs but only utilize 1 set of 25G optics 2. Add 100G ONUs but only utilize 1 set of 25G optics	1 25G ONU 1 50G ONU 1 100G ONU	↑Only 3 ONU variations ↑Simplest standard ↓Highest ONU cost to expand network capacity ↓Optics for other 25G are not used
2	Fixed, λ_0 Fixed, λ_1 Fixed, λ_2 Fixed, λ_3	1. Add 25G ONU's at λ_1 2. Add 25G ONU's at λ_2 3. Add 25G ONU's at λ_3	4 25G ONU 1 50G ONU 1 100G ONU	↓More (6) ONU variations = Simpler standard ↑Lowest ONU cost to expand network capacity

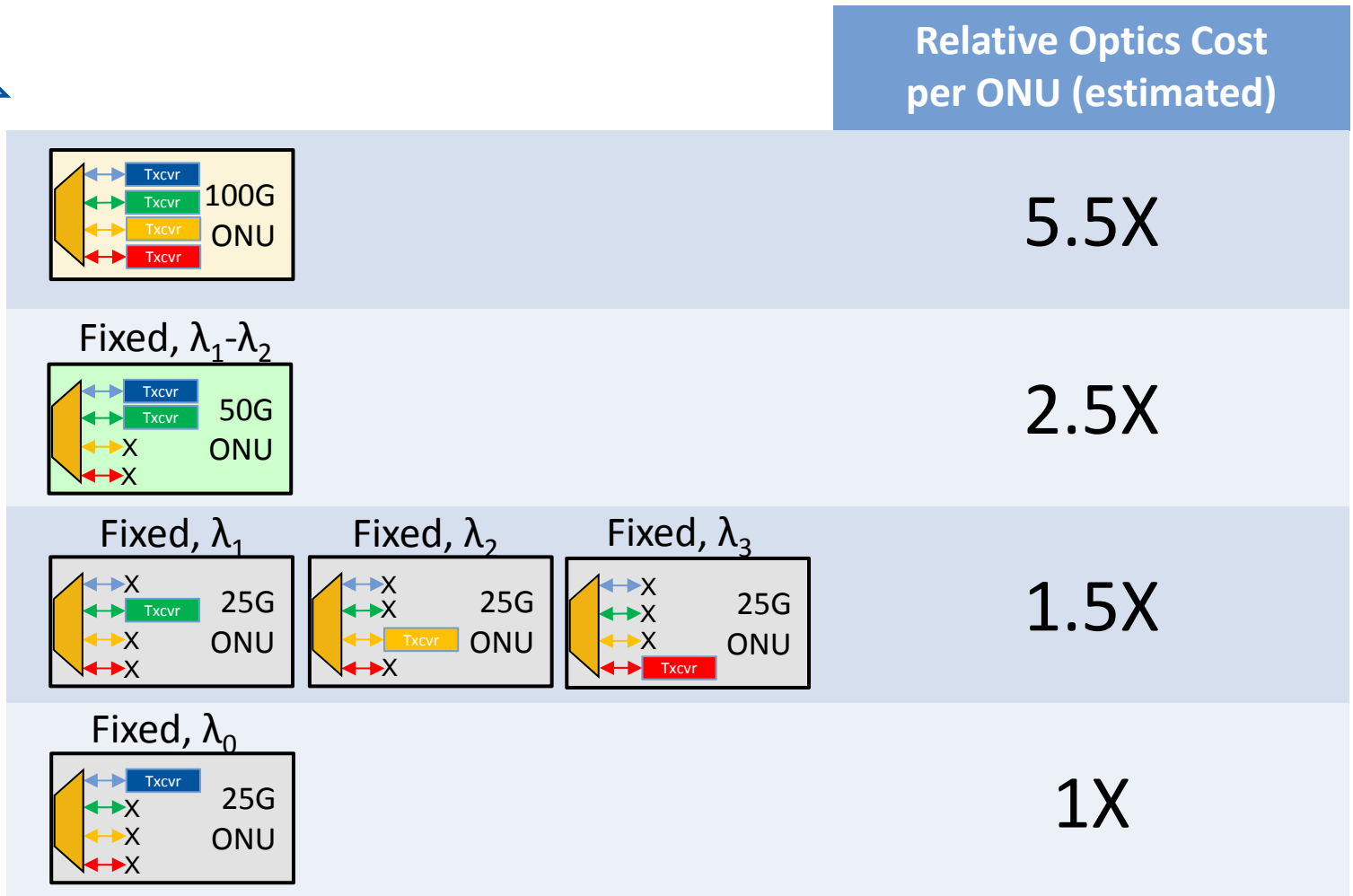# 25G ONU Options to increase Network Capacity

Option	25G ONU λ Plan	25G ONU Types
1	Fixed, λ_0 Only	
2	Fixed, λ_0 Fixed, λ_1 Fixed, λ_2 Fixed, λ_3	

