

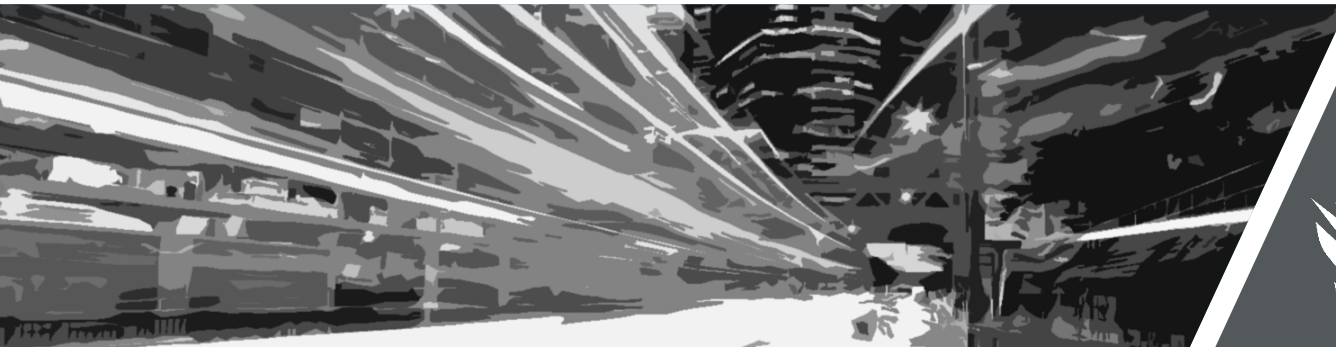


# TeraFlex™

Ultra Dense Open Terminal



April 2020



**NETWELL**



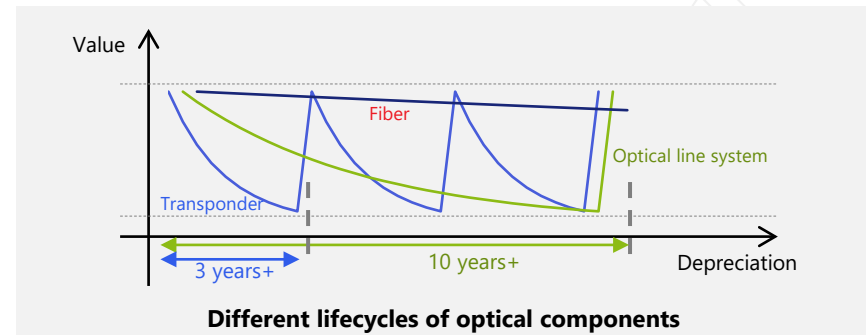
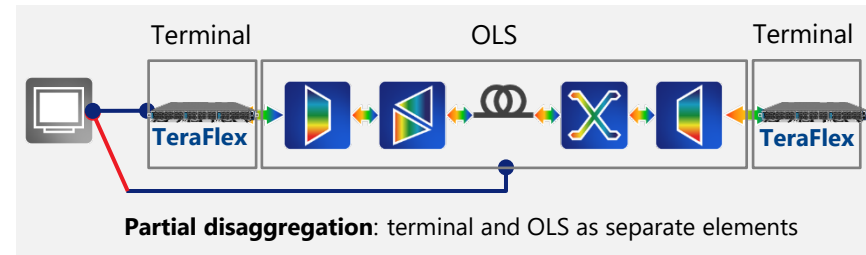
# Market Requirements

Disaggregation - Scalability - Flexibility

# Disaggregating networks with TeraFlex

## Disaggregation benefits

- Triggers innovation and evolution
- Accommodates different lifecycles
- Enables flexibility to deploy best-in-class equipment for all network needs
- Facilitates multi-vendor environments
- Avoids implementation lock-ins
- Integrates into open-source and commercial orchestration systems



TeraFlex provides the required flexibility for use in disaggregated networks

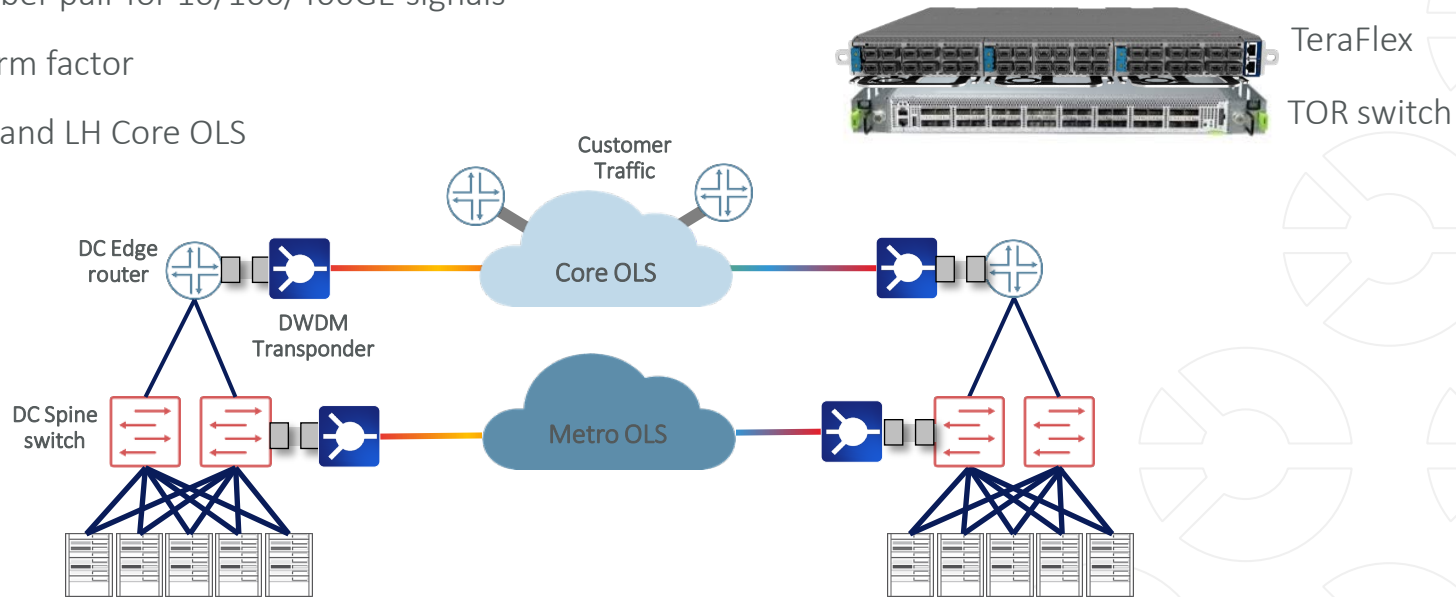
# DCI requires massive bandwidth

TeraFlex provides DCI scalability

Multiple 10Tb/s per fiber pair for 10/100/400GE signals

High density in DCI form factor

Simple Metro 100km and LH Core OLS

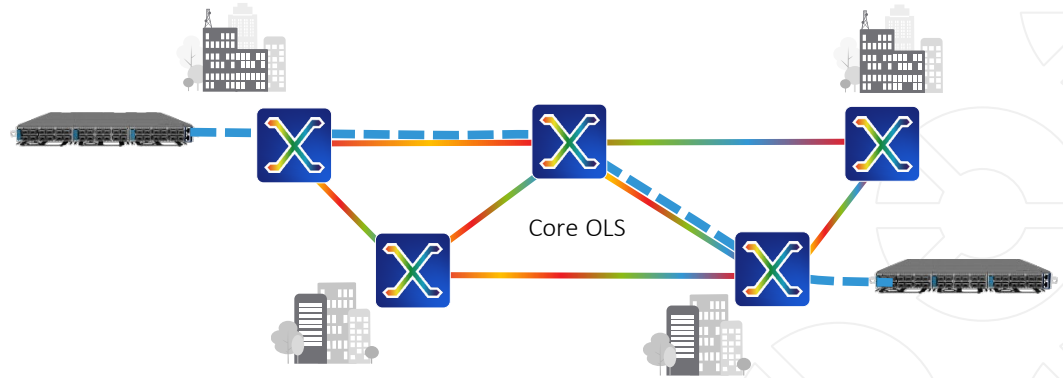


TeraFlex provides highest scalability at record density

# Core networks require flexibility

TeraFlex optimizes any optical path at any distance

- Path characteristics govern maximum capacity per channel/wavelength
- OLS filters and ROADMs may limit the signal passband
- TeraFlex interface is flexibly configurable – fine granular optimization maximizes capacity per optical interface
- Typically 200-400G per wavelength over LH distances



