CORNING

Shuffling Solutions for AI/ML-GPU Clusters and Modern Data Centers:

Enhancing Scalability and Reducing Complexity

Introduction

This document provides an overview of the shuffling applications, scalability impact, and various configurations used in AI/ML architectures.

Shuffling Applications FAQ

What is the Purpose of Shuffling in Fiber Optic Networks?

Shuffling, also known as meshing, is essential for managing complex cabling requirements in data centers, especially when dealing with high-density connections and multiple servers or switches. It helps in organizing and routing fibers efficiently to ensure optimal performance and reduce the risk of errors during installation and maintenance. Shuffling minimizes cabling complexity in spine-and-leaf networks by using optical interconnection components to support data signal transmission. Fiber shuffling is the regrouping of optical fibers to provide a greater number of fiber connections. Fiber shuffling routes a set of input fibers to a set of output fibers.

How does shuffling impact the scalability of a data center?

Shuffling significantly impacts the scalability of a data center by simplifying the integration of new switches and servers, allowing for easy expansion without increasing cabling complexity. By using optical interconnection components, data centers can scale out more easily. This is achieved by organizing fiber connections into discrete channels, which reduces the need for multiple individual connections and allows for multiple channels to be provided from a spine or leaf switch to a central optical interconnection component using a single signal. This approach supports “flattening” the network architecture, facilitating scalability and ensuring efficient use of infrastructure while maintaining high performance and signal integrity.

How is shuffling done?

To perform shuffling in a data center, utilize either passive **shuffle modules/boxes** or **multifiber shuffle assemblies** to efficiently manage optical lanes between network interface cards (NICs) and switches. Installing shuffle components enables high-speed connections (for example, 2x400G DR4 with 100G lanes) to multiple switches, redistributing signals across fibers and optimizing network connections by spreading the data across multiple outputs.

What types of shuffling are the most common?

The most common shuffling types are:

- **4x4 Shuffle:** In this method, pairs of fibers from a single MPO connector (left, unshuffled) are distributed across four different MPO connectors (right, shuffled), allowing connections to more switch ports with the same number of MPO connectors.