Relative Cost of Optics in ONU Types
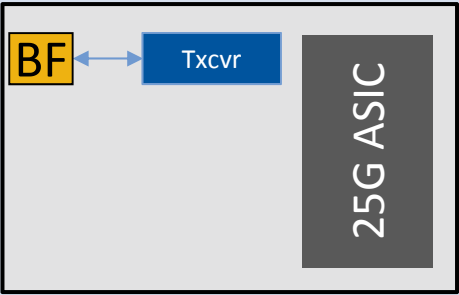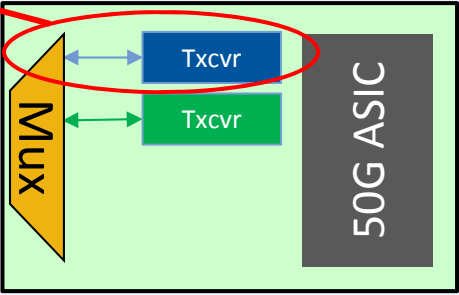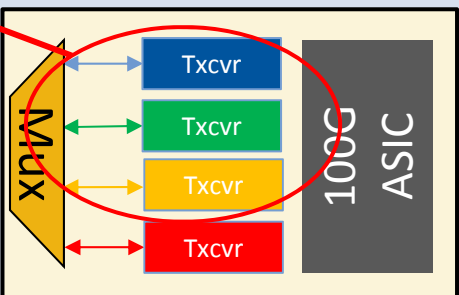
Highest Cost

Lowest Cost

	Relative Optics Cost per ONU (estimated)
100G ONU (Txcvr, Txcvr, Txcvr, Txcvr)	5.5X
Fixed, λ_1-λ_2 — 50G ONU (Txcvr, Txcvr, X, X)	2.5X
Fixed, λ_1 25G ONU · **Fixed, λ_2** 25G ONU · **Fixed, λ_3** 25G ONU	1.5X
Fixed, λ_0 — 25G ONU (Txcvr, X, X, X)	1X
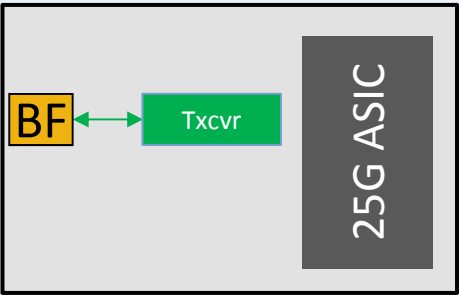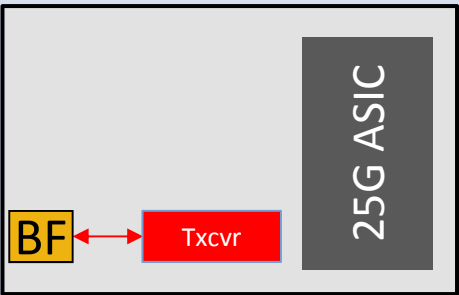
Option 1 ONU Costs by Network Capacity

Network Capacity	ONU Service Levels	Wavelength Pairs	New ONUs Deployed	ONU Cost
25G	$\leq$ 25G	λ_0	BF — Txcvr — 25G ASIC	1X
50G	$\leq$ 25G	λ_0, λ_1	not used — Mux — Txcvr, Txcvr — 50G ASIC	2.5X
100G	$\leq$ 25G	$\lambda_0, \lambda_1, \lambda_2, \lambda_3$	not used — Mux — Txcvr, Txcvr, Txcvr, Txcvr — 100G ASIC	5.5X

Option 2 ONU Costs by Network Capacity
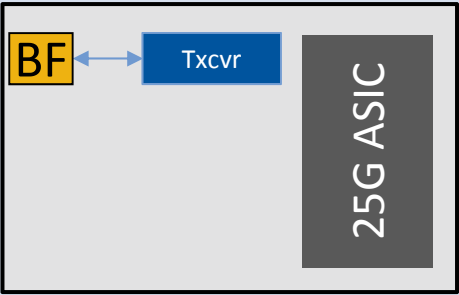
Network Capacity	ONU Service Levels	Wavelength Pairs	New ONUs Deployed	ONU Cost
25G	$\leq 25G$	λ_0	BF ↔ Txcvr, 25G ASIC	1X
50G	$\leq 25G$	λ_0, λ_1	BF ↔ Txcvr, 25G ASIC	1.5X
100G	$\leq 25G$	$\lambda_0, \lambda_1, \lambda_2, \lambda_3$	BF ↔ Txcvr, 25G ASIC	1.5X

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Option 1 Migration:
25G Network Capacity, ONUs with 25G Max Req'd

1. Deploy 25G, Fixed λ_0

Billboard Service Level = ½ of Network Capacity
Billboard Service Level = 12.5Gb/s