Integrated or disaggregated OLS and terminals

TeraFlex flexibility yields lowest cost per bit for any infrastructure



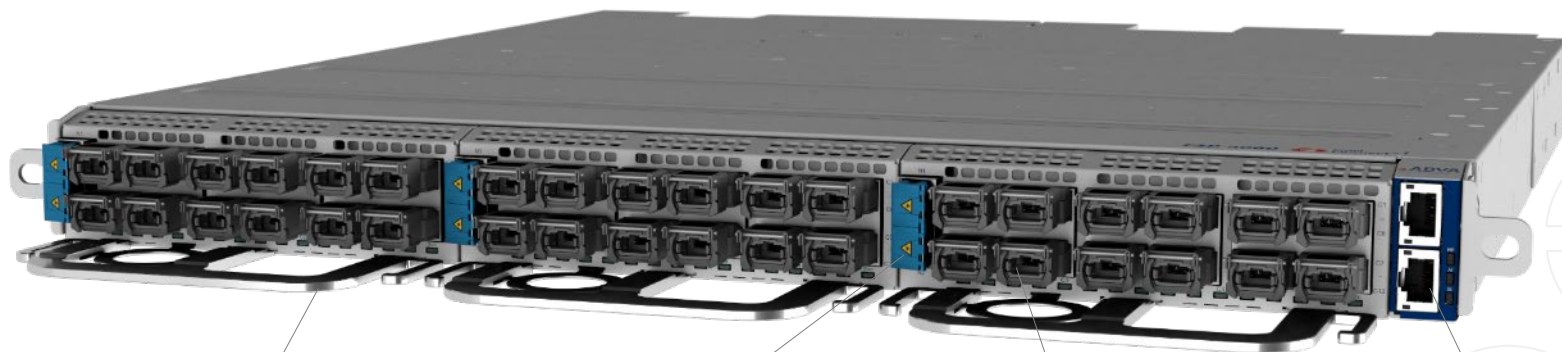
# TeraFlex™

Ultra dense Open Terminal



# 7 TeraFlex™

1RU platform supporting 3.6Tb/s



Ultra compact  
footprint

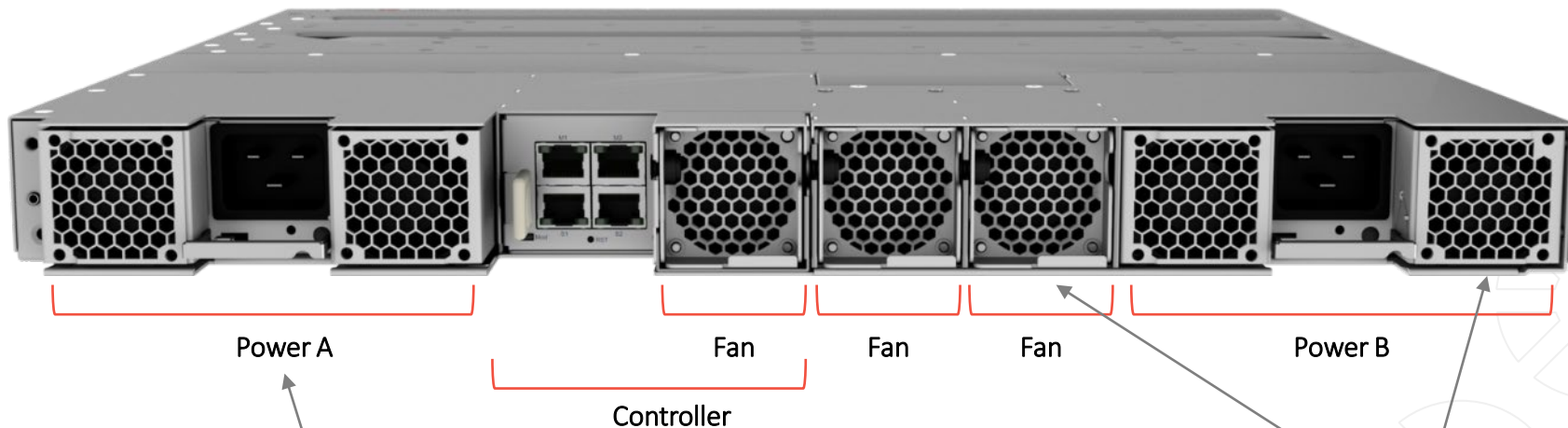
Ultra flexible  
network interfaces

High speed clients  
10/100/400GE, OTU4

Open API design

Record density - Record flexibility

# Rear side functions



1+1 hot swappable power supplies  
 AC 105- 230V, DC +/-48V, 240V HVDC  
 Max. 1300W; typ (fully equipped) 960W  
 80+ Platinum power efficiency

Controller

Rear side field replaceable controller  
 Non-service affecting replacement  
 Easy access to non-volatile memory

System fans and power supply  
 integrated fans  
 In-service replacement

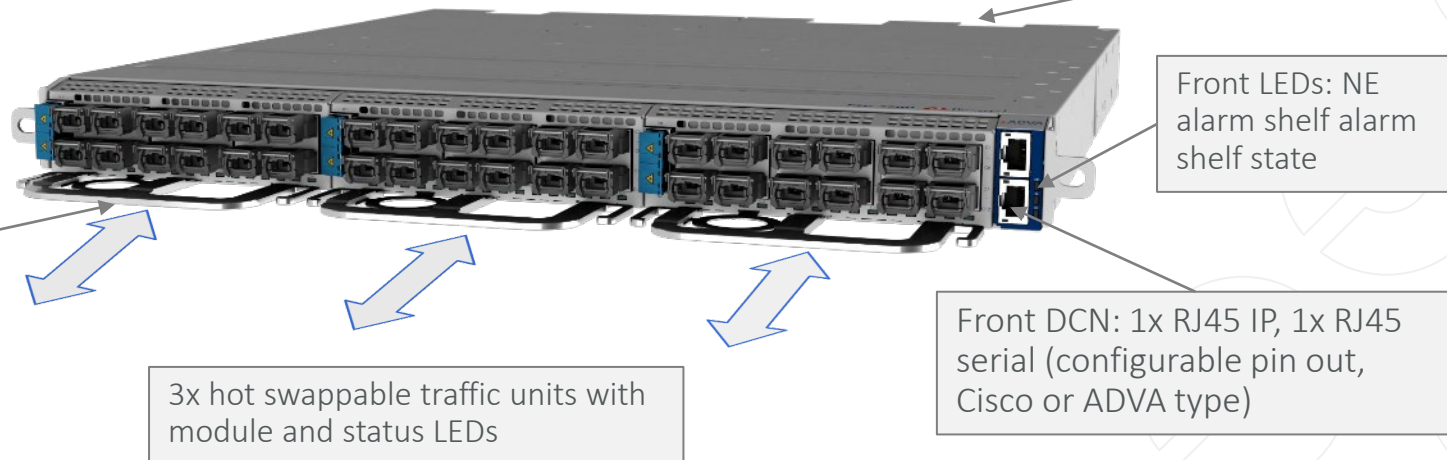


# TeraFlex™ Infrastructure

600mm+ rack compatible

W 448mm, D 495/482mm (with/without rear power cables)

