IETF CCAMP · ROUTED OPTICAL NETWORKING

SRv6 DWDM P2P Integration

RON/POI Stack Collapse — IETF CCAMP, IPoDWDM, Flex-Algo Tiering, and Controllerless Optics

3	40–65%	0
Layers (from 5)	CapEx Reduction	Controllers (Opt. B)

This white paper examines the Routed Optical Networking (RON) and Packet-Optical Integration (POI) architecture endorsed by the IETF CCAMP working group — collapsing the IP-and-optical stack from five layers to three by mapping SRv6 uSID segments directly over coherent pluggable optics. It presents the full before/after architectural transition, Option A/B deployment models, the coherent IPoDWDM router-direct paradigm, Flex-Algo channel grouping, tiered network slicing over fiber, dark fiber and alien wavelength deployment, long-span amplitude tuning, legacy OTN coexistence, the case for eliminating standalone optical domain controllers, full coherent pluggable specifications, the two-phase validation methodology, and complete engagement pricing.

1. The IP/Optical Integration Imperative

Traditional optical architectures impose compounding cost layers on carrier metro and long-haul networks: grey optics ($15K–$40K per transponder chassis module), OTN (G.709) framing for multi-wavelength multiplexing, SONET/SDH for legacy TDM circuit compatibility, ROADM switching infrastructure for wavelength management, and centralized optical controllers (Cisco CNC, Ciena MCP, Nokia NSP) for provisioning. Coherent pluggable optics installed in IP router line card slots establish direct P2P DWDM wavelength channels between router pairs without any of this infrastructure. CapEx reduction: 40–65% on metro and regional P2P connectivity, validated in production deployments.

This is, at its core, a stack collapse: the conventional architecture stacks Application/IP, MPLS/RSVP-TE traffic engineering, OTN framing, SONET/SDH transport, and per-wavelength transponder hardware — five distinct layers, each with its own management plane, before a bit ever reaches the fiber. SRv6 uSID over coherent pluggables collapses this to three: the SRv6 uSID/IP layer, the coherent pluggable optical layer, and the fiber itself. The Routed Optical Networking (RON) and Packet-Optical Integration (POI) architectures formalizing this collapse are actively endorsed by the IETF CCAMP (Common Control and Measurement Plane) working group, the standards body responsible for control-plane interoperability between the IP and optical domains.

"Collapse your IP+Optical stack from 5 layers to 3 — no transponder, no OTN wrapper, no excuses."

40–65%	3	4	$0
CapEx Reduction	Layers (from 5)	Flex-Algo Planes	Controller Cost (Opt. B)

Stack collapse: Three of the five legacy layers — OTN, SONET/SDH, and the per-wavelength transponder — exist purely to manage the optical domain and contribute nothing to the IP forwarding decision itself. Removing them is not a simplification that trades away capability; it removes pure overhead.



Figure 1 (Before): Legacy Grey Optics — Per-Wavelength Transponder + OTN/SONET Stack

The before-state diagram above shows the full legacy stack in practice: every wavelength requires its own dedicated transponder module inside a chassis costing $200,000–$800,000, the OTN and SONET/SDH layers add rigid framing overhead with limited flexibility, ROADM hardware is required for any wavelength switching decision, and a centralized optical controller (Cisco CNC, Ciena MCP, or Nokia NSP) is mandatory simply to provision a new circuit.

2. Option A vs. Option B — Architecture Comparison

Two distinct deployment models exist depending on whether the operator needs dynamic wavelength reallocation (Option A) or values controllerless simplicity for fixed point-to-point capacity (Option B).

