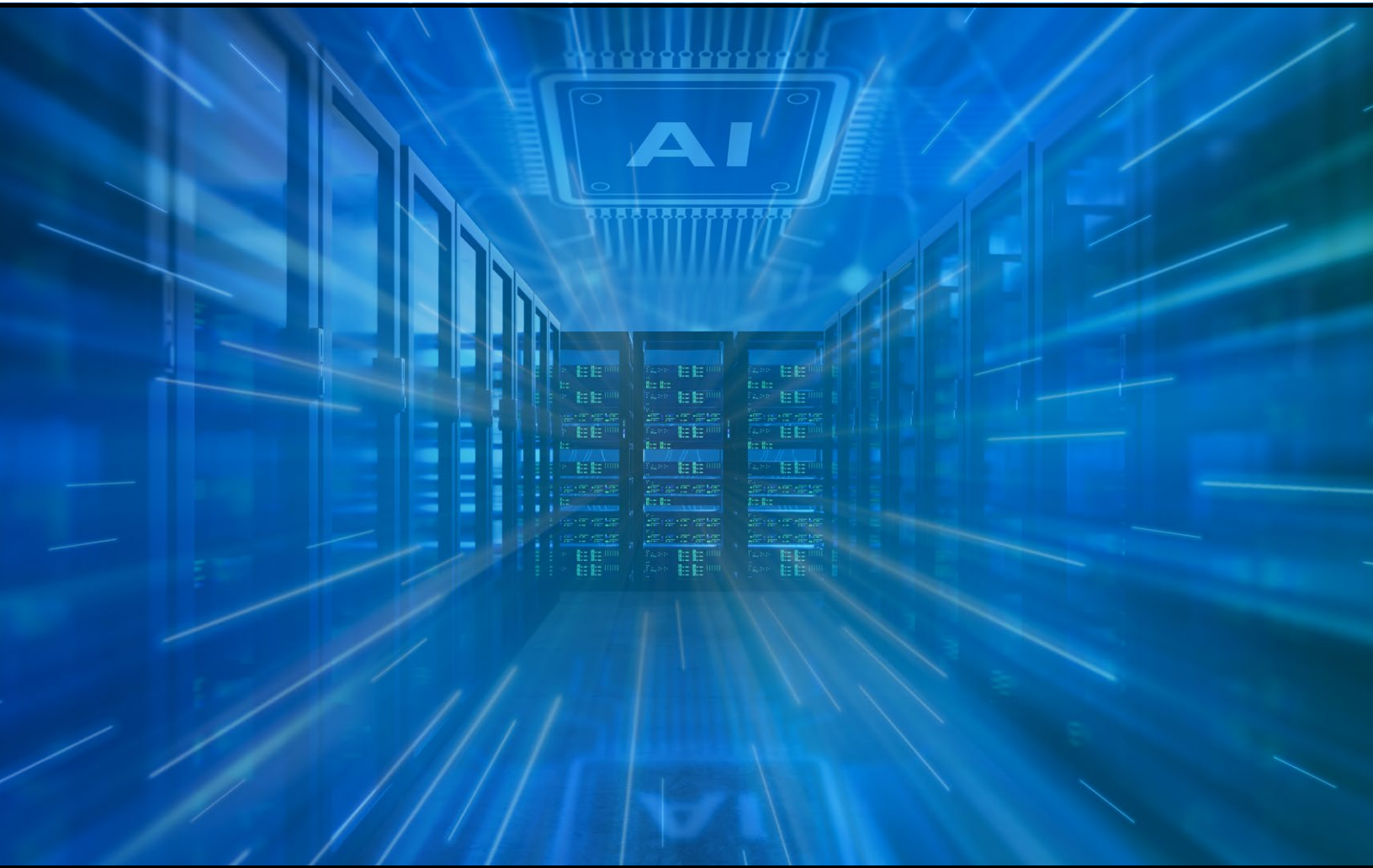




The seismic shift to shuffle

How fiber-optic shuffle and multiplane architectures are redefining tokenomics

AI factories need higher performance from flatter networks

Even for an AI data center industry characterized by rapid evolution, the growing importance of shuffle architecture is a game-changing development that's flattening network design complexity and improving the efficiency of token generation. It's much more than just a buzzword; shuffle architecture has already changed the way hyperscale AI factories operate—and it's not through yet.

What is fiber-optic shuffling?

Fiber-optic shuffle (sometimes confused with cable-level “mesh”) architecture unlocks a new level of switch port density, reduces network congestion and increases reliability of expanding GPU clusters to both boost bandwidth and reduce network latency. Shuffle enables higher switching capacities at the network layers by dynamically distributing traffic across multiple physical paths embedded into multiple discrete switching planes.