Temperature range -5°...+45°C



Data Center footprint for high speed terminals

# Ultimate Transport Density

## TeraFlex Sleds

Network data rate flexible from 100G to 600G

Record density at 3.6Tb/s per 1RU

38.4Tb/s per fiber pair

AES256 encryption variant



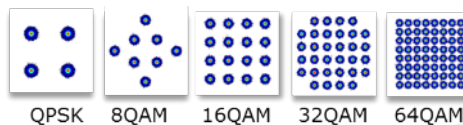
Market leading power efficiency

- 0.16 W/Gb/s (according TEER)
- Full shelf ~960W



2x Flexgrid Network port  
4-64QAM with interleaving  
28-72GBaud

12x QSFP28 clients



Flexible Transport up to 3.6Tb/s per 1RU

# TeraFlex network application

## Optimizing bandwidth use

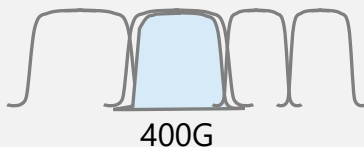
### Greenfield Metro DCI

- 600G per lambda
- 75GHz channel spacing with AWG filters
- 38.4Tb/s fiber capacity



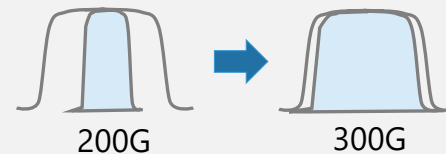
### Flexgrid Brownfield

- Maximum baud rate with Flexgrid ROADMs
- 75...100GHz channel spacing
- High reach 200-400G LH/ULH



### Fixgrid Brownfield

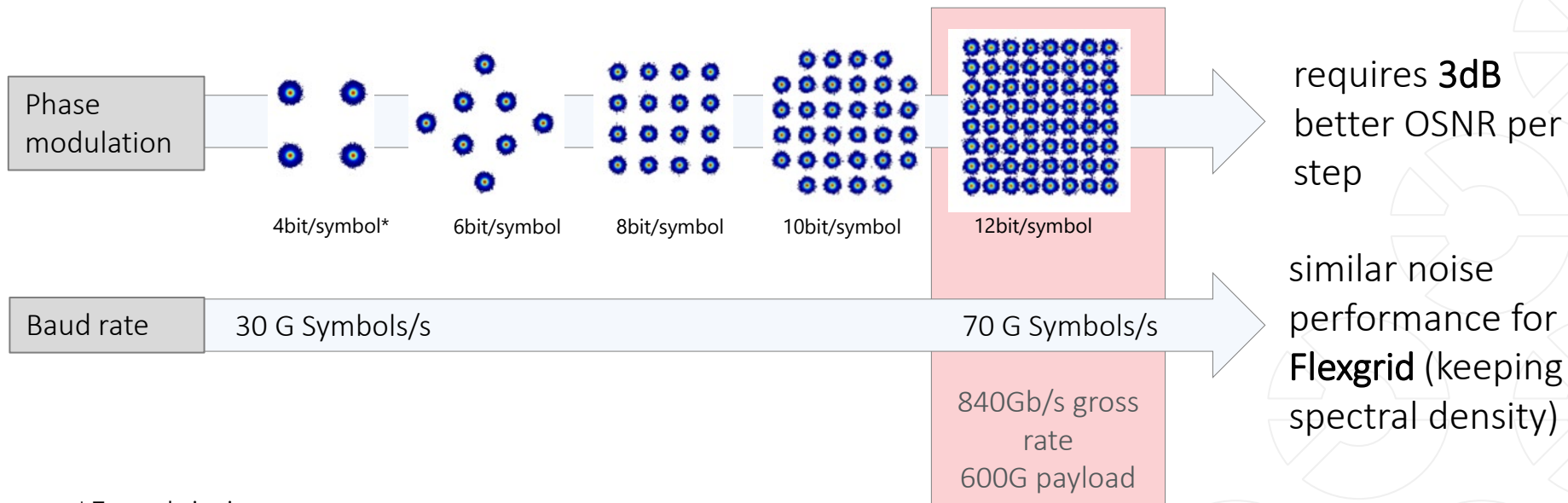
- 200-300G for 50GHz spacing
- Ultra flexible modulation enables filling the passband



Ultra flexible modulation adapts to any infrastructure

# DSP Technology

## Higher Order Modulation (QAM)



\* Two polarizations

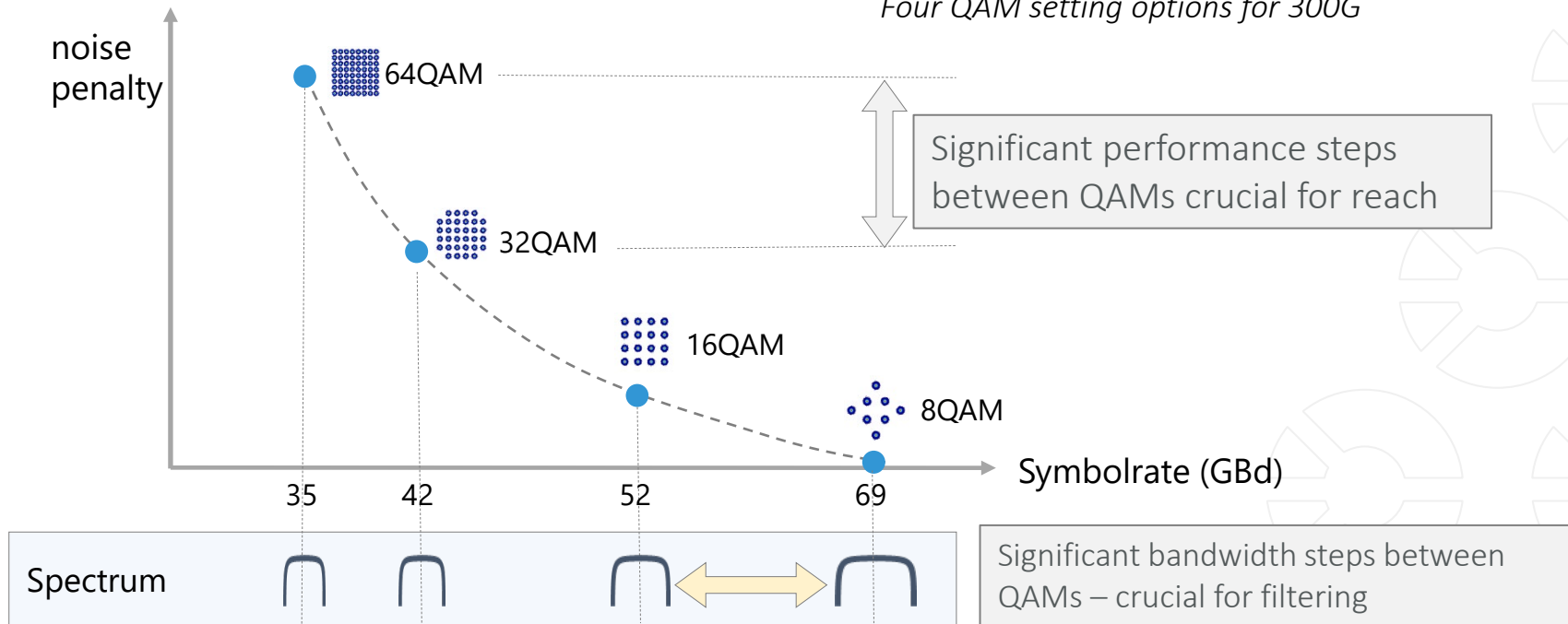
Increasing Baud rate provides highest reach

