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# Approaches for inter-building connection with 400Gbps link

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# Contributors

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# Introduction

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■ Discussion in previous meetings.

・Service provider's needs for extended reach optical interface

・Technical investigations for FEC and optical transmission

■ Issue raised in the last meeting

・Show broader areas of market interest.

・Compare a greater variety of solutions for extended reach interface, for example, including physical link aggregation.

■ Target of this presentation

・Investigate possible solutions that meet required functionality for the market space of 400GbE extended reach.

・Discuss tradeoff and comparison criteria among solutions.

# Application and required functionality

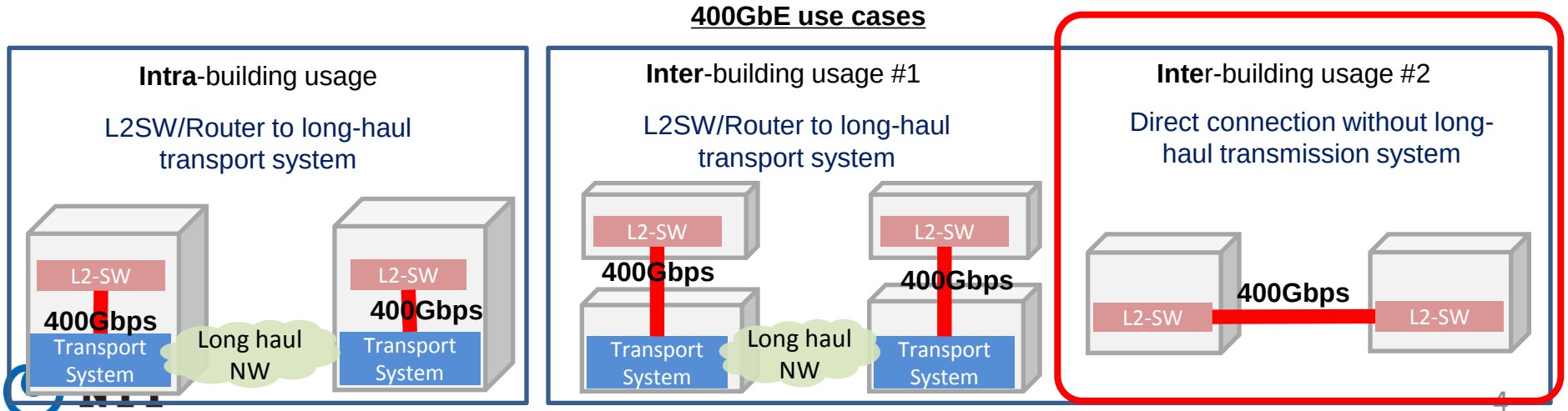
■ Application

Inter-building connection in service providers/datacenter networks.
(But not limited to this application)