Dimension	Option A — ROADM Fat Pipe	Option B — Disaggregated λ Channels
Controller	CS-SR + PCE + Optical Controller (WSON/GMPLS) mandatory	None — controllerless. IS-IS/SR-PCE manage all TE
Network Slicing	Via CS-SR circuit-style policies — complex coordination	Native — one Flex-Algo plane per λ (FA-128/129/130/131)
Bandwidth	Dynamic wavelength reallocation — max utilization	Fixed per-lambda capacity — simple, deterministic
CapEx vs OpEx	Controller licensing $200K–$800K/yr. Max BW efficiency	Zero controller cost. 40–65% capex reduction
Best For	Fiber-constrained routes needing max utilization	P2P metro/regional with fixed capacity needs

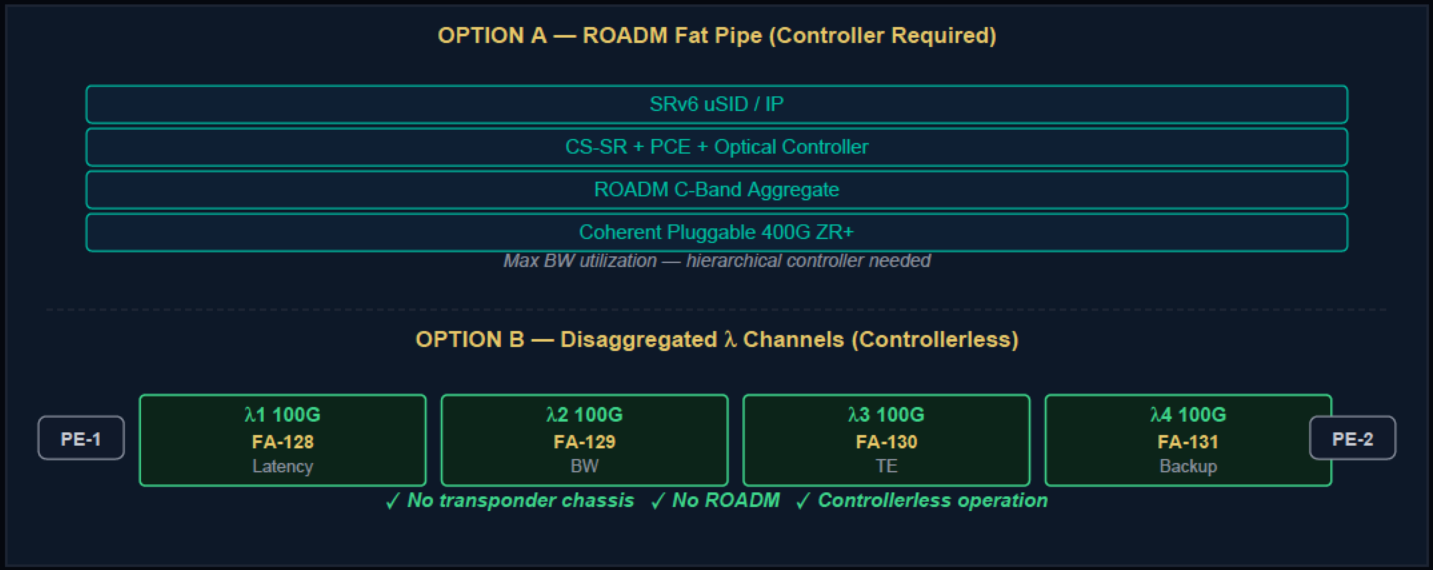


Figure 2 (After): POI P2P Coherent Pluggables — Option A (ROADM) vs Option B (Disaggregated λ)

Option A, shown in the upper half of Figure 2, stacks SRv6 uSID/IP directly atop a CS-SR (Circuit-Style Segment Routing) control plane combining a PCE IP controller with an optical controller, feeding a ROADM C-Band aggregate carried over 400G ZR+ coherent pluggables — Cisco CNC or the Huawei Hierarchical Controller are the two production-proven implementations of this hierarchical CS-SR + PCE + WSON Optical controller combination. Option B, shown in the lower half, dispenses with all of that: four discrete 100G wavelength channels, each running its own SRv6 Flex-Algo plane (FA-128 Latency, FA-129 BW, FA-130 TE, FA-131 Backup) directly between PE-1 and PE-2, with no transponder chassis, no ROADM, and no controller of any kind required.