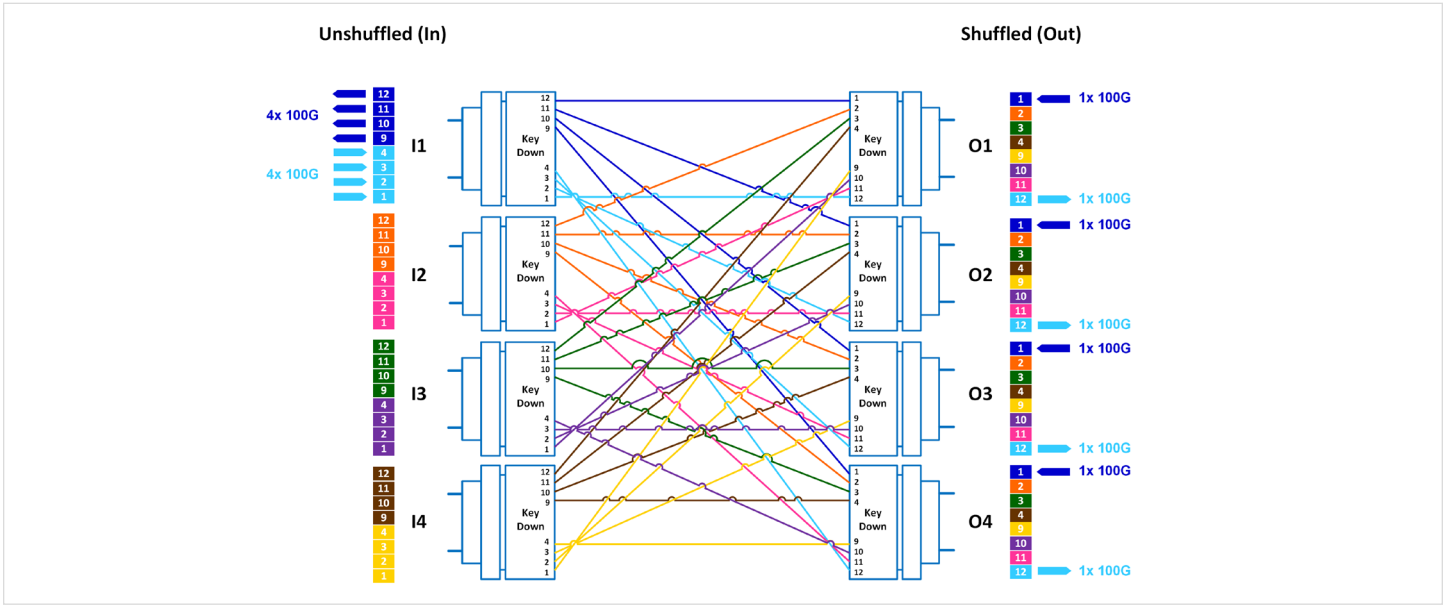


Figure 1. 4x4 Shuffle: Shuffling four 100G data lanes from a 400G Transceiver

- **2x2 Shuffle:** In the 2x2 shuffle approach, two pairs of fibers from one MPO connector (left, unshuffled) are spread across two MPO connectors (right, shuffled). This setup simplifies fiber routing by providing a straightforward way to manage optical lanes with fewer connections. It is ideal for applications where cable management is critical and where you need to maintain efficient connectivity without overly complex setups. It provides double the bandwidth for each connection compared to 4x4 shuffle.

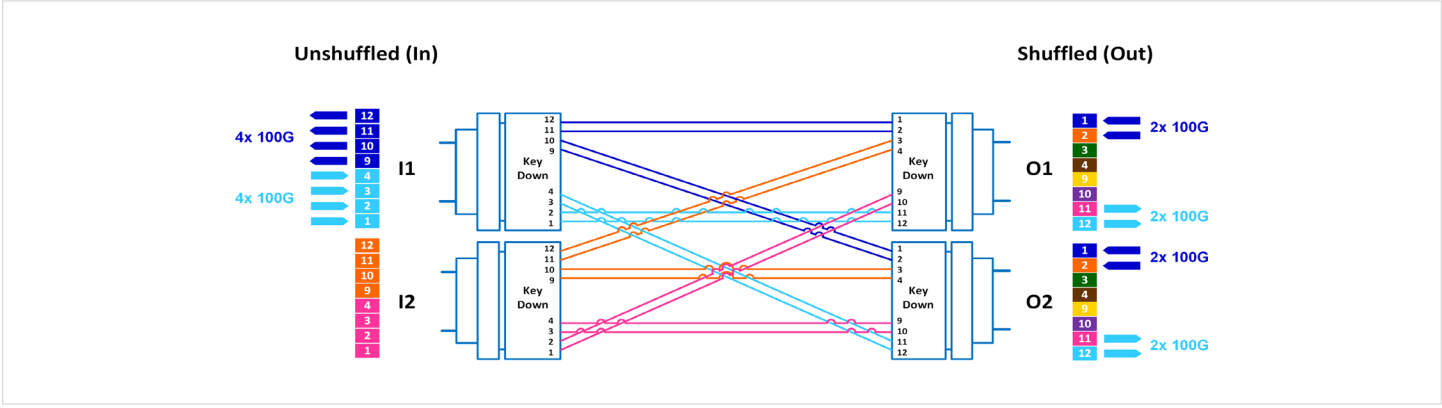


Figure 2. 2x2 Shuffle, Shuffling four 100G data lanes in 2-lane increments at 200G from a 400G Transceiver

- **Custom shuffling:** Customized configurations can also be created to meet specific customer/project needs.

What are the differences between a shuffle box and multifiber shuffle assemblies?

- **Shuffle Box:** Shuffle boxes are passive modules designed to manage complex fiber interconnections within a controlled enclosure or housing. They are often used in high-density environments where a centralized solution for organizing and routing fibers is essential.

  These durable boxes allow custom configurations with multiple types of connectivity.
  They provide a modular, centralized point for connections, making them suitable for scalable network growth.

  The shuffle box can be utilized in both single-mode and multimode infrastructures, along with structured cabling or point-to-point cabling components.

Figure 3. Example of Shuffle Box and its Modules

Shuffle Box

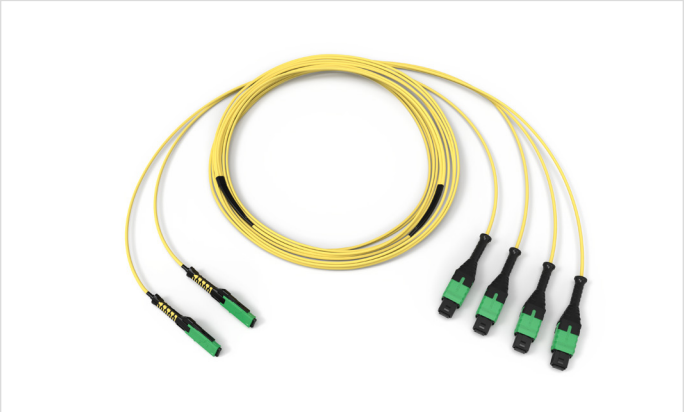
Module

- **Multifiber Shuffle Assemblies:** Multifiber shuffle assemblies are cable systems that support the shuffling of optical lanes between network interfaces. They provide flexible routing options to organize fiber connections efficiently.

