Building the Next-Generation Optical Networks

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what THE NETWORK will be

The Landscape Is Being Transformed Radically

Network demand will be heavily skewed

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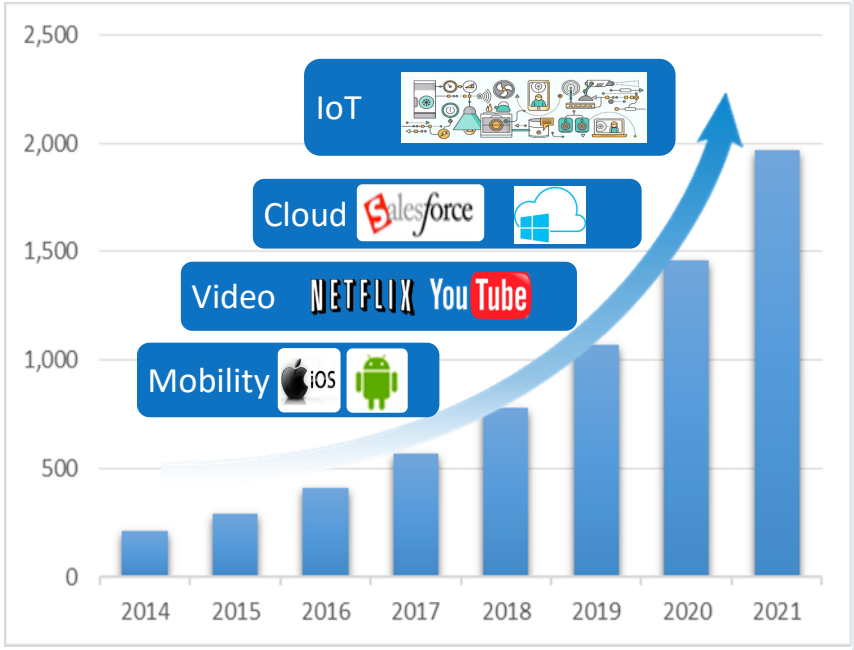
Internet Of Things (IoT) & 5G Wireless Explosion

Total Bandwidth Usage (Tbps)



Source: TeleGeography Global Bandwidth Forecast Q3 2015

Mobility in 2020

- 11.6B mobile devices…Exceeds world population
- 30+ exabytes per month
- 75% of traffic will be video

Internet of Things in 2019

- 24B networked devices globally
- 42.5 Mbps = Global avg fixed broadband speed…double of 2014

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Cloud Technology Intersects New Business Dynamics