Service Level
≤ 12.5Gb/s

Txcvr
25G
ONU

Network Capacity = **25Gb/s**

25G

λ Mux

OLT

1 x 32
Splitter

Txcvr
25G
ONU

≤ 12.5Gb/s

Txcvr
25G
ONU
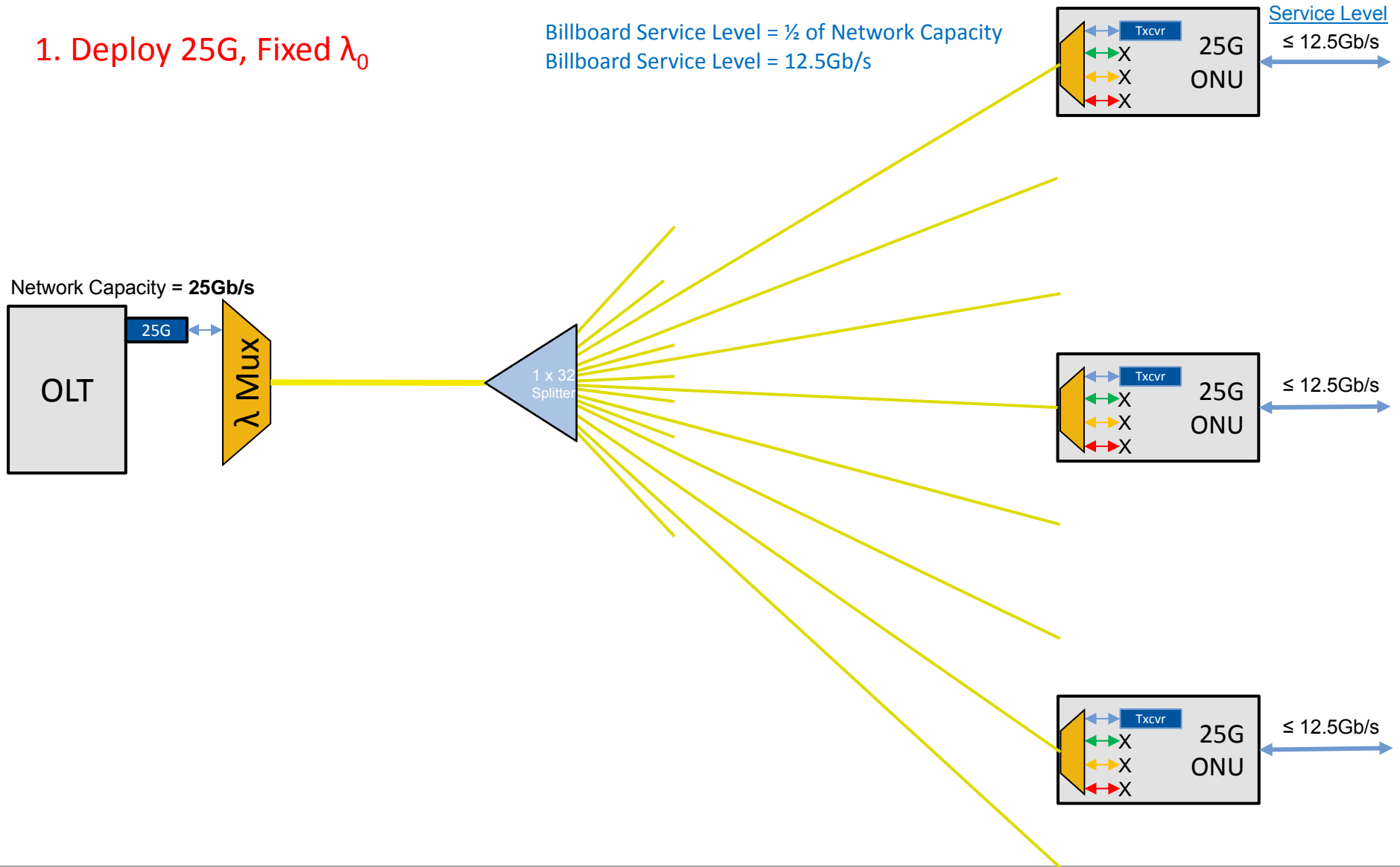
≤ 12.5Gb/s

Option 1 Migration:
50G Network, ONUs with 25G Max Req'd

1. Deploy 25G, Fixed λ_0
2. Add 50G ONUs but only utilize 1 set of 25G optics (λ_1)

Billboard Service Level = ½ of Network Capacity
Billboard Service Level = 25Gb/s

Service Level

Txcvr 25G ONU
≤ 25Gb/s

Not Used / Txcvr 50G ONU
≤ 25Gb/s

Network Capacity = **50Gb/s**