  By pre-organizing fibers, these assemblies reduce the complexity and time required for setting up connections.

  The shuffle assembly can be utilized in both single-mode and multimode infrastructures, along with structured cabling or point-to-point cabling components.

Figure 4. Example of Shuffle Assemblies with different connector types



32-fiber Shuffle Assembly MMC-16 to MPO-8/12 APC

32-fiber Shuffle Assembly MPO-8/12 APC to MPO-8/12 APC

What connector types are available for shuffle boxes and multifiber shuffle assemblies?

- 8-fiber MPO APC to 8-fiber MPO APC. Available in single-mode and multimode fiber.
- 8-fiber MPO PC to 8-fiber MPO PC. Available in multimode fiber.
- MMC-16 to 8-fiber MPO APC. Available in single-mode fiber.
- MMC-24 to 8-fiber MPO APC. Available in single-mode fiber.
- Other connector types are available upon request.

Single-mode connectors:

- Insertion Loss, Max. 0.35 dB (mated).
- Return Loss, Min. 65 dB (mated).

Multimode connectors:

- Insertion Loss, Max. 0.35 dB (mated).
- Return Loss, Min. 45 dB (mated).

What type of customization can be done for shuffle boxes and multifiber shuffle assemblies?

Shuffle Boxes:

- Housing size. Available from 1 to 6 rack units, with special sizes possible upon request.
- Density per RU. Customizable depending on the connector type and desired configuration.
- Access. Front access only, or both front and back access.
- Modular. Passive modules available with either slidable features or fixed housing/enclosure.
- Non-Modular. A single fixed housing/enclosure with ports.

Multifiber Shuffle Assemblies:

- Cable lengths.
- Straight or staggered legs.
- Special labeling and connector color coding.

What are the pros and cons of shuffle boxes and multifiber shuffle assemblies?

Aspect	Multifiber Shuffle Assemblies	Shuffle Boxes
Pros		
Flexibility in Routing	Offers flexibility in routing fibers, allowing for customized configurations.	Simplifies complex cabling by organizing and routing fibers within a controlled environment. Customized configurations are easier.
Scalability	Enables easy additions to the network without significant rework.	Facilitates network scale-out and enables easy additions and changes to the network without significant rework.
Installation Efficiency	Reduces installation time compared to a network that doesn't implement shuffling, by pre-organizing fibers and simplifying the connection process.	Allows for easier and faster installation by providing a modular centralized point for connections.
Cost-Effectiveness	Reduces the need for multiple individual connections, lowering overall costs.	Provides durability and reliability with robust designs that can withstand network changes.
Performance	Maintains high performance and signal integrity across the different interconnects.	Maintains high performance and signal integrity across the different interconnects.
Cons		
Flexibility	Less adaptable to changes once installed.	–
Performance	–	Adds one more connector pair compared to shuffle harnesses, increasing channel loss.
Potential for Errors	Risk of mispatching or connection errors if not properly labeled and organized.	Risk of mispatching or connection errors if not properly labeled and organized.
Troubleshooting	Can be complex and time-consuming.	Can be complex and time-consuming.

Which Shuffling Technology is Best Suited for Different Data Center Sizes?

- Small and Medium-Scale Data Centers: Typically suited for EDGE™ 4x4 Mesh Modules or 4x4 Shuffle Assemblies.

- Medium to Large-Scale Data Centers: Options include Shuffle Boxes (4x4 or 2x2), EDGE 4x4 Mesh Modules, or Shuffle Assemblies (4x4 or 2x2), selected based on specific design needs and infrastructure requirements.