# Flexible modulation

Multiple QAMs for each data rate

Example:

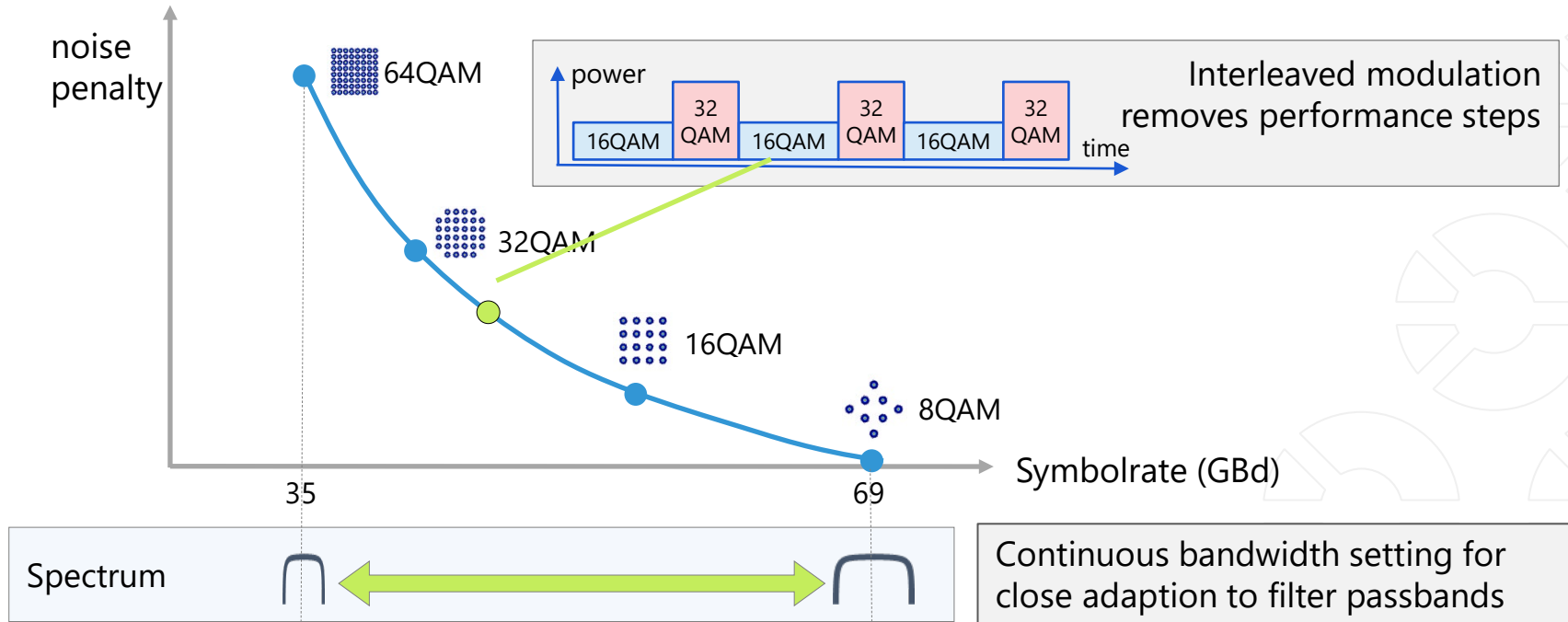
Four QAM setting options for 300G



Multiple QAM settings allow optimizing networks with performance steps

# Ultra flexible modulation

## Interleaving of symbols



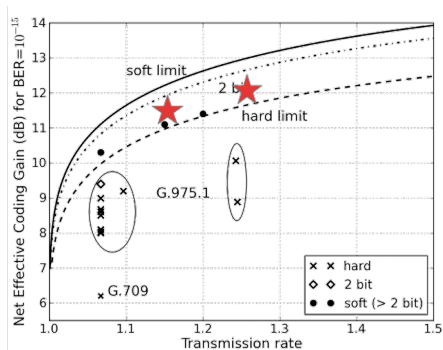
Interleaving removes steps in optimization

# Ultra flexible modulation

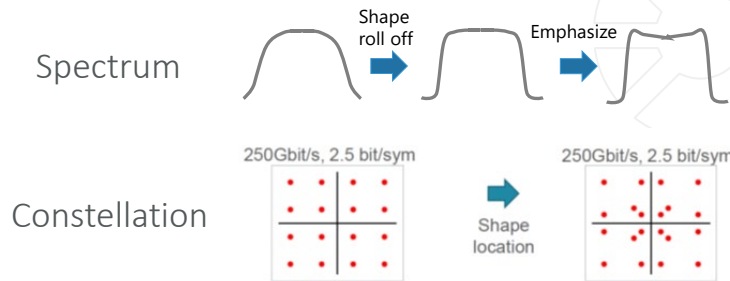
## Shaping and FEC

Performance improvements by shaping of the spectrum using preemphasis and roll off (configurable).

Improved tolerance to distortions by geometrical constellation shaping and in-built compensation of nonlinearities.



27% and 15% FEC:  
further level to  
manage reach vs.  
bandwidth

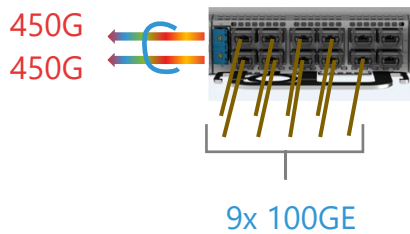


Market leading DSP provides record performance over any network

# Bandwidth optimization with 50G Granularity

## 2-Carrier Superchannels

Couple two channels on TeraFlex sled to create a Nx 100G superchannel



Integrated deskew between channels – need to take same path

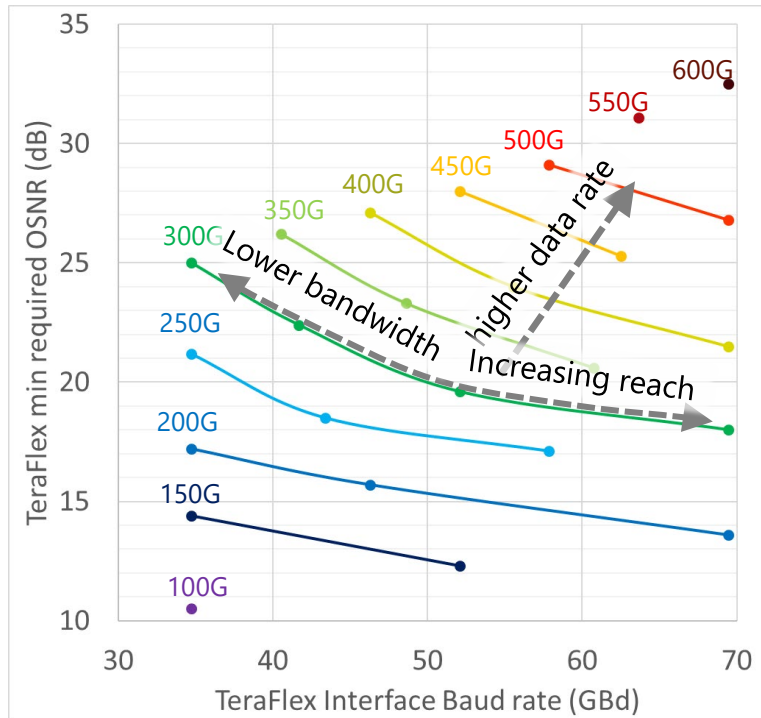
Creating another level of flexibility minimizing cost per service