Most common transceivers use parallel fiber pairs to achieve higher effective speeds, such as 400G performance yield from four parallel 100G channels, or 800G via four 200G channels. Parallel optics is a common method of boosting speed because it is less expensive than achieving it via four discrete wavelengths on a single channel. This multi-fiber approach is what makes shuffling possible. Instead of connecting all of the optical lanes from a single GPU port to a single switch port in a single fabric—as is found in a traditional leaf-and-spine architecture—optical lane shuffling distributes each pair of the transmit and receive lanes from a single GPU port across multiple leaf switches in multiple switched planes. Since a single switched port at the leaf layer is no longer dedicated to a single GPU port at the node, higher GPU count clusters can be enabled with just two tiers of switching, avoiding the latency penalties that can come from a three-tier model.

Why is shuffle so important to AI data centers today?

Shuffle enables multiplane networks that can support two, four or even eight times as many GPUs as single plane networks without adding a third switching tier. Because it splits network traffic across multiple parallel network planes, multiplaning helps maximize token generation and time to first token (TTFT) by making the network more efficient and robust. By breaking out physical switch ports into multiple lanes, the number of GPUs that are (partially) connected to those ports is multiplied (e.g., breaking out 800G into 4x200G). Every switch port can now be connected to a lane of four different GPUs, and every GPU can now be connected to four different switches. This provides path redundancy and enables the connection of four times as many GPUs to a single switch—effectively quadrupling the number of deployable GPUs.

Shuffle-enabled multiplane networks have significant advantages in latency, scalability and efficiency, and their built-in multipath redundancy even improves network resiliency against costly network bottlenecks or downtime. Together, these operational advantages effectively redefine token economics—tokenomics—by redefining the time cost to receive, process and deliver those tokens.

While implementing shuffle architecture can increase network complexity, the right solutions can reduce the impact of the increased number of connections through the thoughtful use of high-density connectors and breakout harnesses to reduce physical clutter. At the same time, shuffle also reduces the number of switches required and provides built-in resilience against installation errors and fiber damage, allowing three channels to operate normally even if a fourth is unavailable. This is important for large AI clusters with very limited service windows.

What are the different kinds of multiplane architecture?

The most common multiplane architectures (dual plane, four plane, and octal plane) use 2x2, 4x4 and, most recently, 8x8 fiber shuffling. They operate similarly, with the choice being determined by whether port density or bandwidth is the most important priority. There are corresponding shuffle solutions that enable each kind.

- **8x8 shuffle** redistributes pairs of fibers across eight different MPO connectors, maximizing port density in multi-ASIC switch architectures and allowing each GPU to be broken out across