■ Requirement

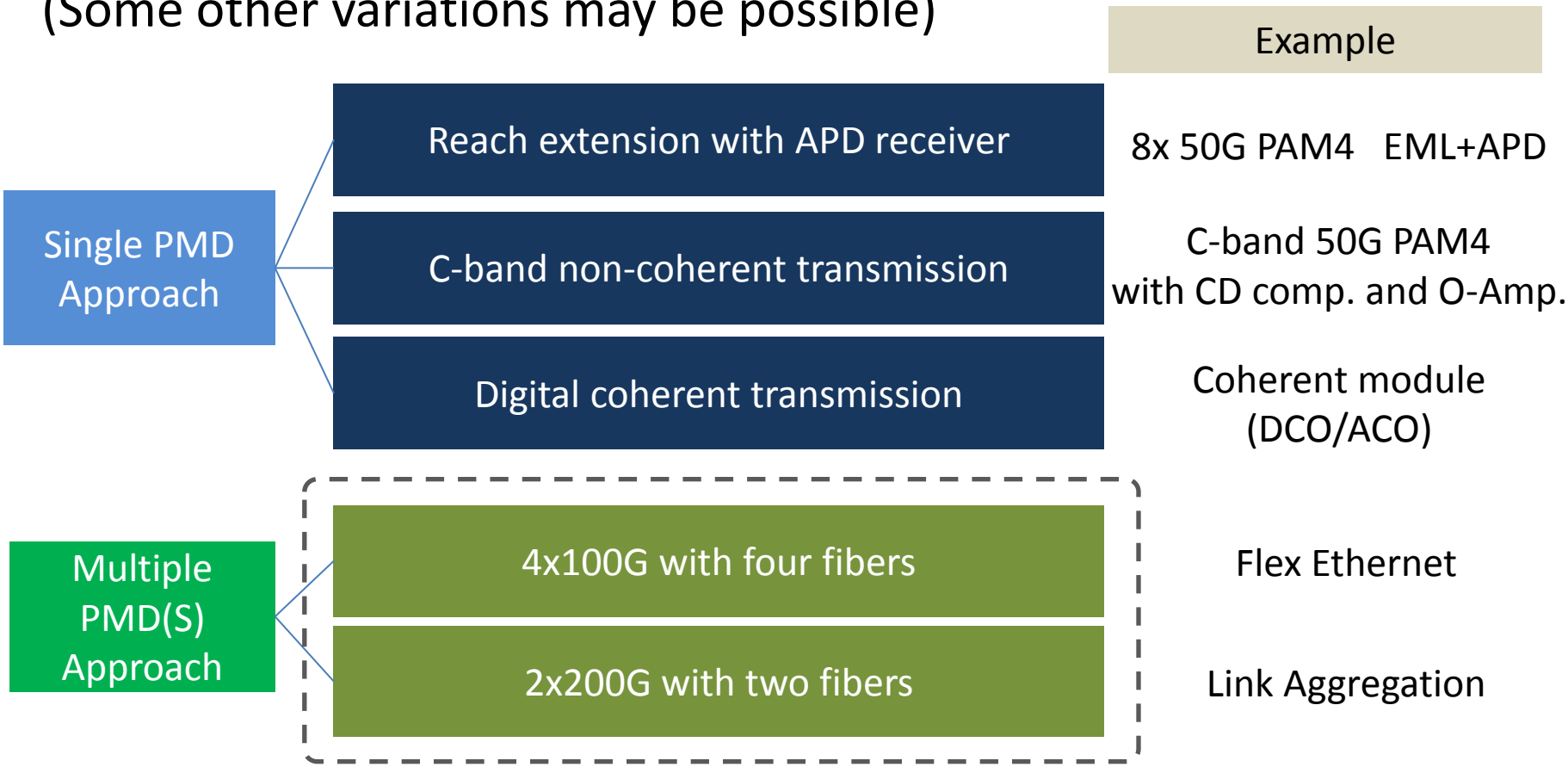
Functionality: Transport Ethernet frames at about 400Gbps over 40km between Router/L2-SW.

Implementation : No consideration of any implementation constraint (e.g. Form factor ).



# Rough classification of possible approaches

- Three basic transmission approaches(Single PMD)
- Three multiplication schemes using lower rate PMD(s).
  (Some other variations may be possible)