Business agility driving infrastructure change

70% of business cloud enabled by 2020, VZ to auction DCs

Massive shift in bandwidth drivers

62% Internet traffic on CDN by 2019 (38% in 2014), Subsea ↑

145+ data centers, $8B invested capital

100+ data centers, $15B invested capital

Source: Ovum, Cisco, Equinix, Microsoft

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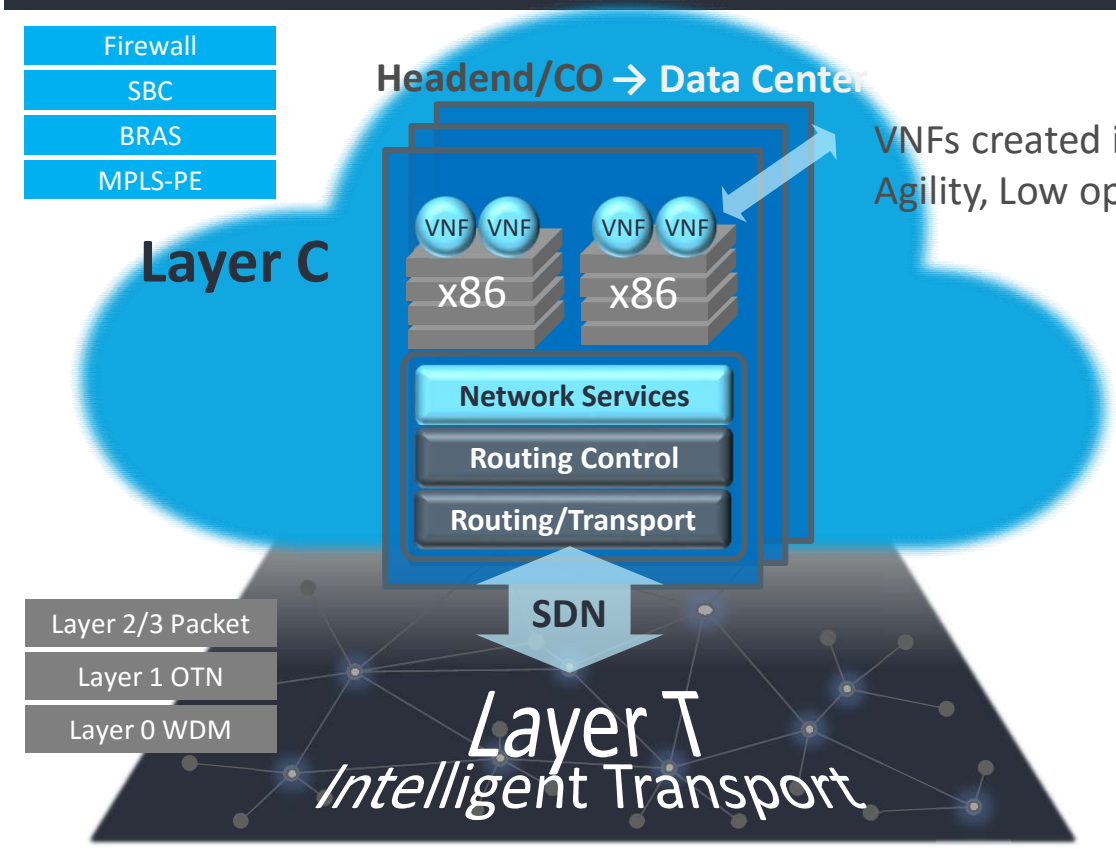
The Shift to a Layer **C** and Layer **T** Network Model



VNFs created in/moved to other COs
Agility, Low opex, New traffic patterns

Large Operator Views

Tom Tofigh, AT&T. Oct 2014

~5% network virtualized @ 2015	75% of network virtualized by 2020

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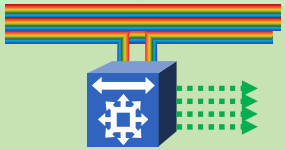
Building the Best Layer T (Intelligent Transport)

Programmable and Agile → SDN Control
Abstracted, Open APIs

SDN-Virtualized Optical

Flexible Granular Control → Across Layers
Lean Packet, Digital, Optical



Packet, OTN & ROADM Switching

Scalable Optics → Super-channels, Coherent Detection
Programmable Modulation
Photonic Integration as Foundation

Photonic Integration

Scalable Optics: Foundation for an Intelligent Layer T

FlexCoherent Modulation 2.4Tbps Widely Tunable & Sliceable

Photonics
Large Scale PIC

+

Electronics
FlexCoherent™ DSP/ASIC

=

Infinite Capacity Engine Architecture

100G…200G….500G….1.2T….2.4T….

Important Note: Requires **Advanced Optical Tools (ACT)** to maximize fiber investment….

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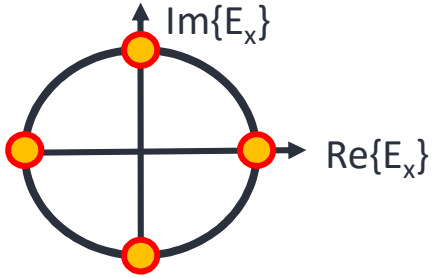
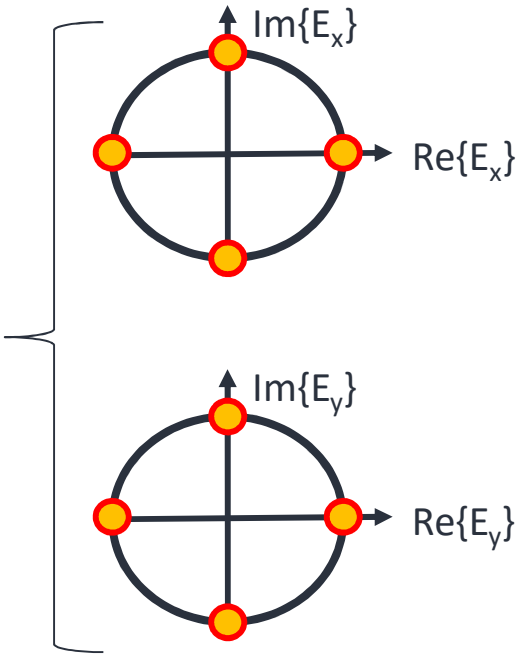
Tool 1: Support for Advanced Modulation