OLT — 25G / 25G — λ Mux

1 x 32 Splitter

Txcvr 25G ONU
≤ 25Gb/s

Not Used / Txcvr 50G ONU
≤ 25Gb/s

Txcvr 25G ONU
≤ 25Gb/s

Not Used / Txcvr 50G ONU
≤ 25Gb/s

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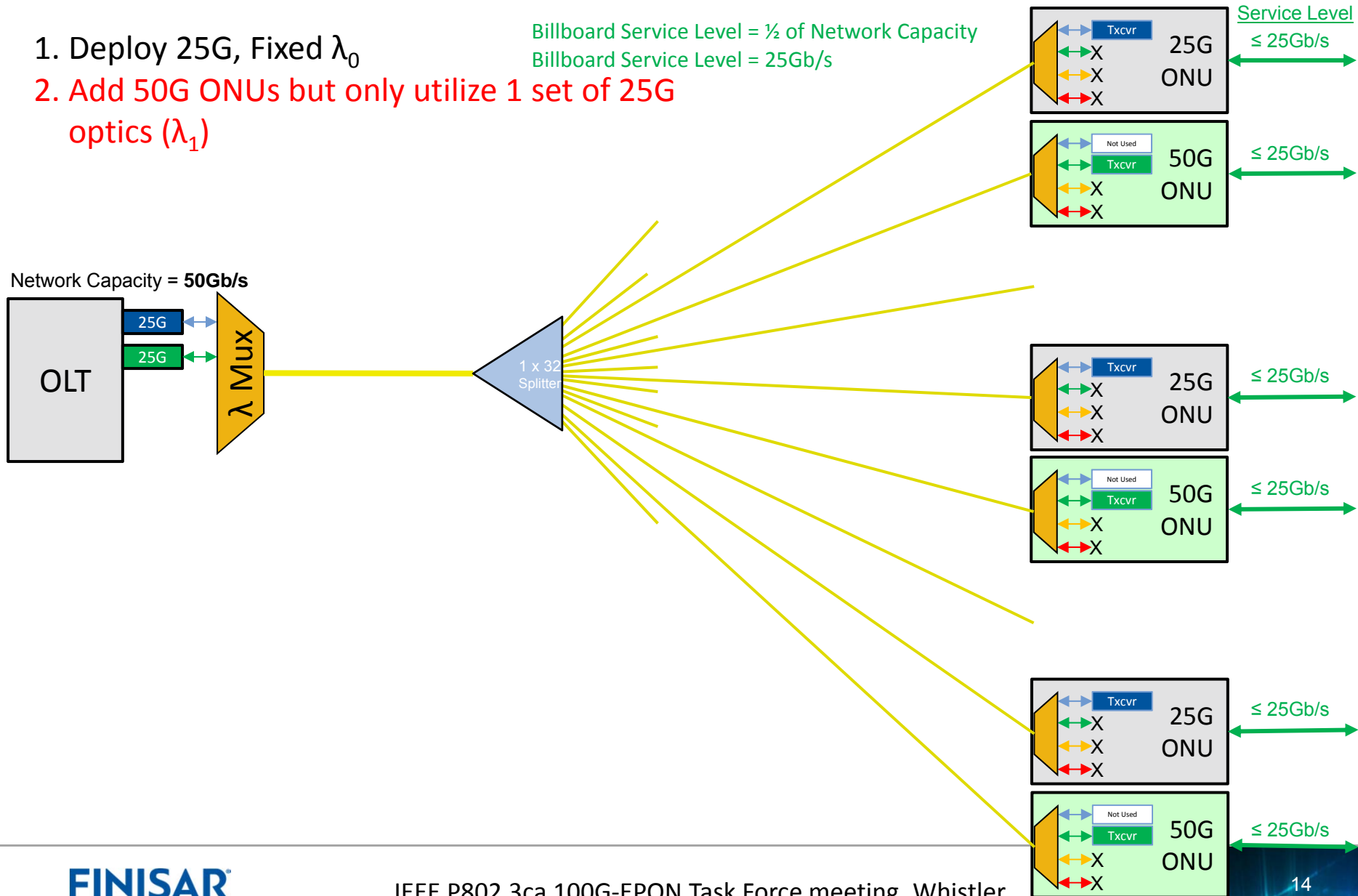
Option 1 Migration:
100G Network, ONUs with 25G Max Req'd

1. Deploy 25G, Fixed λ_0
2. Add 50G ONUs but only utilize 1 set of 25G optics (λ_1)
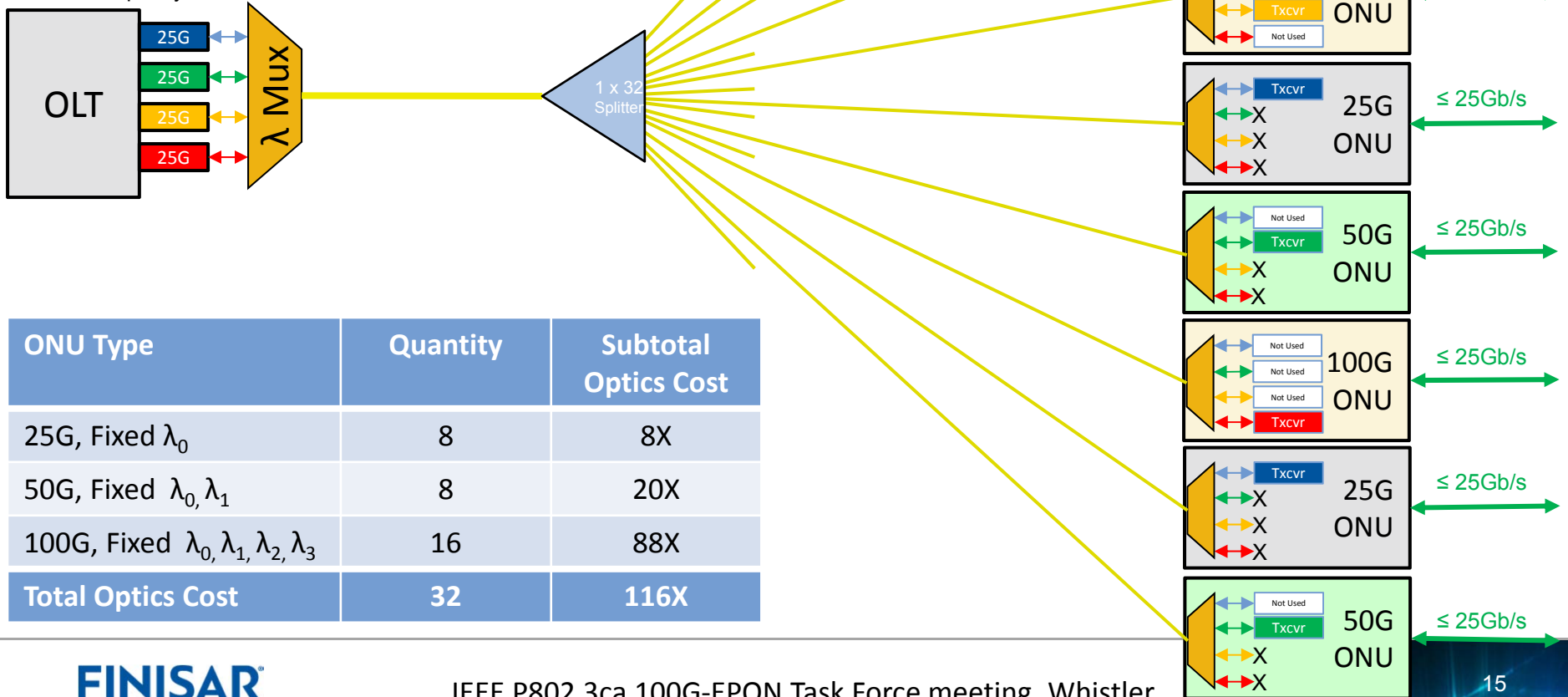3. Add 100G ONUs but only utilize 1 set of 25G optics (λ_2 or λ_3)