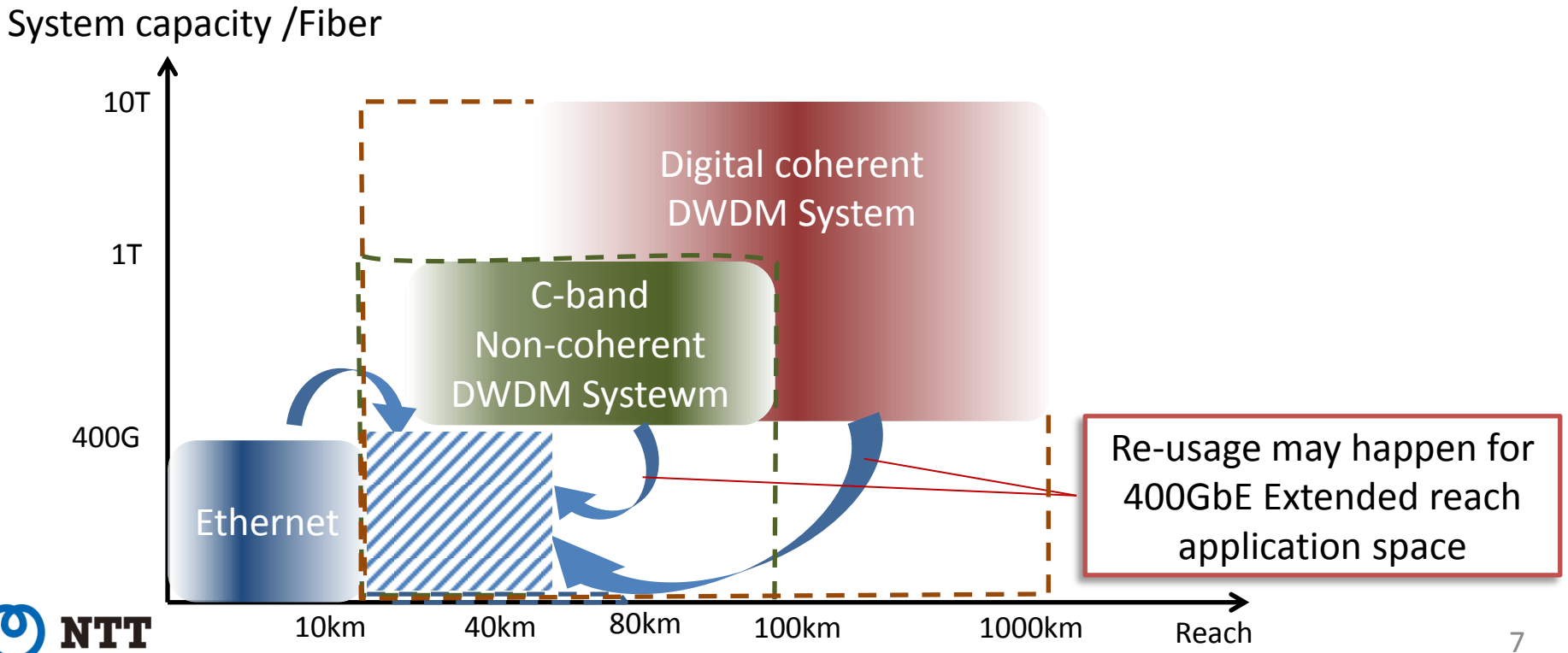
# Single PMD approach

# Original target of each compared technology

Each technology have different target market spaces according to

- system-capacity/fiber requirement
- reach requirement

From market experiences, the technologies developed for long-haul DWDM system have been successfully utilized for non-DWDM short reach application like Ethernet.



# Comparison criteria for 40km transmission application

Two criteria given the comparison in the same application space.

1)performance margin

Potential capability to achieve required performance (40km transmission).

2) Potential cost = commonality of technologies

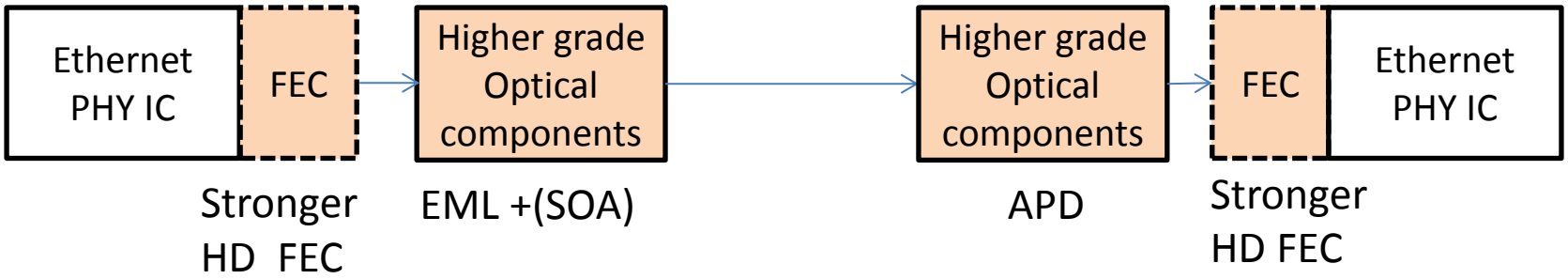
Cost depends on the implementation and the production volume.
Currently, no detailed implementation and large volume assumption.
The component commonality with existing Ethernet (existing large volume product) is important factor for understanding the potential cost.