Polarization-Multiplexed Quadrature Phase-Shift-Keyed (PM-QPSK) Modulation

4 bits per symbol



4 phases = 2 bits per symbol



X-Polarization

Y-Polarization

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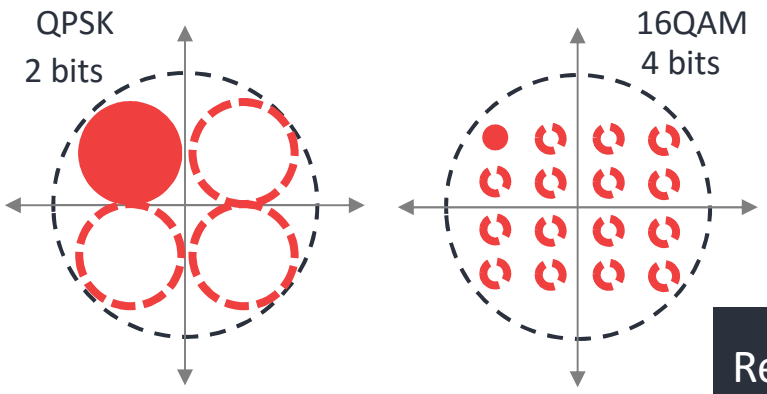
Higher Order Modulation

- Higher order modulation has “fewer photons per bit”, and requires higher symbol resolution



- A given symbol has the same absolute optical power limit, but 16QAM is carrying twice the number of bits
- The resolution between symbol states is much tighter for 16QAM

Result: 16QAM has 2X increase in spectral efficiency vs QPSK, But for shorter distances

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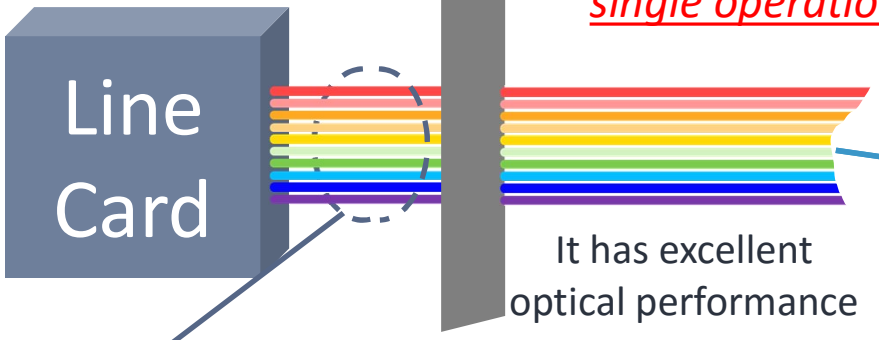
Tool 2: Support for Multi-terabit Super-channels

A super-channel implements multiple carriers - ideally in a single line card…

It's *practical* to build…



All carriers are provisioned in a *single operational cycle*…

It has excellent optical performance

Up to 2.4T Super-channel

BPSK, ME-PSK, 3QAM, QPSK, 8QAM, 16QAM

Up to 12000km

And is seen as a *single unit of capacity* by the services that use it

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Tool 3: Spectral Efficiency Controls

Infinera Advanced Coherent Toolkit (ACT)

- **Nyquist Subcarriers**
- **SD-FEC Gain Sharing**
- **ME-PSK modulation**
- **High Gain SD-FEC**
- **Flexible Channel Spacing**

Subsea

Capacity-Reach increase: BPSK → ME-PSK + 3QAM mix & Margin Q-value increase via SD-FEC enhancements

Regional/Metro

Move to higher-order modulation on existing fiber QPSK (1.2T) → 8QAM (1.8T), 50% increase