Application examples

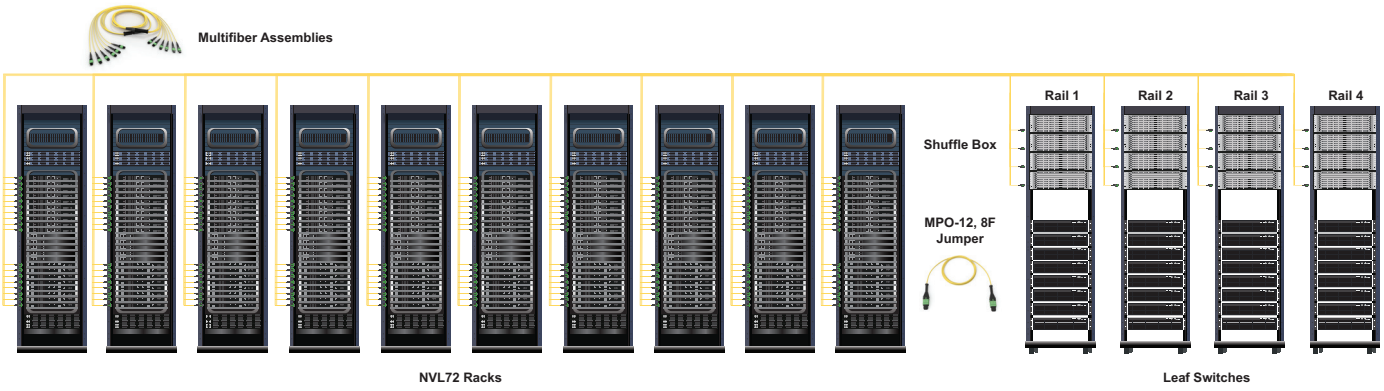
Shuffle Box

Point-to-Point Cabling

Switch/Server | MPO-12, 8F Jumper | EDGE HPC 3U 8x Shuffle Modules | MPO-12 8F Jumper | Switch

Structured Cabling

Switch/Server | MPO-12, 8F Jumper | EDGE HPC 3U 8x Shuffle Modules | MPO-12, 8F Jumper | EDGE8 4U Housing | EDGE8 Trunk | EDGE8 4U Housing | MPO-12, 8F Jumper | Switch



Note: Shuffle and Cabling components available in single-mode and multimode fiber.

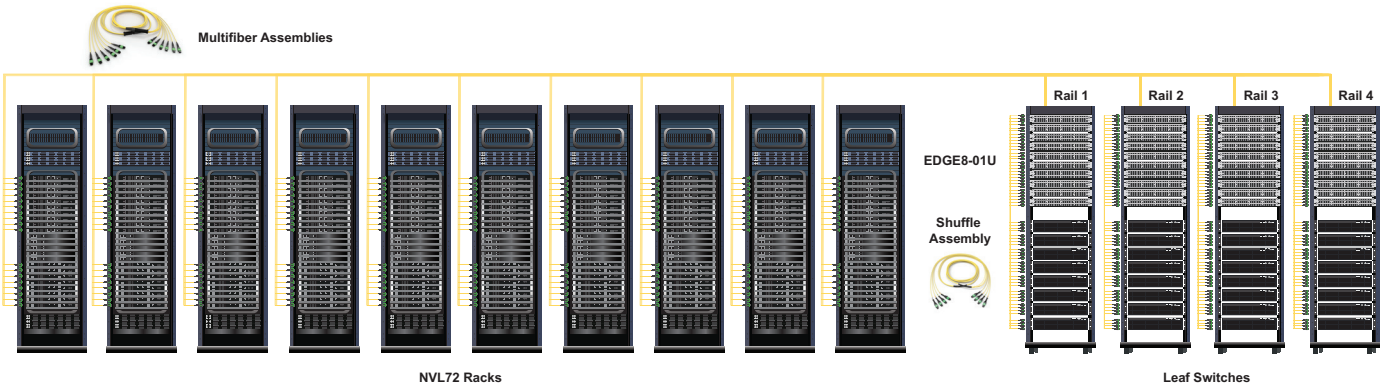
Multifiber Shuffle Assemblies

Point-to-Point Cabling

Switch/Server | MPO-12 4x4 Shuffle Assembly | Server

Structured Cabling

Switch/Server | MPO-12 4x4 Shuffle Assembly | EDGE8 4U Housing | EDGE8® Trunk | EDGE8 4U Housing | MPO-12, 8F Jumper | Server



Note: Shuffle and Cabling components available in single-mode and multimode fiber.

Conclusion

By utilizing shuffling applications, data centers such as AI/ML GPU clusters, cloud environments, private or enterprise setups, and general-purpose facilities, can improve scalability, optimize performance, and reduce cabling complexity. This approach is especially useful for AI/ML GPU clusters, allowing them to handle high-density connections and maintain consistent and reliable operation.

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