4 plane – 400Gb at a GPU port, 400Gb at a switch port

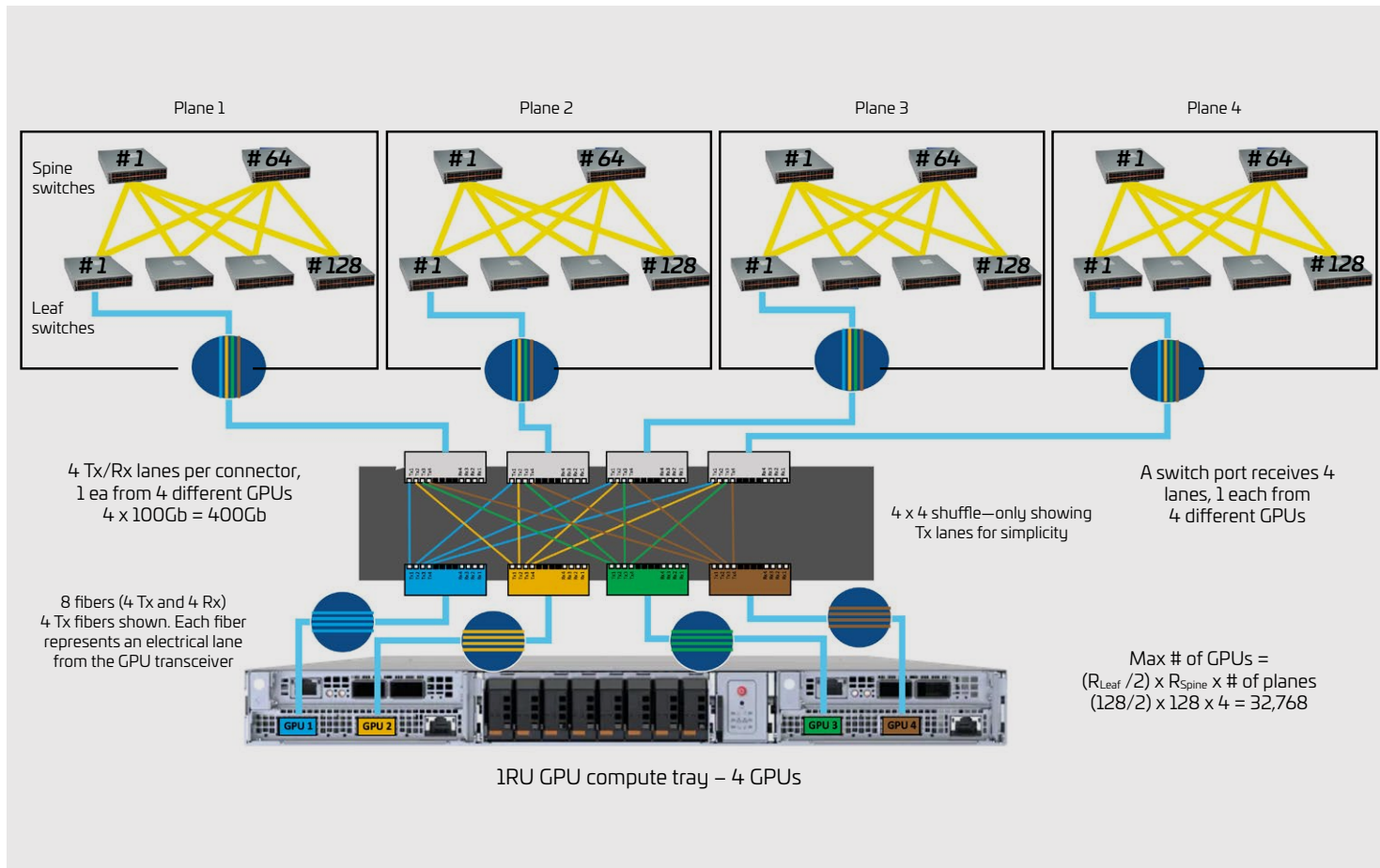


Figure 1: 4x4 shuffle architecture

eight planes to support 800G/1.6T network speeds. There are also high-speed transceivers that use eight pairs of fiber to open the door to eight-plane architectures, as is the case for the 800GDR8 transceiver using 8x100G lanes, as well as the newer 1.6TB transceivers using 8x200G lanes.

- **4x4 shuffle** redistributes pairs of fibers across four different MPO connectors. In Figure 1, 400G Ethernet is shuffled to four switches, delivering 100G to each of four switches in four different planes. With the arrival of 200G lanes, the same relationship holds true for 800G Ethernet, and for 400G lanes to achieve 1.6T.

- **2x2 shuffle** is similar, but it distributes two fiber pairs across two MPO connectors to support a two-plane architecture instead of four-plane, which enables enterprise or smaller AI inference loads to operate sufficiently while reducing the required space, power and upfront cost.

What technologies enable shuffle architecture?

Because shuffling can be accomplished in different parts of network infrastructure, the solutions that enable it can also vary. These include shuffle cables, shuffle modules or shuffle panels. The best choice of solution will be driven by the architectural or application requirements of the AI network being deployed.

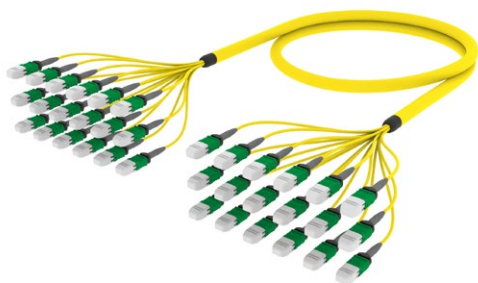
CommScope shuffle solutions

CommScope's shuffle-enabling offerings include a number of solutions that enable shuffle in a cable assembly, via dedicated modules or even in a box or panel configuration.

Multi-shuffle cable assemblies.

CommScope can construct shuffle-enabling cable assemblies to meet specifications for shuffle within the fiber fabric, including:

- Cable type (singlemode or multimode)
- Connector type (MPO12/8, MPO16, including push-pull option; pinned or unpinned; MMC16)
- Fiber count (16 for 2x2 shuffle with two MPO12/8; 32 for 4x4; or 128 for 8x8 using MPO16)
- Shuffle option (2x2, 4x4 or 8x8)
- Cable length, breakout structure and labeling to simplify installation and reduce opportunities for error



CommScope MPO-connector shuffle cable

Single-shuffle cables and patch cords.

These solutions enable additions and changes as needed, one shuffle at a time, without impact to other shuffle cables.

Shuffle modules.

CommScope's Propel® shuffle modules enable the addition of more modules as needed, without disrupting the operation of other installed modules. Cassettes are available for 2x2, 4x4 and 8x8 shuffles. A single module can hold one or more circuits, depending on port count. Modules fit in standard Propel panels (front and rear access) or Propel XFrame™ panels (front access).



CommScope Propel 4x4 shuffle module (left) and 2x2 shuffle module (right)

Propel panels.

These high-density solutions provide a modular design for use with Propel modules and pass-through adapter packs.



Scale, evolve and win with CommScope

Shuffle architecture is a revolutionary development in the design of AI factories as well as in the latency costs of tokenomics. CommScope is proud to partner with data center operators worldwide to offer these and other state-of-the-art fiber infrastructure solutions.

To see how we can help your data center scale, evolve and win, reach out to your CommScope representative. You can locate your representative [here](#).



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