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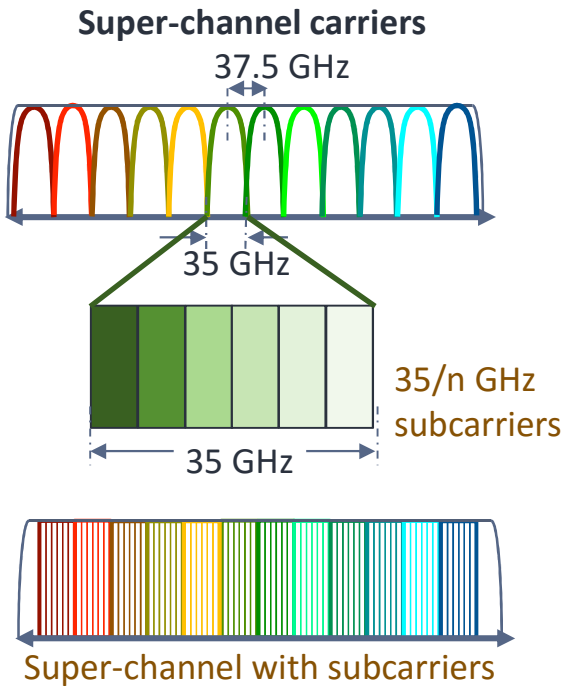
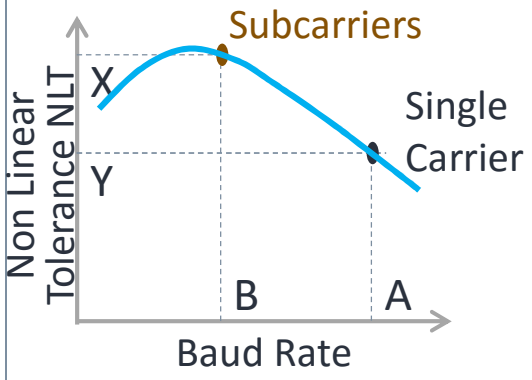
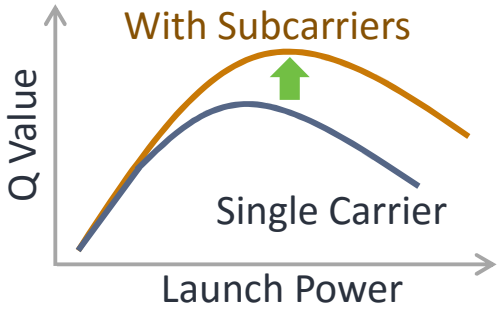
Nyquist Subcarriers

- Super-channel *carriers* are split into Nyquist *subcarriers*
- Lower baud rate of subcarriers increases tolerance to nonlinearities such as XPM
- Increased tolerance to nonlinearities results in increased reach







Increased overall fiber capacity and reach

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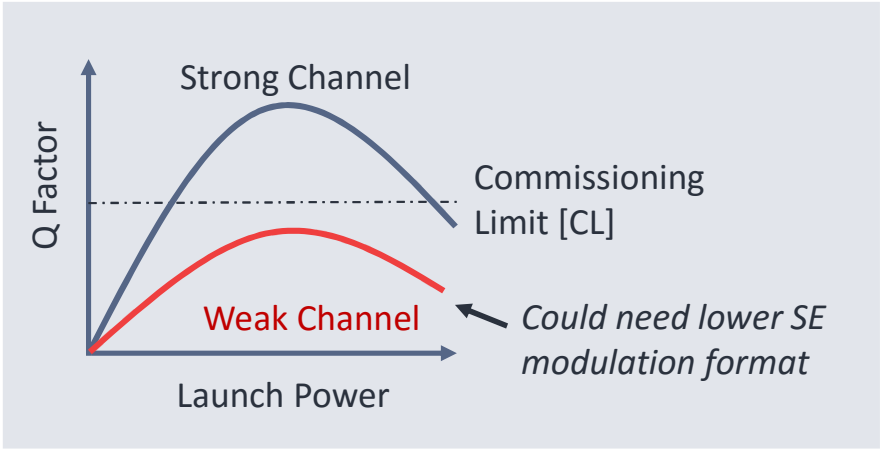
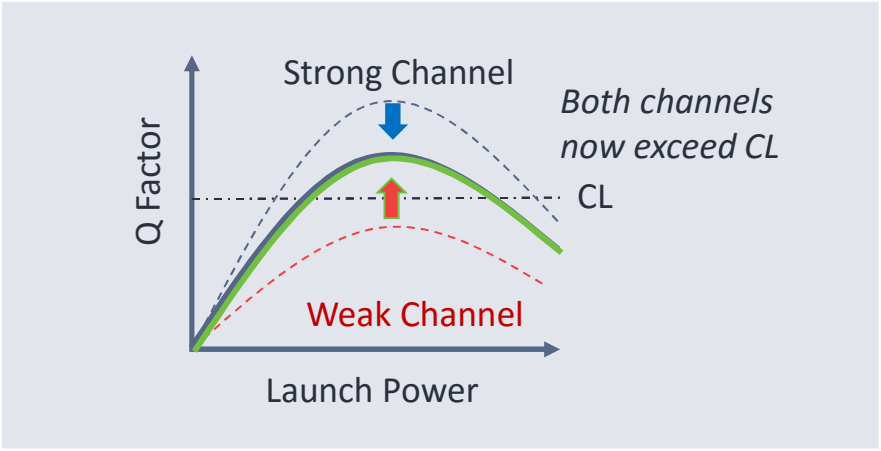
SD-FEC Gain Sharing