Data rate settings (single and coupled): 100, 150, 200... 600G

Ultra flexible interfaces squeeze maximum capacity from the interfaces



# How to use ultra flexible modulation



Change OSNR tolerance vs Baud rate for a selected data rate

Higher Baud rate increases reach and signal bandwidth

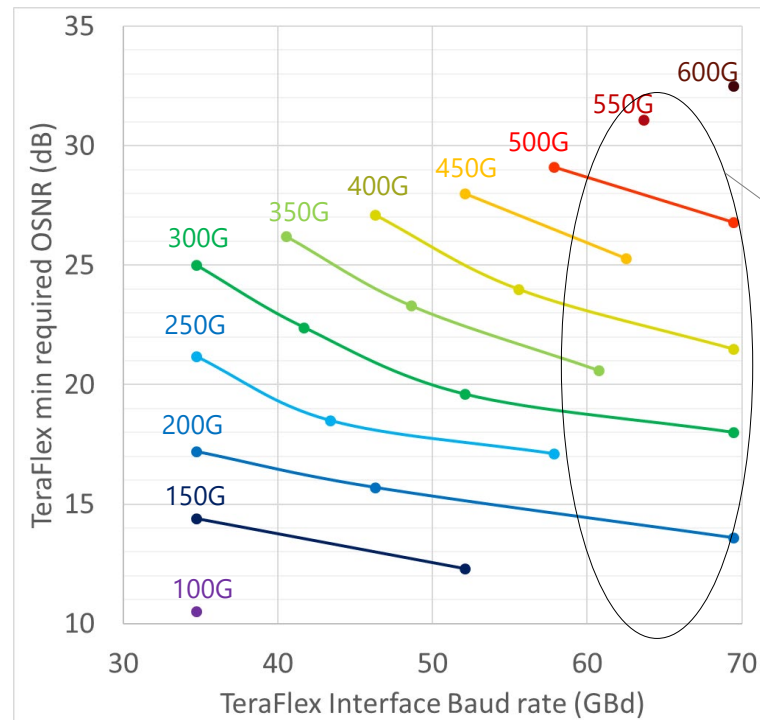
Interleaved modulation allows continuously optimizing along lines - conventional systems can only select the dots

Fine granular adaptation to any network infrastructure

# Optimizing flexgrid networks

Optimization in FLEXGRID networks:

- High Baud rate yields maximum data rates thus minimized cost per bit
- OLS flexgrid setting is done after interface setting (bandwidth)



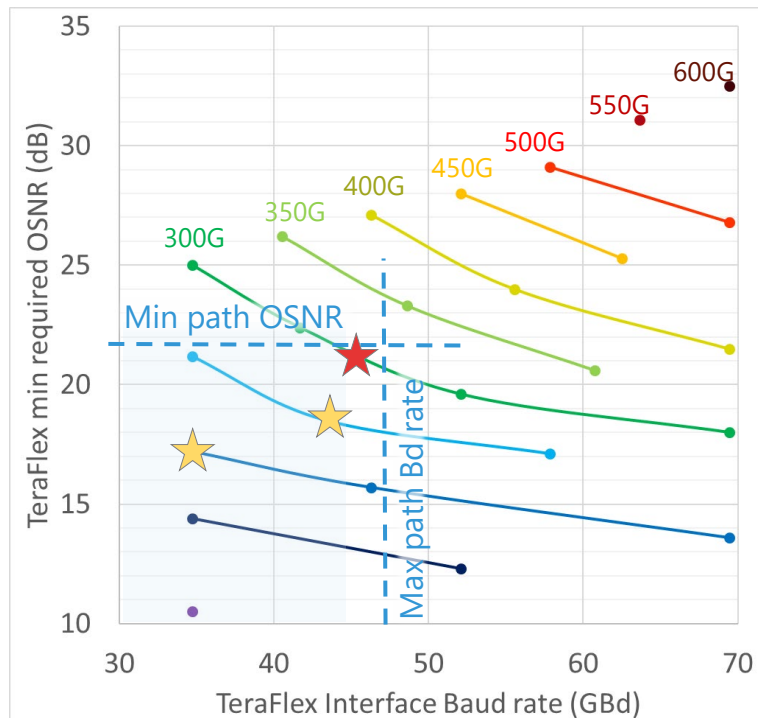
Flexgrid optimum range:  
Maximum bit rate at high Baud rate

High Baud rates achieve lowest cost per service

# Maximum performance for brownfield upgrade

Optimization in LIMITED GRID networks:

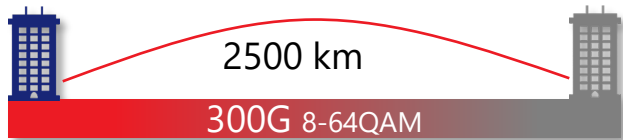
- Max. Baud rate from path filter characteristics
- Minimum required OSNR from path
- Interleaved modulation provides better performance ★ than base formats ★ (w/ or w/o 50G granularity)



Ultra flexible modulation increases data rate per interface

# TeraFlex System Reach

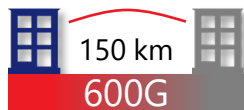
Versatile application from Metro to Long Haul terrestrial networks



**Long Haul:** Maximum distance



**Regional:** maximum capacity per fiber



**Metro:** fiber capacity



Optimizing flexible reach vs capacity

# High speed trial via Open OLS

600G wavelengths over 50-100  
km links using Open OLS

600G - 400G - 200G interface  
reconfiguration



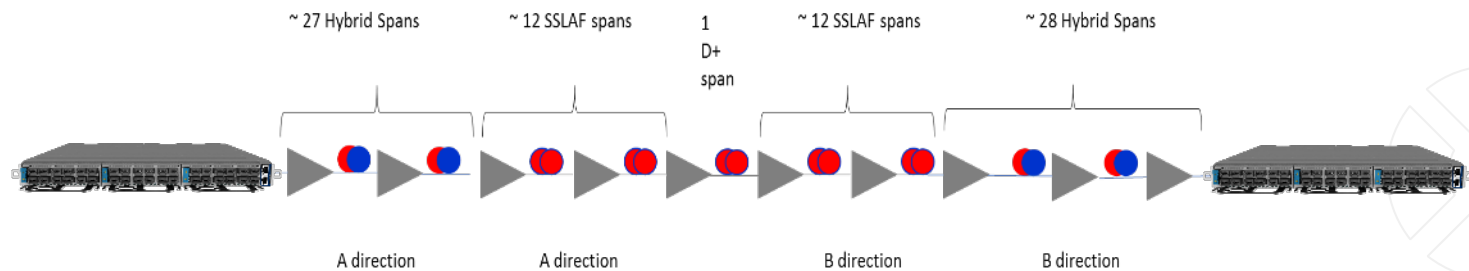
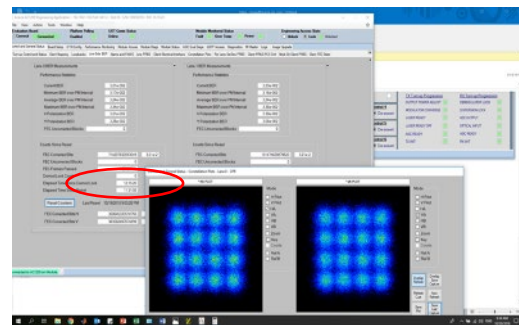
Hyperscale Cloud interconnect at highest capacity and density