# Single PMD approach A
# Reach extension with APD

Existing Ethernet (8x50G PAM4)


## Example configurations for 40km(5x80G)

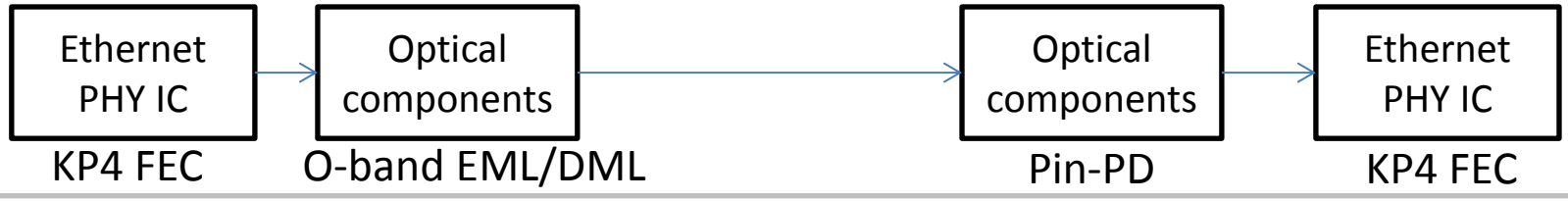
Not necessary to use all the functions



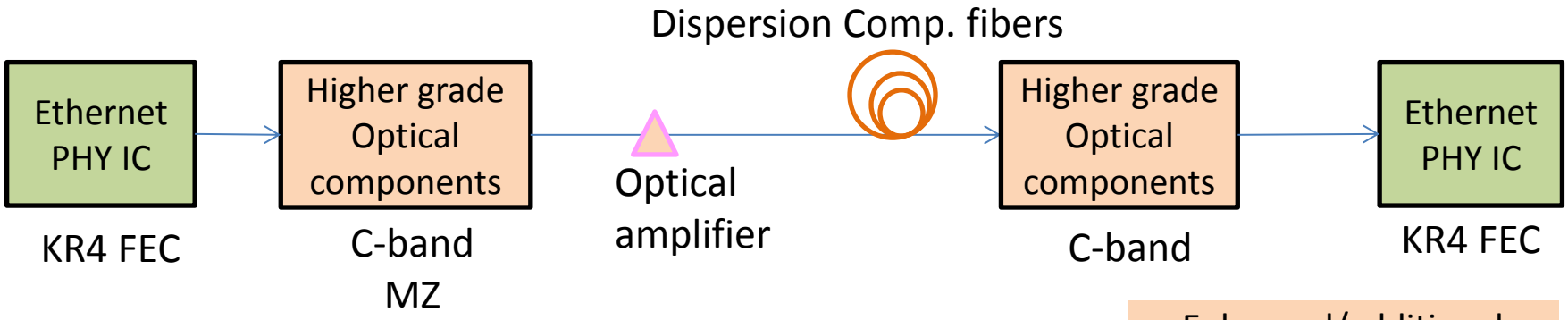

Enhanced Function block

# Single PMD approach B
# C-band non-coherent transmission

Existing Ethernet (8x50G PAM4)




## Example configurations for 80km (8X50G)




Enhanced/additional Function block

Simpler function block

- Above configuration referenced from *OFC2016 W1k.5*
- Configuration for 40km is not clear.
- Variety of other configurations might be possible. (e.g. DSP based dispersion compensation, etc)