- Mitigates nonlinearities
- Enables use of higher order modulation format

Increased overall fiber capacity and reach

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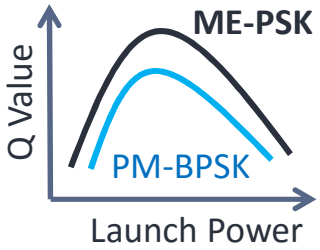
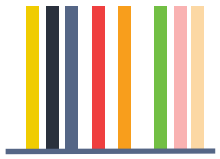
Other Must Have Coherent Technology Tools



- Matrix Enhanced - Phase Shift Keying (ME-PSK)
  - Enhancement to PM-BPSK (for subsea reach)
  - Enhanced coding techniques w/advanced constellation
  - Increased channel gain over PM-BPSK

- High Gain SD-FEC: Advanced algorithm for optimized SD-FEC gain, low latency or higher optical reach



- Flexible channel spacing: Granular spatial tuning
  - Applicable to carriers within, fraction or entire super-channel
  - Reduced impact of non-linear effects (XPM)

Maximizing available spectrum and boosting fiber capacity

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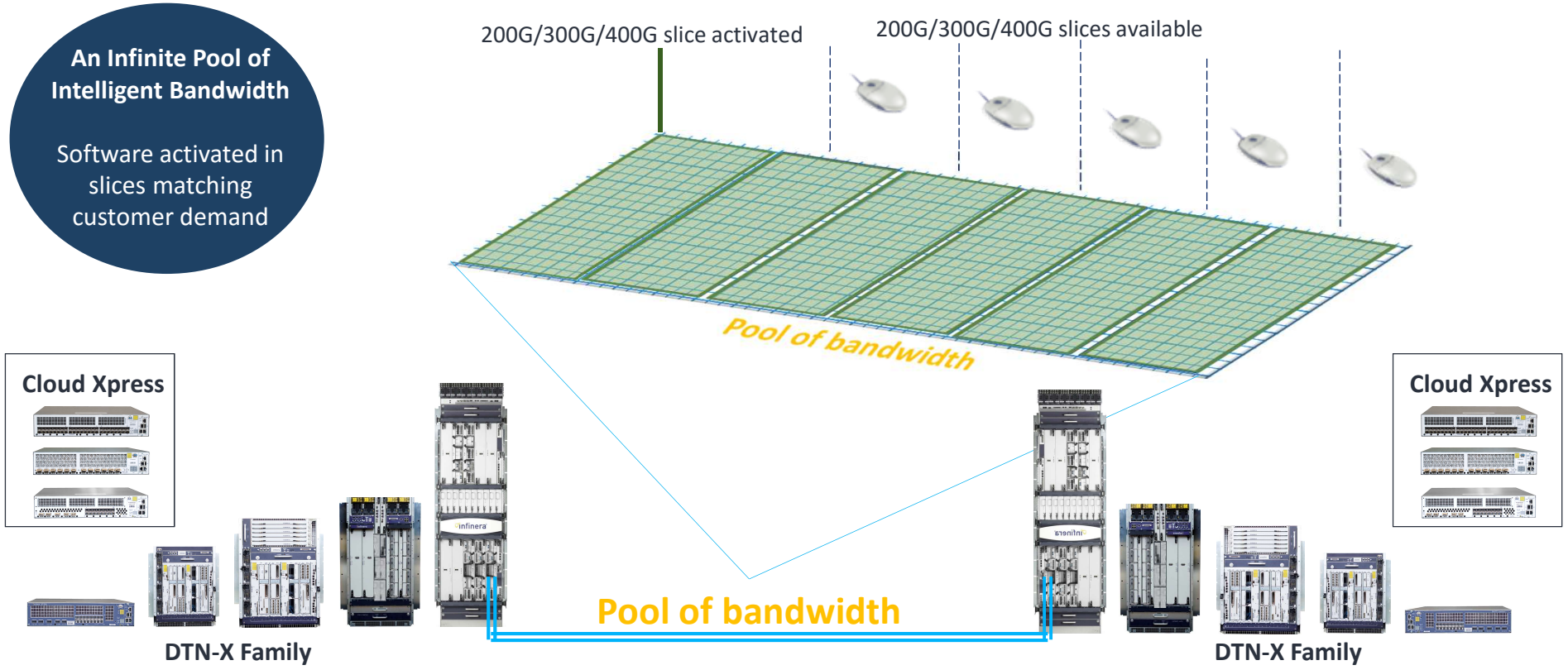
Ability to Dynamically Assign Bandwidth as needed