# Submarine Network Application

6800 km testbed at submarine network player

Achieved 300G error free transmission at 75GHz channel spacing

Strongly increased capacity for Open Cable systems



Maximizing reach x capacity in every network

# Performance Monitoring

## PM points

### Network

- Physical: TX/RX power, coh ch power, laser bias/temp
- SD-FEC: corrected errors, uncorrected blocks, BER, Q
- DSP: SNR, OSNR (<25dB), EVM, CD, SOP, DGD, PDL, frequ offset
- OTN: SM/PM, GCC, BBE, ES/SES/UAS, TCM



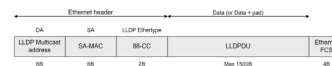
### Client

- Physical: TX/RX power, laser bias, temp
- 802.3bj FEC: corrected errors, uncorrected blocks, BER, Q



### Ethernet

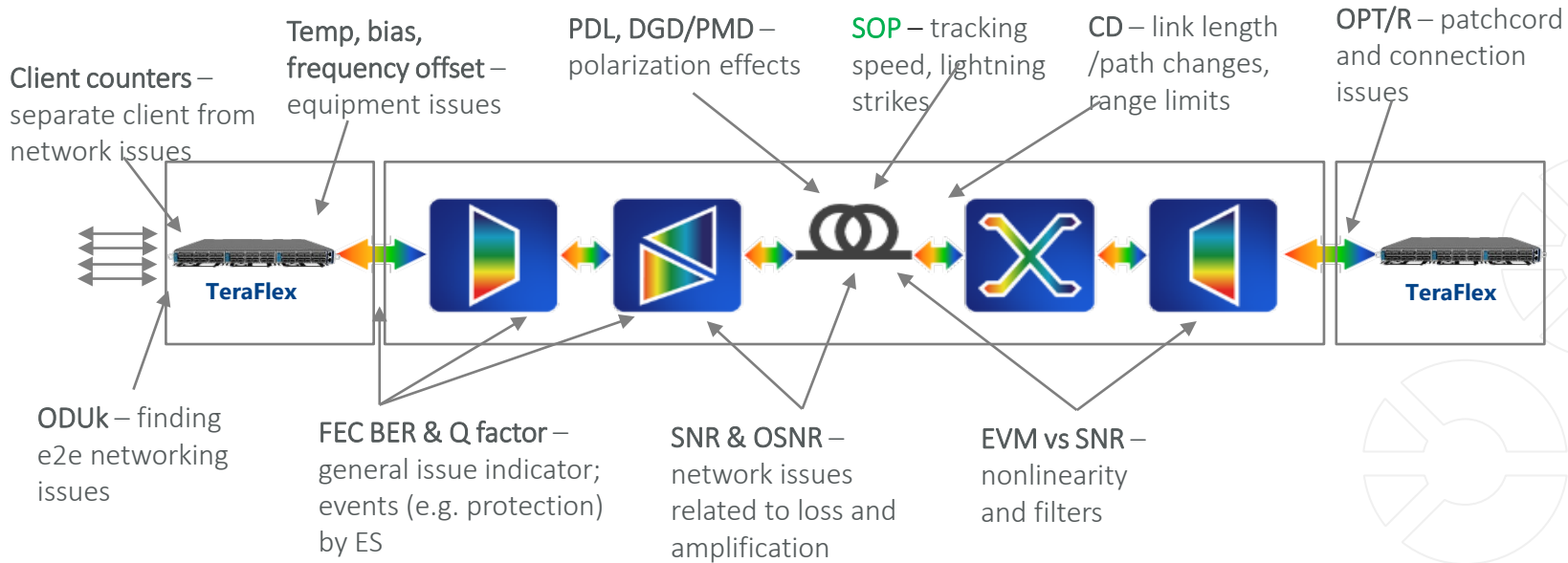
- Ethernet statistics (RMON): good & bad frames, bytes, packet buckets, utilization
- PCS layer: block/BIP errors, ES
- LLDP (non-intrusive): TLVs, address



Comprehensive Data Set via Streaming Telemetry

# Maintenance in disaggregated networks

Quick trouble shooting by rich terminal monitoring options



Tracking down network issues in disaggregated networks



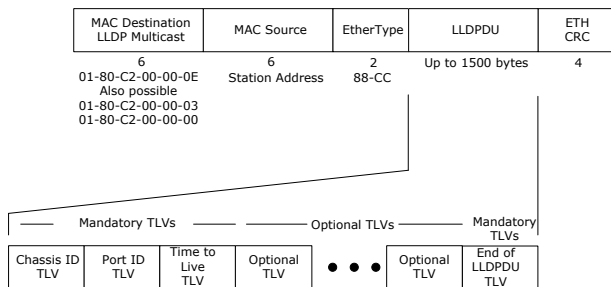
# LLDP Monitoring

Near & far end monitoring per port for nearest bridge

Non-intrusive sniffing of LLDP packets (EtherType x0088)

Monitoring of TLV ('type length value') fields

- Chassis Type, Chassis ID, Port Type, Port ID, System Name, System Description, System Capability Supported, System Capability Enabled
- Management information: Type, address(es), interface type, interface number, OID



*Q: ,Where is my connected client equipment ?'*

*A: ,You are connected to Switch 192.127.1.17  
Port 00:11:22:33:44:55  
Aisle 26, rack 4'*

# 26 Protection Options

## 1 - Line Protection

- Optical line protection using external switching module
- Trigger options on line protection module
- <50ms



## 2 - Path Protection

- Diverse network paths
- 1+1 protection on ODU4 level
- <50ms



## 3 - CCCP Protection

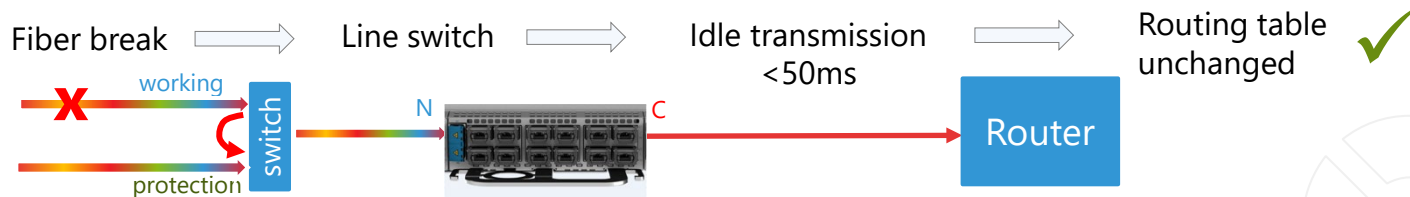
- Client signal splitting by Y-cable or PM module
- LR4/CWDM4E client optics – requires power budget >3dB
- <50ms