Billboard Service Level = ½ of Network Capacity
Billboard Service Level = 50Gb/s

Network Capacity = **100Gb/s**

ONU Type	Quantity	Subtotal Optics Cost
25G, Fixed λ_0	8	8X
50G, Fixed λ_0, λ_1	8	20X
100G, Fixed $\lambda_0, \lambda_1, \lambda_2, \lambda_3$	16	88X
Total Optics Cost	**32**	**116X**

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15

Option 1 Forced ONU Distribution

◆ Option 1 forces 50G ONUs and 100G ONUs to be deployed even if only 25Gb/s ONU capacity would be sufficient.

Forced Distribution of ONUs by Network Capacity

Assumes 25G ONUs are only available on λ0.
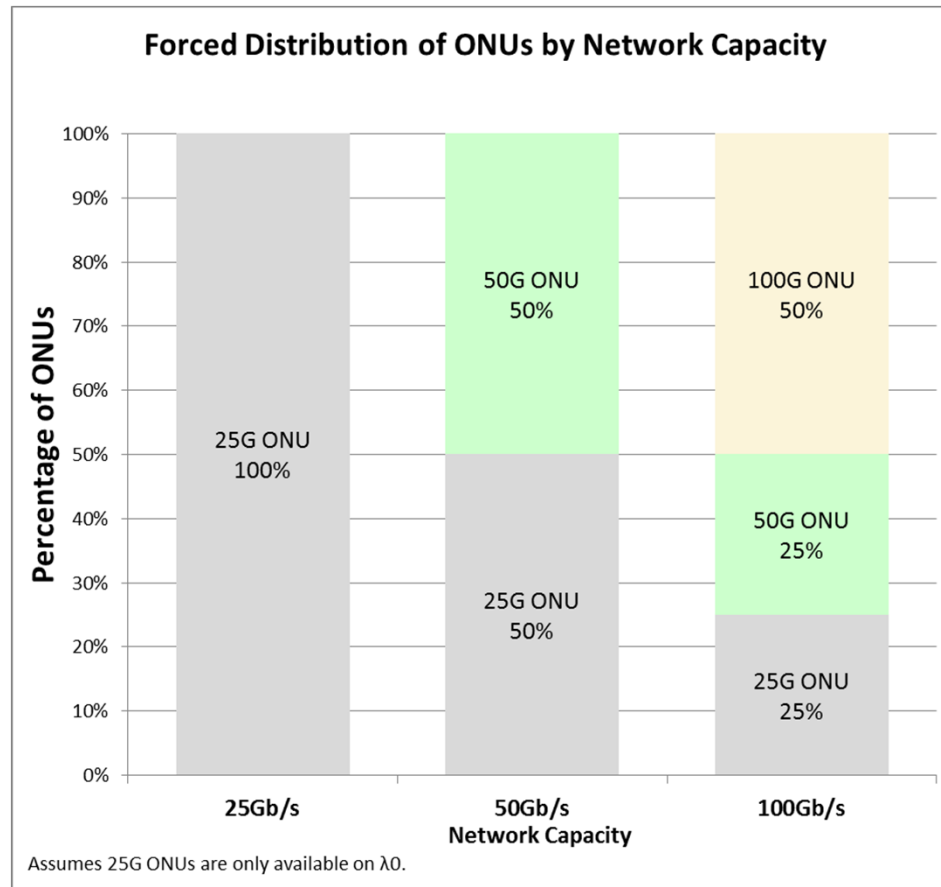
Option 2 Migration: 25G Network, ONUs with 25G Max Req'd