An Infinite Pool of Intelligent Bandwidth

Software activated in slices matching customer demand



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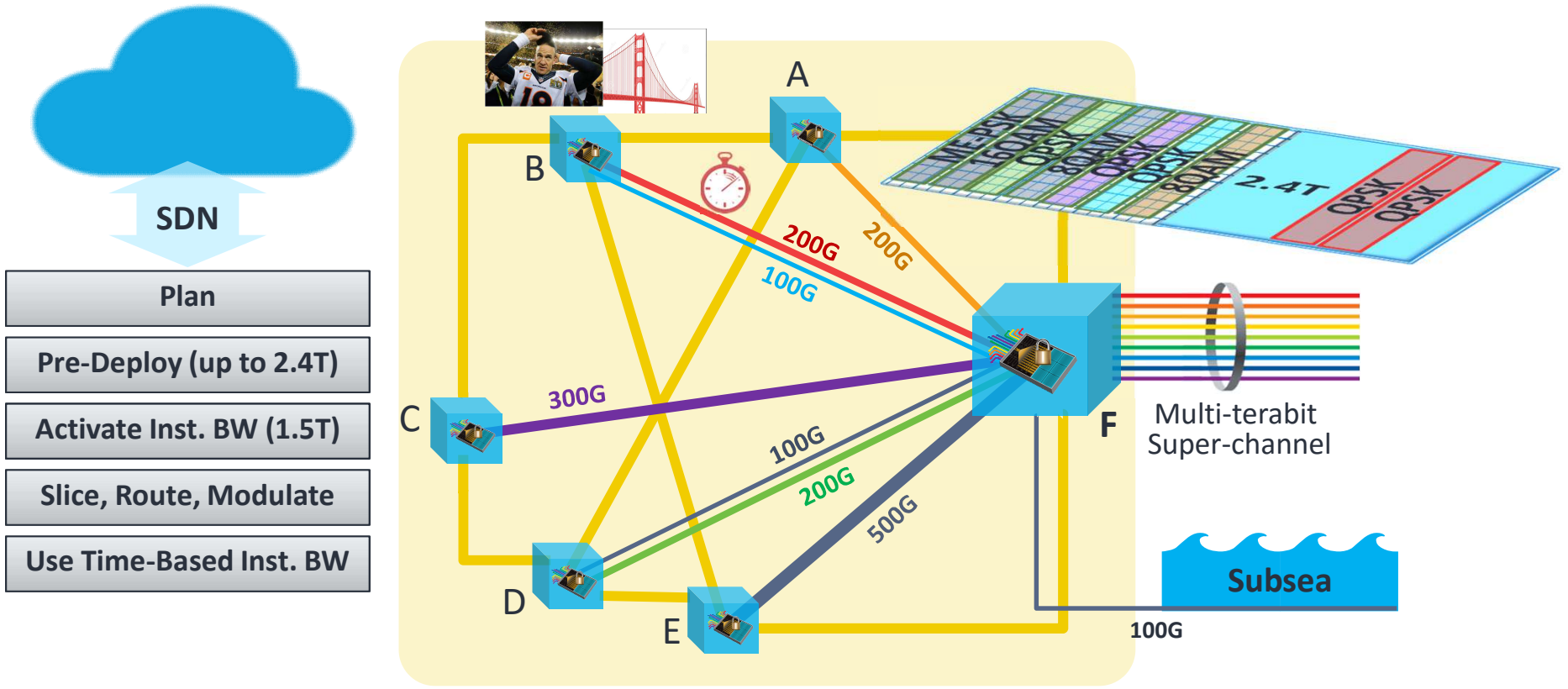
What the future of optics looks like: Scalable, Sliceable & Instant Bandwidth