# Fast line protection with suppression of router flapping

Fast traffic resynchronization ensures <50ms traffic interruption for line protection switching

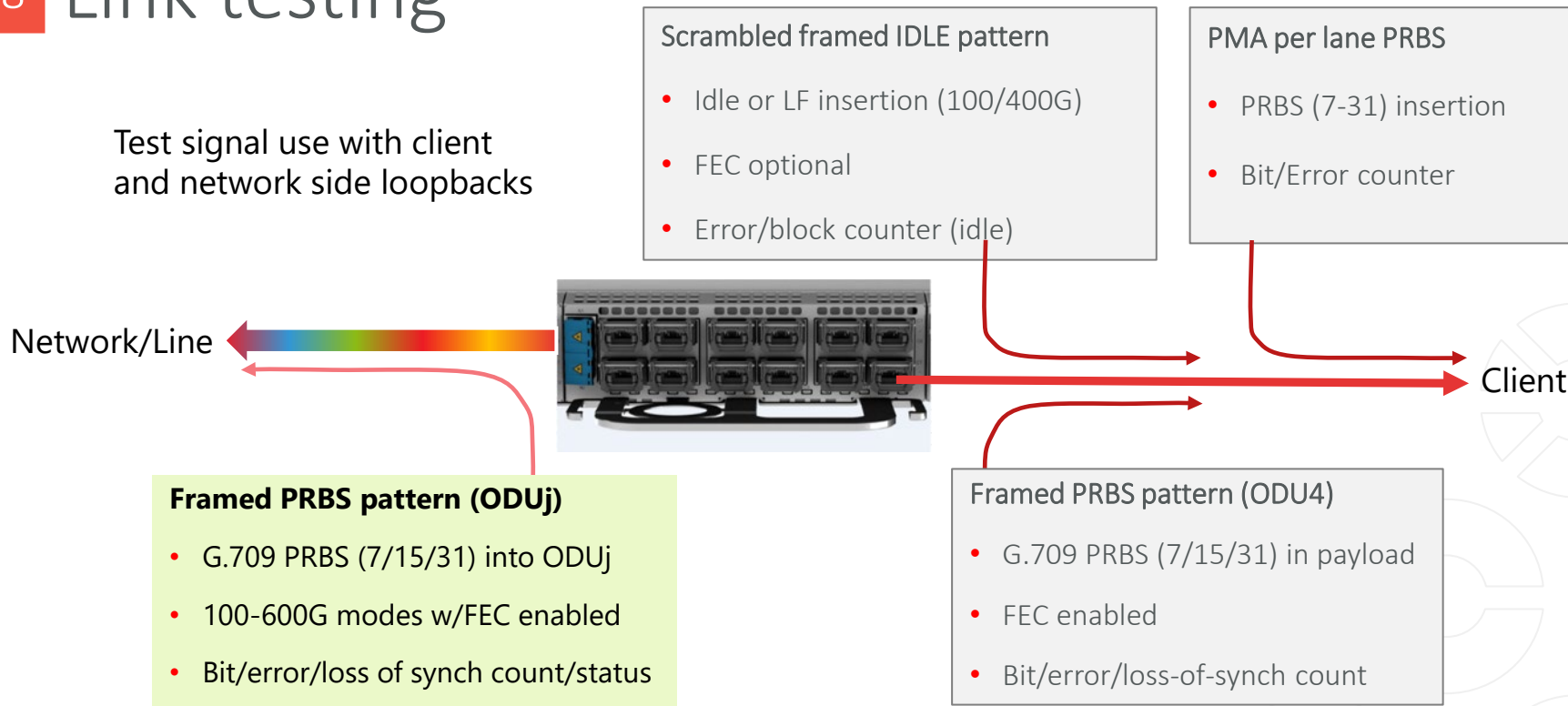
Graceful idle insertion (configurable) during traffic switchover (including alignment markers) prevents routers from flapping



Providing highest service availability on router level

# Link testing

Test signal use with client  
and network side loopbacks



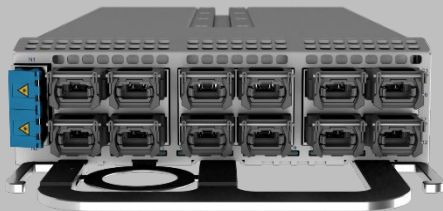
Line and client Test signals for burn in application



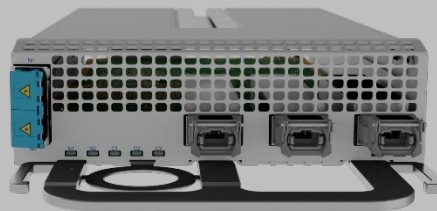
# 400GE Support

# Service Speed Growth

From 10GE/100GE to 400GE



- 12x 100GE/OTU4
- 120x 10GE via MicroMux
- FlexE support (future)

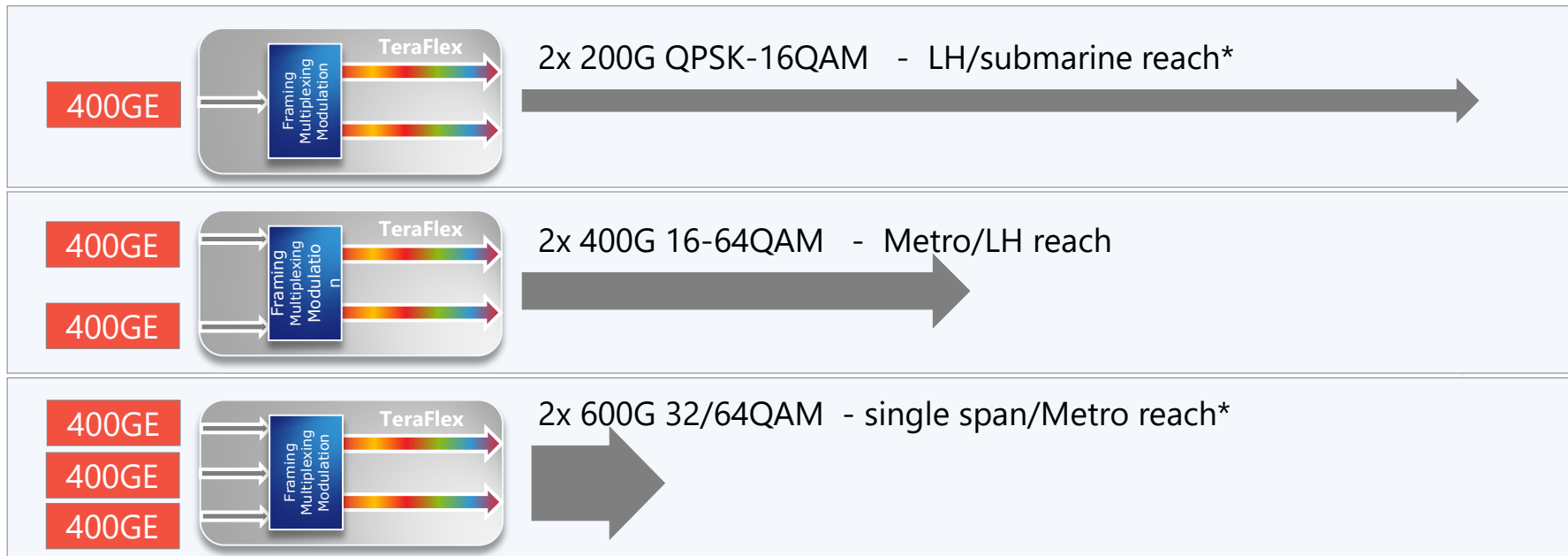


- 3x 400GE
- QSFP56-DD PAM4 technology
- 12x 100GE via QSFP-DD/DR4 fan out to QSFP28/DR