1. Deploy 25G, Fixed λ_0

Billboard Service Level = ½ of Network Capacity
Billboard Service Level = 12.5Gb/s

Network Capacity = **25Gb/s**

OLT — 25G — λ Mux — 1 x 32 Splitter

Service Level
≤ 12.5Gb/s

Txcvr — 25G ONU — ≤ 12.5Gb/s

Txcvr — 25G ONU — ≤ 12.5Gb/s

Txcvr — 25G ONU — ≤ 12.5Gb/s

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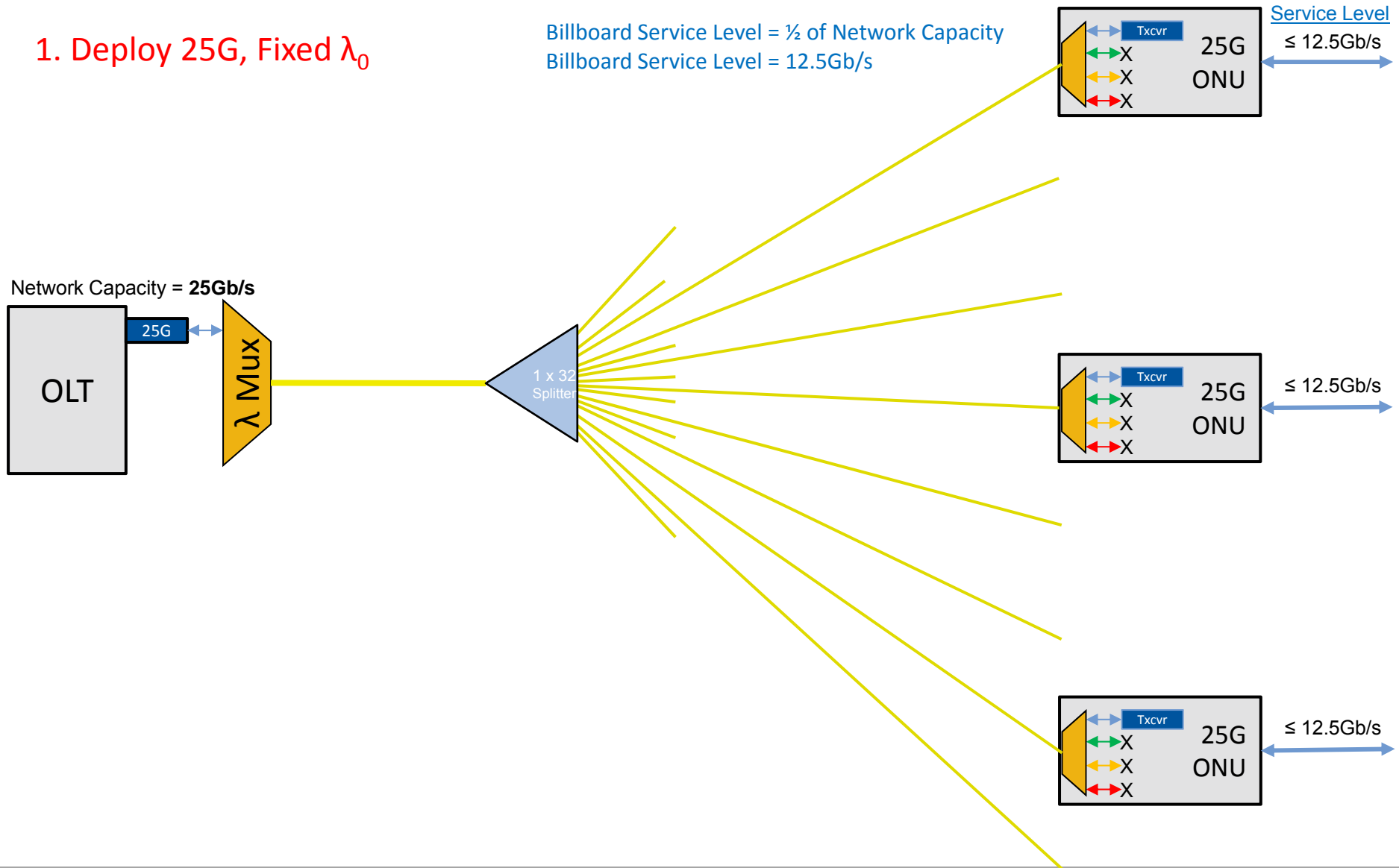
Option 2 Migration:
50G Network, ONUs with 25G Max Req'd