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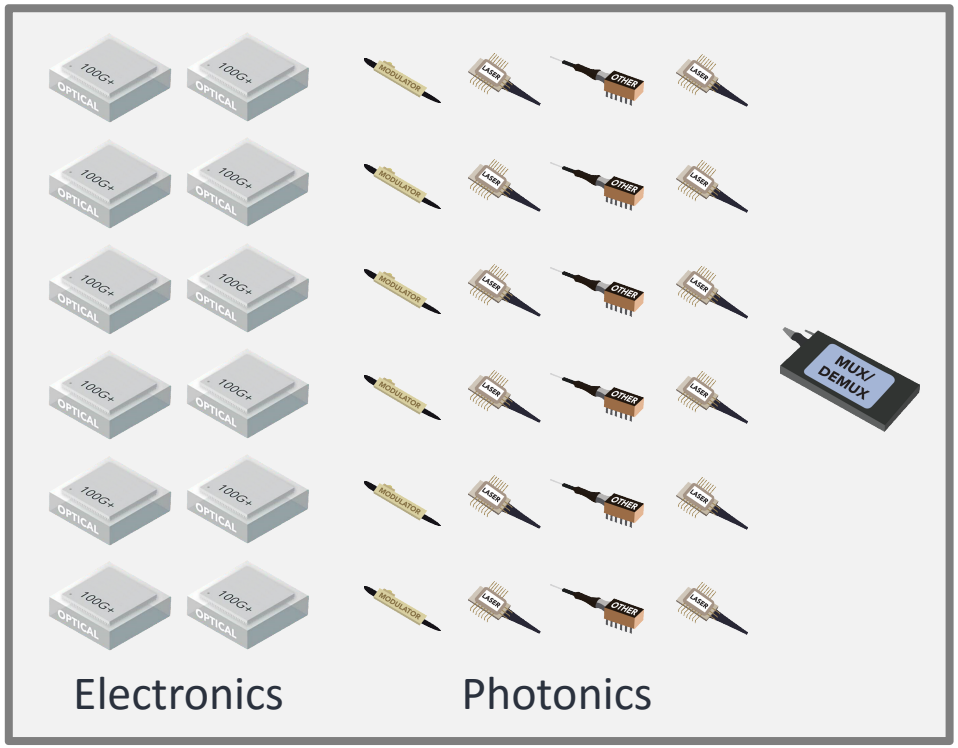
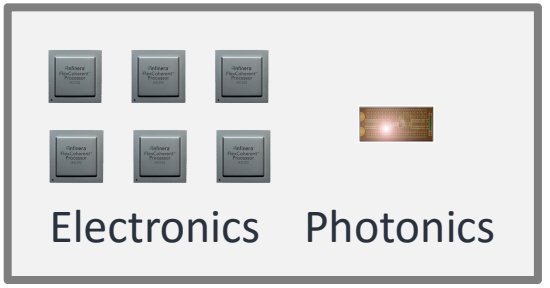
The Value of Photonic Integration