3. The Coherent IPoDWDM Paradigm

Network operators have historically maintained two structurally separate infrastructure layers: an IP routing plane managed by network engineers and an optical transport (DWDM) plane managed by a distinct optical engineering discipline. This two-tier model is not simply an organizational artifact — it is a physical and financial cost structure, requiring arrays of short-reach gray optics on the router side, external transponder chassis on the optical side, and heavy mid-tier cabling connecting the two layers.

Direct Router-Based DWDM	High-power coherent optical transceivers (400G/800G ZR+) plug directly into standard routing line cards, eliminating the external transponder chassis layer entirely — the router line card is the DWDM endpoint.
Stateless Cross-Layer Sync	Standard SRv6 Flex-Algo manages physical wavelength path selection directly, removing the need for proprietary optical control software to keep the IP and optical layers synchronized.
Massive Cost Reclamation	Removing external optical transponder chassis directly reduces data center power consumption and physical rack space — capital and operating cost reductions that compound across every router pair in the network.

IMPACT: **Wavelength management becomes a routing console operation rather than a separate optical engineering discipline — the same engineer provisioning IS-IS and SRv6 SID policy is, by extension, provisioning the wavelength path the traffic rides on.**

4. Flex-Algo Channel Grouping vs. Fat-Pipe

Traditional optical transport relies on Fat-Pipe Aggregation: grouping diverse traffic types into a single, rigid optical wavelength passing through static ROADM channels. This treats all traffic identically — a low-latency financial transaction, a high-volume cloud backup, and standard internet traffic all compete for the same physical path, an inefficiency that becomes increasingly costly as spectral capacity itself becomes the scarce resource.

→ Application-Aware Wavelengths: Flex-Algo maps traffic to distinct optical channels based on real-time latency and path criteria — the wavelength selection itself becomes traffic-class-aware rather than uniform.

→ Granular Bandwidth Control: Fiber spectrum is segregated into purpose-built channels rather than one undifferentiated trunk — each Flex-Algo plane maps to its own spectral allocation.

→ Automated Load Management: Traffic redistributes onto clear frequencies automatically when a span degrades, without requiring a centralized optical controller to detect and orchestrate the move.

5. Gold, Silver, Bronze Network Slicing on Fiber

Maximizing infrastructure revenue increasingly requires operators to sell guaranteed, performance-tiered service classes rather than undifferentiated bandwidth. Implementing strict tiering over raw fiber using conventional methods typically means deploying a complex Layer 2 provisioning layer — labor-intensive to configure and just as labor-intensive to maintain as the service catalog evolves.

Tier	Path Behavior
Gold	Dynamically steered over the absolute lowest-latency, shortest-reach fiber spans via dedicated Flex-Algo metrics — the premium tier maps directly to the physically shortest available path.
Silver	Reliable, protection-mapped optical channels balancing distance against latency, full TI-LFA protection without the Gold tier's strict shortest-path constraint.
Bronze	High-volume, non-urgent transfers directed over high-capacity, longer-reach paths, maximizing cost efficiency for traffic with no latency sensitivity.

IMPACT: **Because tiering is expressed natively at the SRv6 Flex-Algo protocol layer — not bolted on through a separate provisioning system — the physical transport network itself becomes a directly monetizable, tiered business asset.**

6. Dark Fiber P2P POI for Data Sovereignty

Global financial enterprises and critical infrastructure operators with absolute data sovereignty requirements deploy dedicated P2P POI directly over private dark fiber. The conventional approach requires purchasing expensive, proprietary software suites from optical hardware manufacturers simply to control the underlying laser paths — a vendor lock-in risk layered on top of an already capital-intensive private fiber investment.

→ Direct Laser Management: Coherent transceivers plug straight into routing switches, driving raw dark fiber with no intermediate optical management layer required.

→ Eliminates Middle-Tier Software: Path protection is managed natively through SRv6 TI-LFA algorithms, removing the need for a complex, separate optical controller.

→ Absolute Protocol Privacy: Routing data remains entirely contained within private, unencapsulated IPv6 infrastructure — no intermediate protocol layer for potential interception.