1. Deploy 25G, Fixed λ_0
2. Add 25G ONUs, Fixed λ_1

Billboard Service Level = ½ of Network Capacity
Billboard Service Level = 25Gb/s

Service Level
≤ 25Gb/s

Txcvr   25G ONU

≤ 25Gb/s

Txcvr   25G ONU

Network Capacity = **50Gb/s**

25G
25G

OLT   λ Mux

1 x 32 Splitter

Txcvr   25G ONU   ≤ 25Gb/s

Txcvr   25G ONU   ≤ 25Gb/s

Txcvr   25G ONU   ≤ 25Gb/s

Txcvr   25G ONU   ≤ 25Gb/s

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18
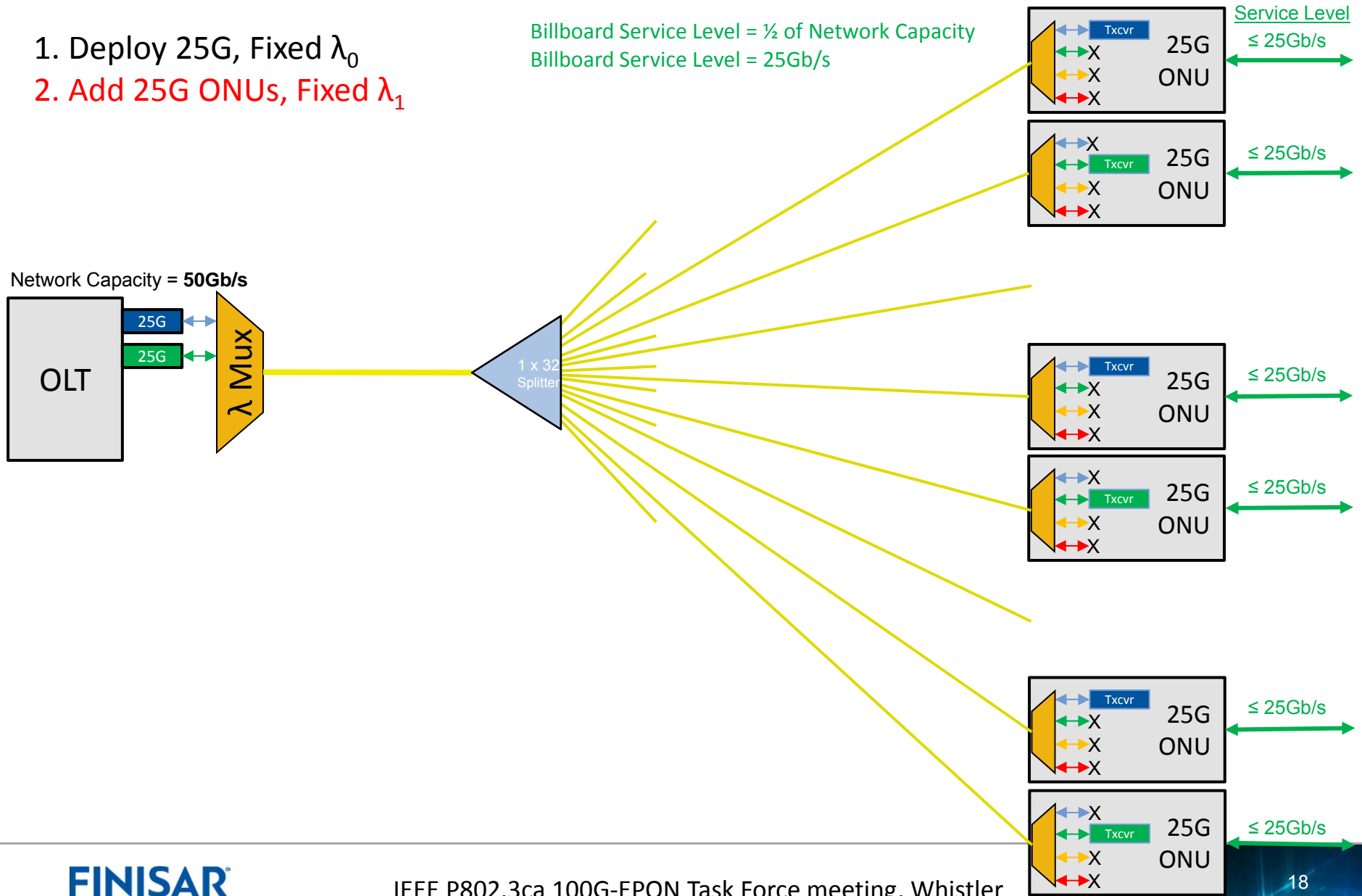
Option 2 Migration:
100G Network, ONUs with 25G Max Req'd