Without Photonic Integration



With Photonic Integration

Infinera Infinite Capacity Engine



Low Power

Comparable Subsystems for 1.2Tb/s

Comparable designs for Infinera and nearest competitor

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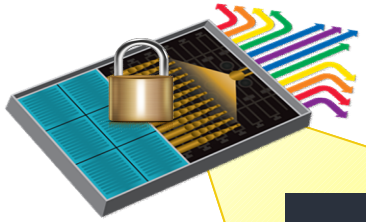
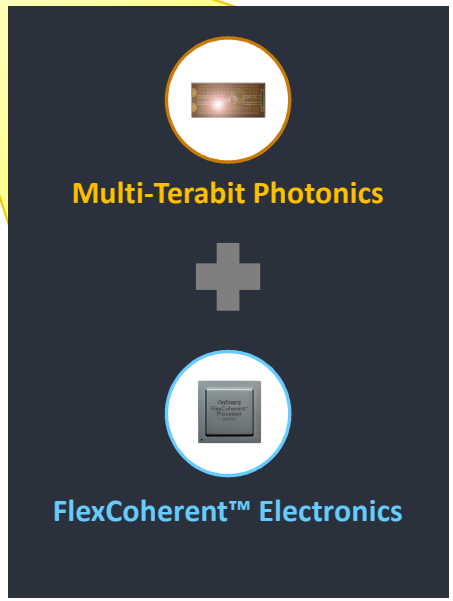
Foundational Technology Leadership: Quantum Leap to Terabits



Infinera Infinite Capacity Engine



- Up to 2.4T Super-channel
- Terabit L1 Encryption
- Low power
- Sliceable Photonics
- Nyquist Subcarriers
- C Band Tunability
- Lightning Tolerance
- SD-FEC Gain Sharing

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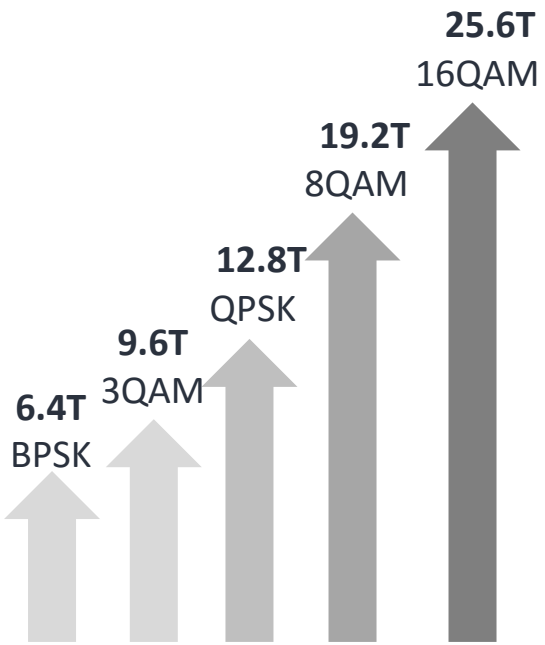
Benefits of Intelligent Layer T as a foundation

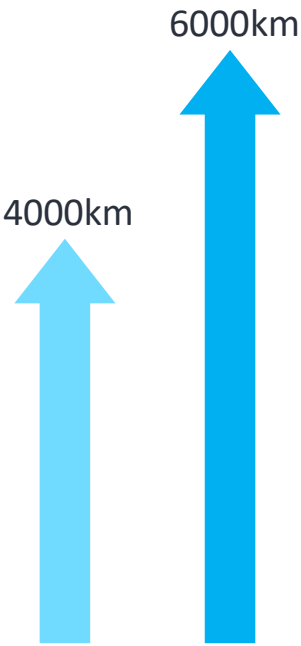
Infinite Capacity Engine

600G – 2.4T Sliceable

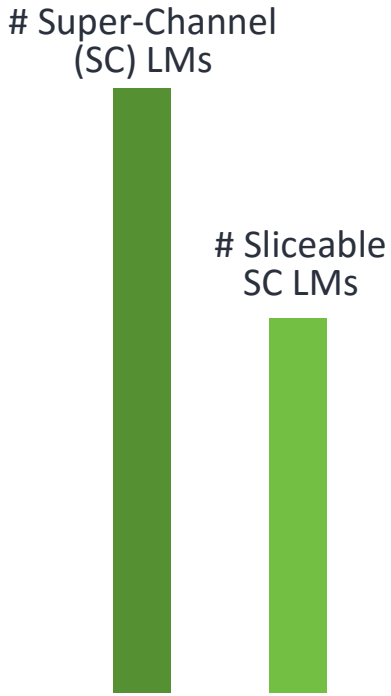
More Capacity



Longer Reach*



Better Economics



*Terrestrial QPSK Reach

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Conclusions

Shift in network architectures	• Networks are evolving to a Layer C and Layer T model • Scalable optics are essential to build the best layer T
Cloud revolution is here	• Cloud scale demands an Intelligent Layer T • We're evolving to Terabits everywhere
Innovation is paramount	• Emergence of advanced DWDM technologies • Photonic integration becomes more pervasive and, ultimately, mandatory

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Thank You

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