**2DLink**
**A Post-SerDes, Spatially Interleaved Communication Architecture**

## Executive Summary

Modern communication systems assume that bandwidth must scale through higher signaling speed and temporal serialization. This assumption shaped SerDes, optical links, and system packaging for decades. However, device physics, packaging density, and optical transport have evolved to a point where this assumption is no longer required.

2DLink is a spatially interleaved, geometry-preserving communication architecture that expresses bandwidth through spatial parallelism rather than temporal acceleration. By removing the requirement for serialization, clock recovery, and high-speed analog front-ends, 2DLink repositions communication as a fabric property rather than a specialized subsystem.

The architecture follows directly from first principles of optics and device physics. It does not rely on new materials or speculative devices. Instead, it emerges from removing inherited constraints that no longer align with physical reality.

## On Practicality

While 2DLink represents a departure from traditional serial interconnects, it is intentionally engineered to reduce—not increase—system complexity. By replacing high-speed temporal serialization with dense spatial signaling, 2DLink eliminates the most fragile elements of modern links while operating within existing packaging, optical, and system constraints. Adoption does not require a wholesale redesign of system fabrics; 2DLink can be introduced selectively as a turnkey advancement where bandwidth density and determinism are limiting factors.

## 1. Why Temporal Serialization Became the Bottleneck

Serializer–Deserializer (SerDes) architectures emerged when pin count was limited and spatial resources were scarce. Bandwidth scaled by increasing per-lane speed, which required progressively complex equalization, clock recovery, and calibration.

As systems scaled, this optimization became an architectural constraint. Power scales superlinearly with signaling rate. Analog front-ends dominate area and energy. Calibration and bring-up complexity grows with lane count. Packaging and layout are dictated by signal integrity rather than system goals.

Optical links improved reach and loss, but largely preserved the same abstraction: serialization, clock recovery, and lane management were retained, simply externalized.

At modern system densities, the SerDes stack is no longer limited by implementation quality, but by representation. It forces inherently spatial systems to collapse information into time, only to reconstruct it later at high cost.

## 2. Reframing Bandwidth as a Spatial Quantity

Dense emitter arrays and advanced packaging make spatial resources abundant. When aggregate bandwidth is expressed as the sum of many modest-speed channels rather than a few extreme-speed lanes, the system trade space changes fundamentally.

Aggregate throughput scales with emitter count, not speed. Per-channel rates can be orders of magnitude lower. Timing margins relax. Power and complexity collapse.

Spatial interleaving is not optional. In dense arrays, adjacent emitters cannot fire simultaneously without interference. This physical constraint naturally enforces interleaving patterns that distribute communication across space and time deterministically.

Once this reframing occurs, high-speed temporal serialization ceases to be a requirement.

## 3. Defining the 2DLink Primitive

We refer to this class of spatially interleaved, geometry-preserving link architectures as 2DLink.

2DLink is defined not by signaling rate, modulation format, or medium, but by the absence of requirements that dominate temporally serialized links. There is no mandatory serialization of spatial information, no per-lane clock recovery, no high-speed analog front-ends, and no dynamic skew training.

Instead, 2DLink exists as a two-dimensional mapping between emitter and receiver arrays. Bandwidth is expressed through geometry. Timing is a system property.

### Architectural Context

To clarify how 2DLink relates to existing and emerging interconnect approaches, the table below contrasts architectural assumptions rather than implementations.

| Dimension | Copper Serial Links | Co-Packaged Optics (CPO) | 2DLink |
|---|---|---|---|
| Primary Abstraction | Time-domain serialization | Time-domain serialization | Spatial interleaving |
| Physical Medium | Copper | Optical (near-package) | Optical (geometry-preserving) |
| Role of Optics | N/A | Medium replacement | Geometry preservation |
| Topology | 1D point-to-point | 1D point-to-point | 2D planar fabric |

| | | | |
|---|---|---|---|
| Clock Recovery | Required | Required | Not required |
| Packetization | Required | Required | Not required |
| Energy Scaling | With speed | With speed & density | With spatial parallelism |
| Architectural Phase | Foundational (legacy) | Transitional | Post-SerDes primitive |

**4. Preserving Spatial Determinism Across Distance**

Once communication is expressed spatially, the transport medium must preserve geometry rather than channel identity.

Coherent, image-preserving optical transport maintains spatial adjacency and relative phase by construction. Geometry is preserved end-to-end without negotiation.

The transport medium becomes a passive spatial bridge rather than an active participant in communication.

**5. System-Level Implications**

Communication becomes infrastructure rather than a bottleneck. Compute is decoupled from extreme I/O constraints. Receiver density becomes feasible. The boundary between interconnect and memory blurs. System bring-up and operation simplify dramatically.

**6. Why 2DLink Is Post-SerDes**

2DLink does not replace SerDes; it follows it. SerDes remains valuable where temporal serialization is appropriate. However, once spatial density and optical transport favor geometry over speed, serialization ceases to be the dominant abstraction.

2DLink is post-SerDes because it aligns system representation with physical reality.

**Conclusion**

2DLink emerges not from inventing new physics, but from removing an assumption: that communication must be expressed primarily in time. When bandwidth is treated as a spatial property, the architecture follows inevitably.

**Author**

Eric Li is the founder of PhotonWeave and the architect behind the 2DLink and spatially interleaved optical fabric concepts. His work focuses on rethinking system interconnects from first principles of physics, optics, and device scaling, with the goal of removing legacy abstractions that no longer align with modern compute, packaging, and optical technologies.