1. Deploy 25G, Fixed λ_0
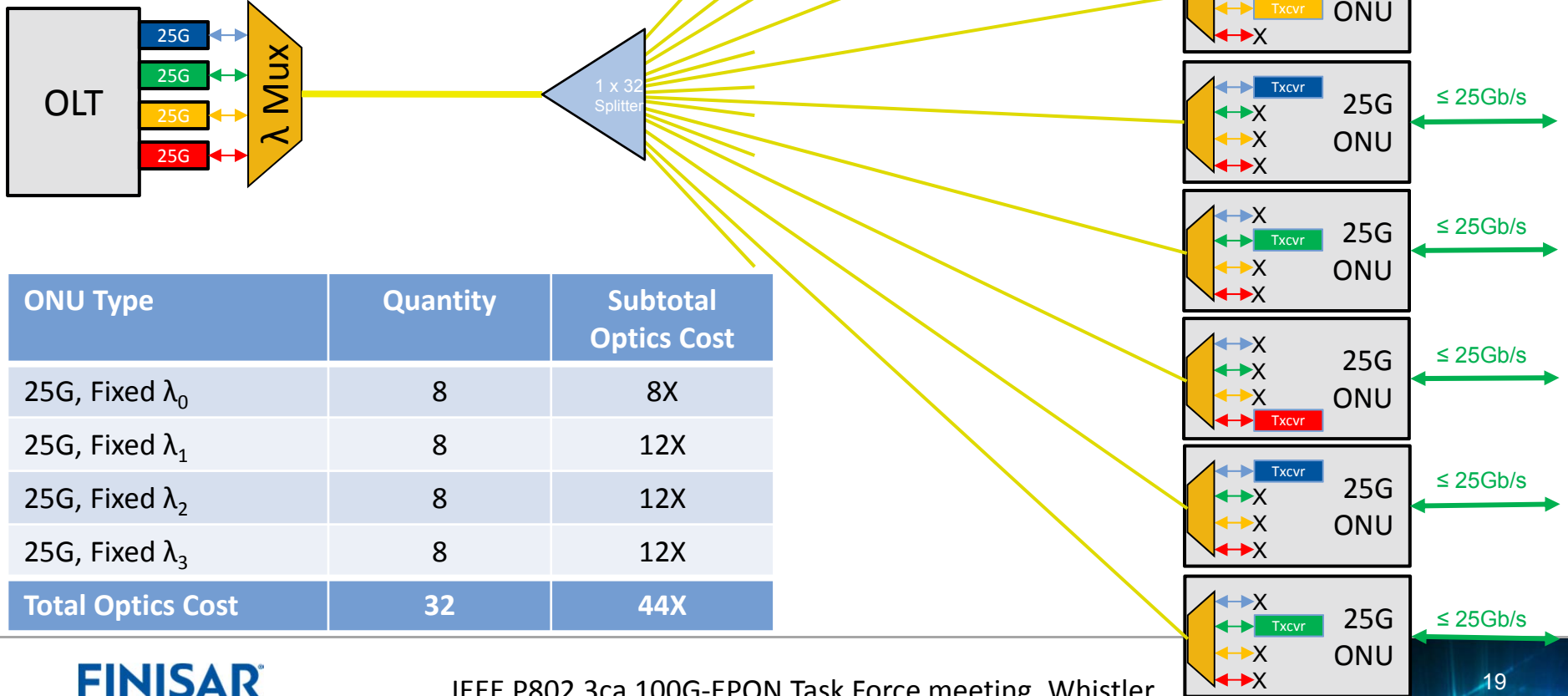2. Add 25G ONUs, Fixed λ_1
3. Add 25G ONUs, Fixed λ_2 and Fixed λ_3

Billboard Service Level = ½ of Network Capacity
Billboard Service Level = 25Gb/s (limited by ONU)

Network Capacity = **100Gb/s**

ONU Type	Quantity	Subtotal Optics Cost
25G, Fixed λ_0	8	8X
25G, Fixed λ_1	8	12X
25G, Fixed λ_2	8	12X
25G, Fixed λ_3	8	12X
Total Optics Cost	**32**	**44X**

Service Level
≤ 25Gb/s
≤ 25Gb/s
≤ 25Gb/s
≤ 25Gb/s
≤ 25Gb/s
≤ 25Gb/s
≤ 25Gb/s
≤ 25Gb/s

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25G ONU Options: Relative Optics Cost/PON Segment

Option	25G ONU λ Plan	Total Relative Optics Cost for PON segment (32 ONUs)
1	Fixed, λ_0 Only (must use 50G and 100G ONUs for increased network capacity)	116X
2	Fixed, λ_0 Fixed, λ_1 Fixed, λ_2 Fixed, λ_3	44X

With Option 1, MSO spends 2.6x more on ONU Optics compared to Option 2.

Assumptions:

- 100G Network Capacity
- Peak rate per ONU required is never over 25Gb/s
- 32 ONU's in PON segment
- Only 1 set of optics are ever needed on every ONU (incl. 50G & 100G ONU's)
- On 32 ONU segment, assumes 8 ONU's on each wavelength $\lambda_0, \lambda_1, \lambda_2, \lambda_3$
- 50G ONU only available at λ_0, λ_1
- Any differences in cost of 25G ASIC, 50G ASIC, 100G ASIC are not considered

Question:

- Are the higher optics costs in Option 1 offset by Operational Savings and/or more network flexibility?

Conclusion: Option 2 is the best path

Option 2: 25G ONUs available on all wavelength pairs

- ◆ Provides the MSOs more cost effective migration to 50G and 100G Network Capacities: 62% savings in optics cost
    - ▪ More favorable business case for MSOs to decide to migrate to higher network capacities
    - ▪ The cost of Option 1 would deter MSOs from migrating to higher network capacities
- ◆ More 25G ONUs will be required which will lower the cost of 25G ONUs
- ◆ Could consider wavelength-tunable optics to reduce number of ONU variants

Optics Cost for PON segment
(32 ONUs, 100G Network Capacity)