# Single PMD approach C
# Digital coherent transmission

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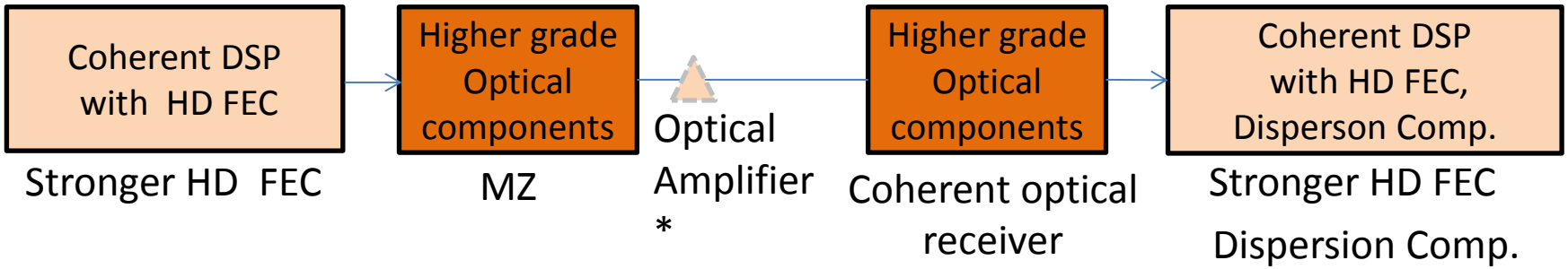
Existing Ethernet (8x50G PAM4)