7. Alien Wavelengths over Leased Lit Fiber

Expanding capacity across leased or pre-existing lit fiber systems traditionally forces operators into the fiber provider's own transponder equipment to light up new channels — an end-to-end optical service purchase that prevents the leasing operator's engineering team from controlling the wavelength paths they are paying for.

→ Direct Transceiver Transmission: Custom optical frequencies generated from standard coherent transceivers at the edge router, bypassing the provider's transponder requirement entirely.

→ Foreign System Interoperability: Custom wavelengths transmit safely across the third-party ROADM infrastructure without causing interference.

→ Instant Capacity Scale: New 400G/800G channels light up on leased fiber in minutes rather than waiting on the provider's internal provisioning cycle.

8. Long-Span Amplitude Tuning and Constellation Shaping

Connecting regional data centers over long-span fiber requires maximizing optical signal strength without introducing data-corrupting noise into the glass. As data speeds climb to 400G and 800G, signal degradation over extended distances typically forces the installation of expensive mid-point optical amplification sites at regular intervals along the route.

Dynamic Signal Shaping	Optical modulation parameters adjusted natively from the router OS to match exact fiber span conditions — constellation shaping tuned in software rather than fixed at manufacture time.

Extended Amplification	Transmit power boosted directly from the line card pluggable, allowing high-capacity signals to traverse longer distances without midpoint regenerator sites.
Spectral Optimization	Data throughput maximized over long spans while maintaining signal clarity across deep regional routes, extending router-direct optics into long-haul territory.

9. Spectral Alignment for Coexistence with Legacy OTN

Operators migrating toward packet-optical architectures rarely have the luxury of empty fiber — next-generation high-speed wavelengths must typically be deployed alongside legacy OTN frequencies inside the same active fiber bundle. High-power 400G/800G coherent signals generate wide spectral footprints that can bleed into adjacent channels, creating noise capable of disrupting existing legacy client services the operator cannot afford to take down for the migration.

> **Why this matters:** Granular grid allocation maps modern wavelengths onto strict, non-overlapping grids directly adjacent to active legacy OTN frequencies — automated laser power shaping prevents high-speed channels from overwhelming sensitive legacy transponders, while SRv6 wraps and routes both generations identically. This is the migration-path complement to every other section: a clean-slate fiber plant is not required to begin adoption.

10. Coherent Signaling Packaging

The full realization of the router-direct DWDM model requires packaging the entire digital signal processing engine inside a small, hot-pluggable optical transceiver module — moving away from large, proprietary transponder shelves that have historically packaged and modulated the light signal as a separate piece of hardware management overhead.

→ Integrated DSP Tracking: The router OS directly controls and monitors chromatic dispersion and signal-to-noise ratio, without a separate optical management plane.

→ Unified Control Automation: Laser configuration is integrated directly into standard network automation code.

→ Wire-Speed Packet Mapping: IP packets feed directly from the switching ASIC into the coherent optical stream, minimizing transponder-hop processing delay.

11. Eliminating Standalone Optical Domain Controllers

Traditional POI architectures require a heavy software layer: a separate, expensive Optical Domain Controller that must continuously synchronize with an IP Network Controller across complex, cross-vendor APIs. This multi-tiered software stack is notoriously fragile — an API update from a single hardware vendor can disrupt cross-layer communication and stall automated traffic engineering, sometimes for the duration of an extended outage.

Single-Engine Routing Logic	Topology calculated by one protocol engine running natively inside the routers — no cross-controller API bottleneck, no second control system to keep synchronized.
Direct Layer-3 Visibility	Routers have complete visibility into fiber path conditions, enabling instantaneous path re-computation without waiting on a separate optical controller's telemetry cycle.
Pure Code-Driven Automation	Optical changes and path protection execute through standard network automation tooling — a single toolchain instead of two.