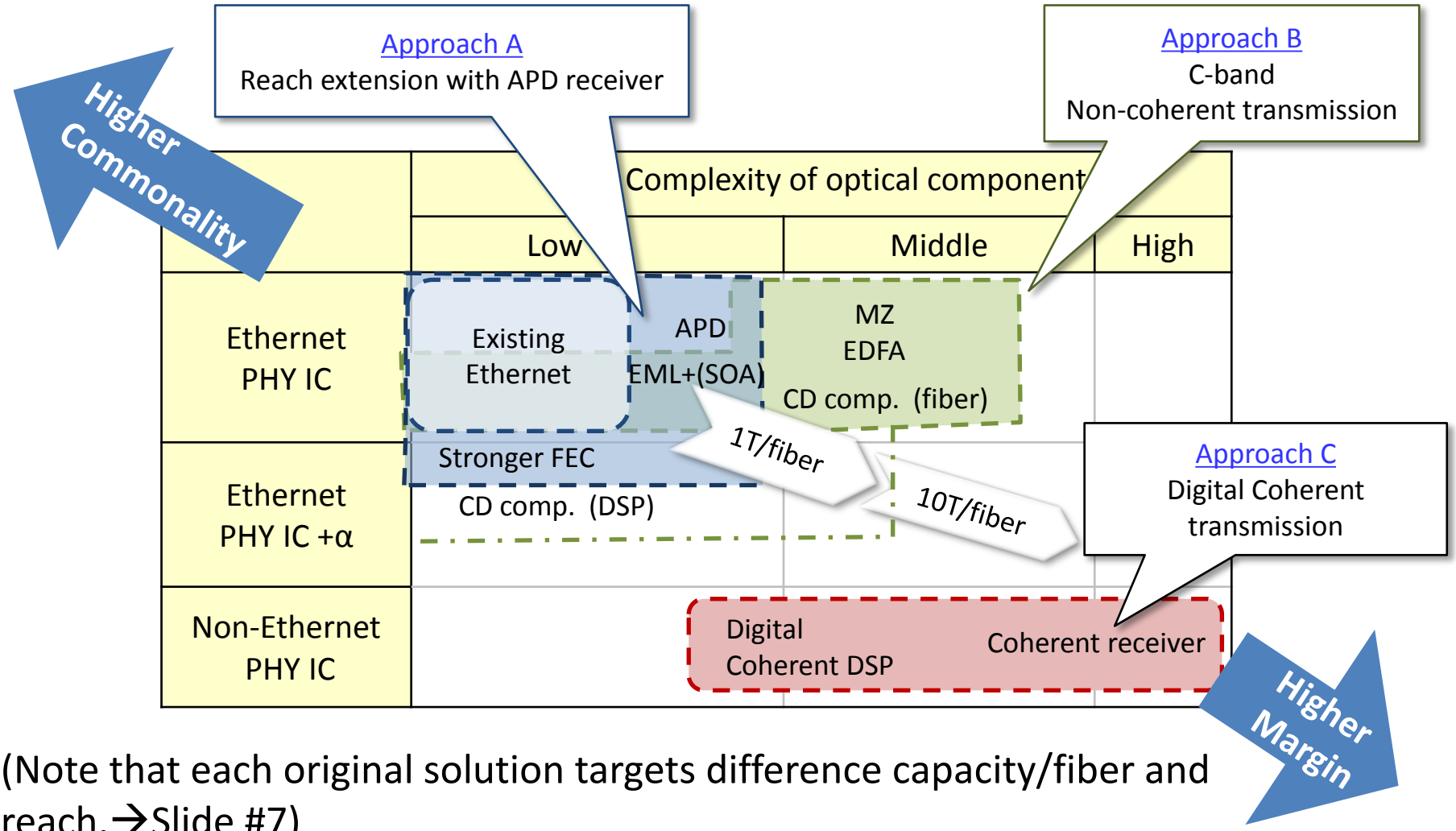

## Example configurations for 40km/80km (4x100G)




Note: Optical Amplifier may not be required for 40km transmission

Enhanced/additional Function block

# Solution Mapping （margin vs commonality）




(Note that each original solution targets difference capacity/fiber and reach.→Slide #7)

# Observation and question (Single PMD)

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## ■Observation

There is a tradeoff between

- Performance margin
- Commonality with existing Ethernet

## ■Question

Where is the balanced point considering the market demand?

Technology with enough margin

- Pro: Enables earlier adoption with enough performance margin.
- Con: May result in high-cost dedicated system.

Commonalizaed technology

- Pro : Maximize cost-advantage in the Ethernet ecosystem and grows low cost solution.
- Con : Could be a constraint for the optimization for the specific market.

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# Multiple-PMD approach

# Single-PMD / Multiple-PMD approaches

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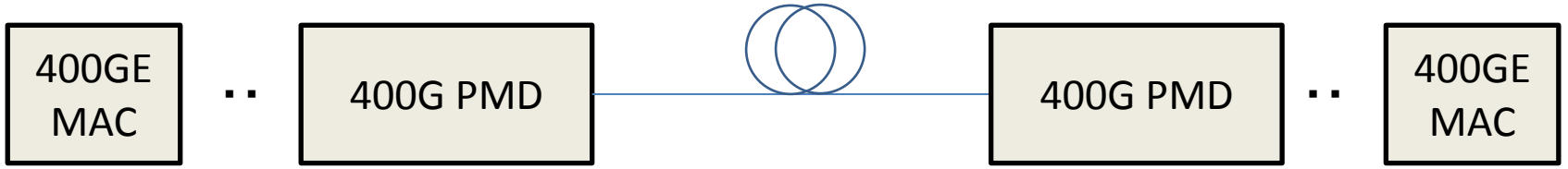
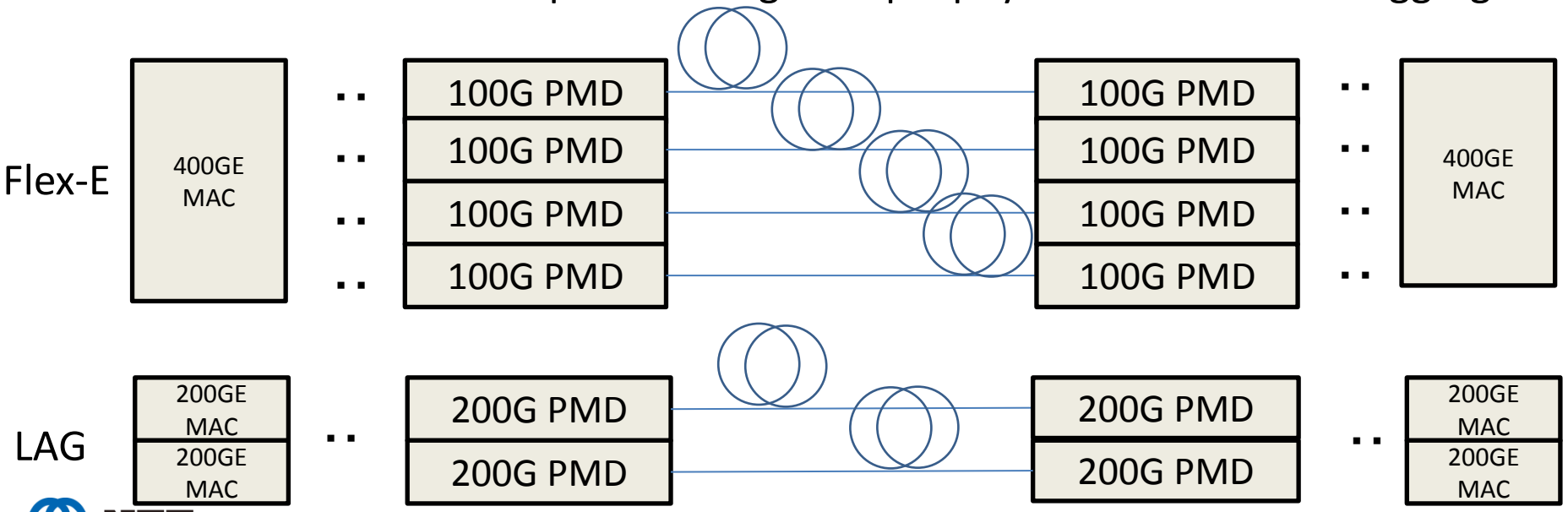
## ■single-PMD approach

Ethernet frames are transported using single physical module




## ■Multiple-PMD approach

Ethernet frame are transported using multiple physical modules with aggregation

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# Relative cost difference

- Both module and media cost will be high for 4x100GbE (A)
- (Almost only)Media cost will be high for 2x200GbE (B )

  But no standardized 200GbE-ER4 nor 200G-based Flex-Ethernet now.

| | | Relative cost | | | |
|---|---|---|---|---|---|
| | | Per Module (definition) | Per fiber (definition) | total | Additional cost to *Ref* |
| A | 4x 100G Base ER4 | Mc | F | 4xMc + 4F | **Module +media > 4F** |
| B | 2x 200G Base ER4 | Mcc | | 2xMcc +2F | **Media ≅ 2F** |
| *Ref* | 1x 400G Base ER8 | Mcd | | Mcd +F | - |

According to experience, higher rate/lambda enables low cost(cost/bit).

4x**M**c(4x25G/ λ) > 2x**Mcc** (4x 50G/ λ) ≅ **Mcd** (8x50G/λ)

Same rate/ λ

# Single PMD or multiple PMD?

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■ Long term goal :single PMD

Single PMD approach for 400GbE 40km is the goal (ultimately with single wavelength, likely with multiple wavelength in near term)

■ Temporally alternative : multiple PMD approach

- Utilized if good (single) PMD is not feasible for the target rate(400Gbps here).
- Required function is satisfied without using new PMD technologies specific to the target rate, if some additional equipment and/or operation cost is allowed.

Questions

It would be far better than nothing, but does it really efficient to make and use temporary solutions while waiting long term goal?

# How to move forward?

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■ Motivation of introducing higher rate

- Reduction of cost/bit to address increasing traffic demand.

■ Situation

- 400GbE is promising to replace 100GbE with cost/bit reduction and is a necessary step for the industry.
- There is a requirement for 200GbE. But it would be small step for the purpose of replacing deployed 100GbE modules.
- Both ER PMD requirement but it would not be as large market as shorter reach.

■ Issues

- Market fragmentation in the not yet large market space.
- Multi-step investment for not so big gain of cost/bit reduction

■ Possible direction

- commonalize technical approaches for these markets and maximize the return of the investment for 200GbE and 400GbE  market space.

# Possible discussion step

Two closely related market requirements for ER PMD.

→ 200G, 400G

Find common technical approach for 200G and 400G single PMD

Consider standardized single PMD solution according to the market demand.