12. Coherent Pluggable Technical Specifications

Standard	Spec
400ZR (OIF)	400Gbps, QPSK, -18dBm sensitivity, 80km unamplified. CMIS 5.0 mgmt via gNMI/YANG.
OpenZR+ (MSA)	400Gbps adaptive (DP-16QAM–DP-QPSK), up to 1,200km with EDFA. Metro-to-regional.
800G ZR	800Gbps DP-64QAM, sub-80km, QSFP-DD/OSFP. Doubles 400ZR capacity on same fiber pair.
OSNR Budget	> 18dB required for 400ZR at 80km. Q-factor crossing triggers automated TI-LFA backup.
TI-LFA Protection	RFC 8355: sub-50ms local repair, pre-installed backup segment list, proactive activation.
POI Control Plane	PCEP-based PCE with TE optical topology abstraction. BGP-LS advertisements of optical link parameters into the IP TE database.

13. Two-Phase Validation Methodology

Phase I — Virtual Containerlab

Multi-vendor topology (Cisco cEOS, Nokia SR Linux, FRRouting, vJunos) on bare-metal Ubuntu. Automated Q-factor/BER degradation injection, TI-LFA < 50ms convergence, H.Encap/H.Insert benchmarks, BGP-LS/PCEP verification.

CI/CD pipeline handed off as a self-service sandbox the customer's own engineering team can continue exercising after the engagement concludes. Deliverable: topology-as-code repo, benchmark report, runbook.

Phase II — Physical Customer Site

Principal architect on-site against physical coherent routers and live fiber. Optical power budget, OSNR/pre-FEC BER baseline, wavelength alignment, SRv6 uSID policy via IaC — zero CLI deviation from the Phase I validated configuration. Live fiber-pull TI-LFA test with telemetry-verified sub-50ms recovery. Deliverable: Hardware

Commissioning Report + Grafana telemetry stack.

14. Pricing and Engagement Terms

Phase II on-site cost breakdown: Principal Architect at $3,500/day × 5 days (commissioning through NOC handoff) = $17,500, with additional days available at the same rate under SOW amendment. Travel and logistics are billed at actuals with a pre-approved cap, typically $1,500–$2,500 depending on site. The combined Phase I + II bundle is offered as a fixed fee of $45,000–$55,000, covering both phases, all deliverables, and 30 days of post-deployment hypercare support.

Base Engineering Fee	$30,000 — Phase I architecture design and Containerlab digital twin setup.
Scale Modifier	$250 per Optical Node. Phase II on-site: $3,500/day + travel actuals.
Phase I + II Bundle	$45,000–$55,000 fixed, including 30 days post-deployment hypercare.
10 Nodes	$30,000 + $2,500 = $32,500
25 Nodes	$30,000 + $6,250 = $36,250
50 Nodes	$30,000 + $12,500 = $42,500

White Paper Summary — SRv6 uSID Technology Conclusion

The router-direct coherent IPoDWDM paradigm completes the architectural thesis this white paper presents: the two-tier IP-and-optical model that has defined carrier transport for decades is not a permanent feature of networking — it is a historical artifact of an era when DSP processing required a standalone transponder chassis. Endorsed by the IETF CCAMP working group, the RON/POI five-to-three layer stack collapse shown in Figures 1 and 2 is now achievable with production-grade coherent pluggables and a choice between Option A's maximum bandwidth utilization or Option B's controllerless operational simplicity.

Every capability examined beyond the core architecture — Flex-Algo channel grouping, tiered Gold/Silver/Bronze slicing, dark fiber sovereignty, alien wavelengths on leased fiber, long-span amplitude tuning, and legacy OTN coexistence — resolves to the same underlying architectural decision already established in Option B: SRv6 Flex-Algo treats wavelength selection, spectral allocation, and service tiering as routable constraints expressed in the same protocol layer that already governs terrestrial IP traffic engineering.

Eliminating the standalone optical domain controller is the logical endpoint of this architecture, validated through the two-phase methodology: a virtual Containerlab digital twin proving the design before any hardware is touched, followed by physical on-site commissioning delivering a Hardware Commissioning Report and live Grafana telemetry. The IP and optical layers have not merely been integrated — they have become the same operationally managed layer, at the fixed engagement economics detailed above.

Ready to Collapse Your IP/Optical Stack?

SRv6 TEK Innovations provides hardware breakpoint audits, Phase I/II migration planning, and digital-twin validation for your specific DWDM platform inventory.

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