If standardization with single PMD is not reasonable, then think about alternatives.
The alternatives may be a multiplication of standardized lower rate PMD(s) or dedicated solutions for each market demand.

# Summary

■Investigated various solutions for 400Gbps interface for inter-building applications
- Single-PMD approach
- Multiple-PMD approach (alternative)

■ Suggested that a balance between performance margin and technology commonality with existing Ethernet is important.

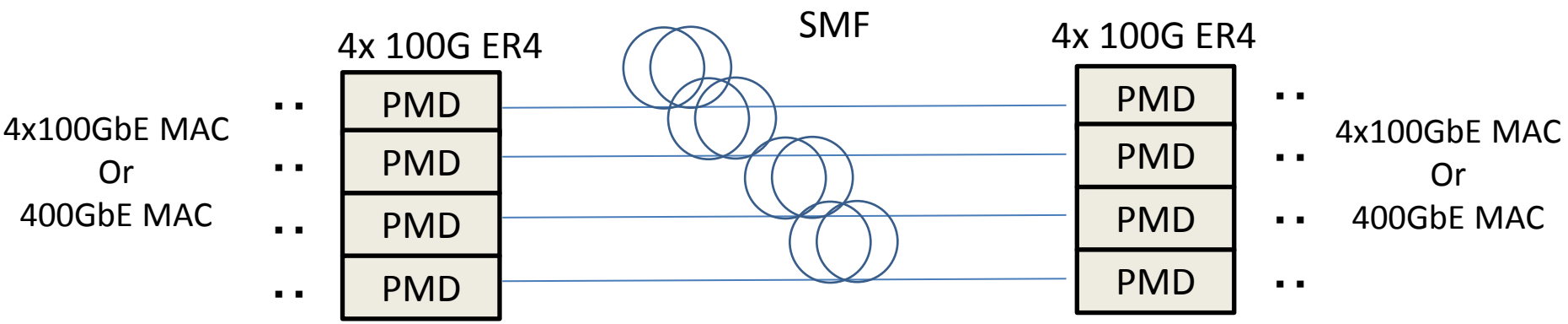
■ Clarified expected additional cost for the multiple PMD approaches as an alternatives to single PMD approaches.

■ Technology commonalization between 200GbE and 400GbE extended reach is important.

# Backup slides

# Multiple PMDs approach A： 4 x 100G PMD

4x 100G Base-ER4 multiplication with Link aggregation*1/ Flex-Ethernet *2



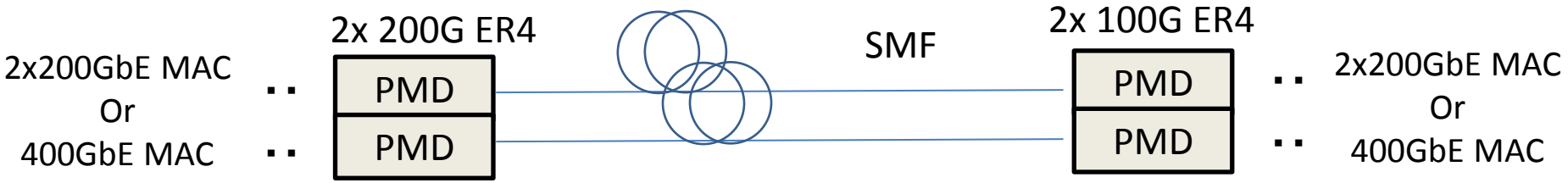

4 x 100G-ER4 + 4 x duplex-fibers

Note 1- (Link Aggregation): Frame transport performance depends on the hash algorithm used. Usually not 100% link utilization

Note 2- (Flex Ethernet) Near 100% bandwidth utilization possible. latency distribution must be within 51us

# Multiple PMDs approach B : 2 x 200G PMD

## 2x 200G Base-ER4[*1] with Link-Aggregation/Flex-Ethernet [*2]




2x 200G-ER4 + 2x duplex-fibers

Note 1- (200G-base ER8) No standard today.

Note 2 – (Flex Ethernet ) Currently does not support 200GbE PMD