Router interface and data center migration to 400GE

# 400GE Transport

## Operation modes



*\*both interfaces via same fiber ; max. 750ns (equ. 150m fiber) path difference*

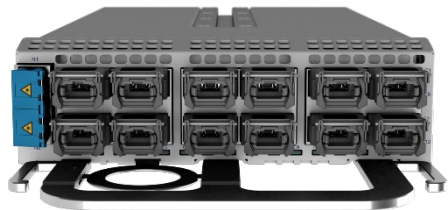
400GE via all network types using high speed transport and inverse multiplexing

# Service Types by Pluggable

## From 100GE to 400GE

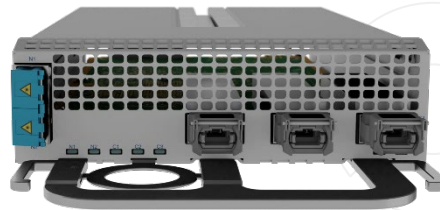
### 12x100G sled – QSFP28

- **100GE** – LR4, CWDM4E, SR4, ER4, AOC, 3<sup>rd</sup> party
  - 12x 100GE per sled
- **10/40GE** via QSFP28 MicroMux
  - up to 120x 10GE /30x 40GE per sled
- **FlexE** support (Nx QSFP28 PHY)



### 3x400G sled – QSFP56-DD

- **400GE** – FR4, DR4, LR4/8, SR8, 3<sup>rd</sup> party
  - 3x 400GE per sled
- **100GE** – DR4 fan out to 4x QSFP28 DR1
  - Up to 12x 100GE per sled
  - Client equipment needs to support DR1
- **FlexE** based inverse muxing via two network ports



Data Center Migration to 400GE



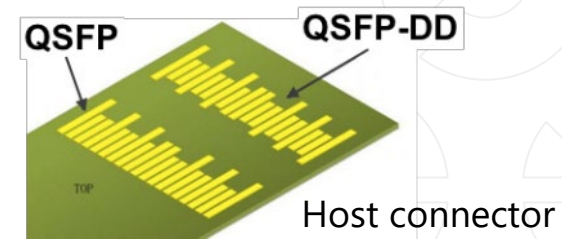
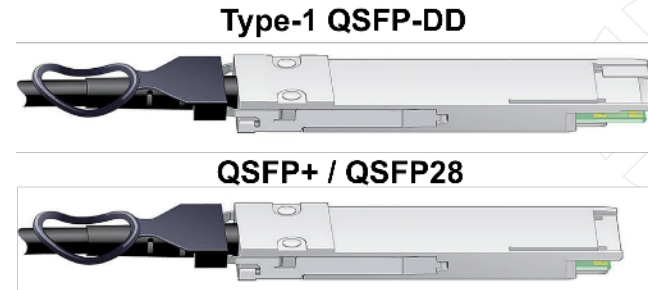
# 400GE pluggables: QSFP56-DD

**Electrical Interface** based on 8 x 50G PAM4 electrical I/O interface (400GAUI-8)

- Dual row of host signals and speed doubling by host PAM4 signal increases capacity from 100G to 400G
- Backwards-compatible with 40G QSFP10 and 100G QSFP28

**Optical interface** variants depending on number of carriers, wavelengths, fibers and modulation (NRZ or PAM4):

- DR4: 500m, 4x 1310nm PAM4 single mode, MPO connector, fan out options to 4x 100G DR (single carrier 100G)
- FR4: 2km, 4x CWDM PAM4 single mode, LC connector
- LR4/8: 10km, 4/8x CWDM or LAN-WDM PAM4, LC connector
- SR8: 100m, 8x 850nm NRZ, MPO connector



See QSFP-DD MSA, <http://www.qsfp-dd.com/>

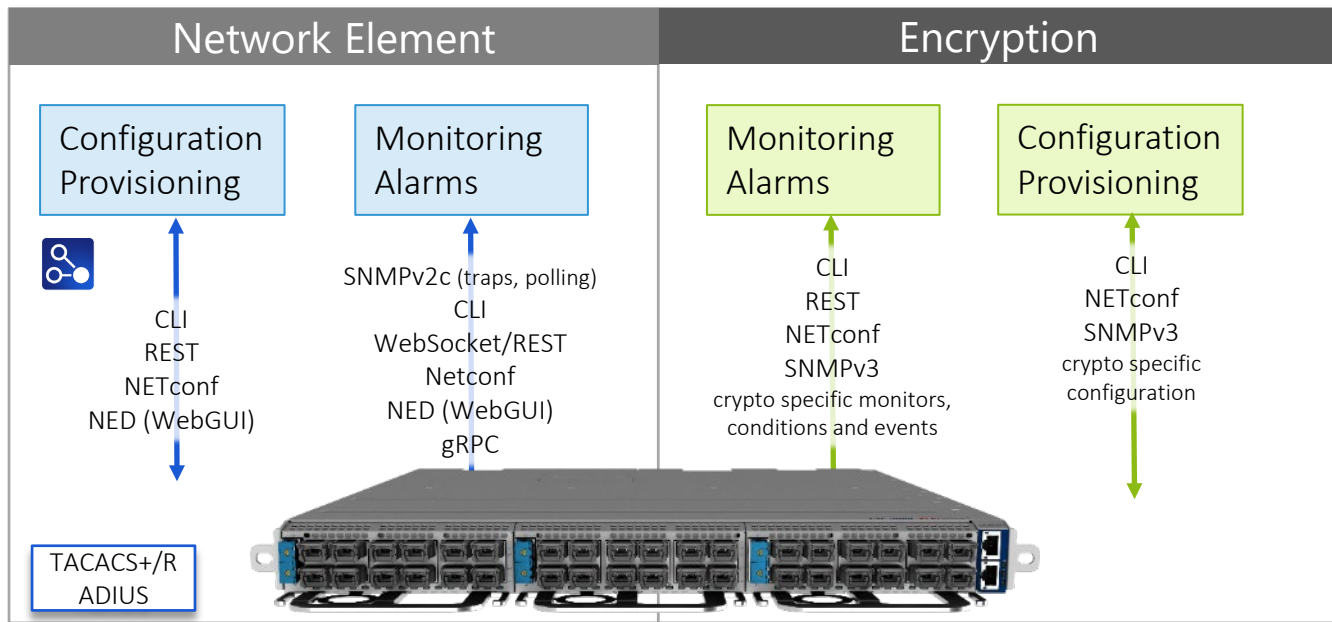
Dense 400G client side pluggables



# Device Management via APIs

# Device management via open interfaces

## FSP 3000 CloudConnect API options



Seamless integration into DC and SDN environment

# Command Line Interface (CLI)

## CLI structure

Full CLI to operate, configure, administer, and maintain the equipment

Model (Yang) driven hierarchical structure; customized for usability where needed

## Commands

Intuitive command set (similar to popular router platforms)

Command completion assistance (hints) and aliasing

Transaction/candidate buffer concept - enter "configure" mode and "commit" to affect system database/traffic

## CLI access options

RS-232 serial access port on the element controller module (ECM)

Telnet session via local or remote connection of the management data communications network (DCN)

Secure shell (SSH) session via local or remote management DCN connection

## Node config import/export

Node configuration may be exported and imported in CLI format.

Available in XML format via NETCONF

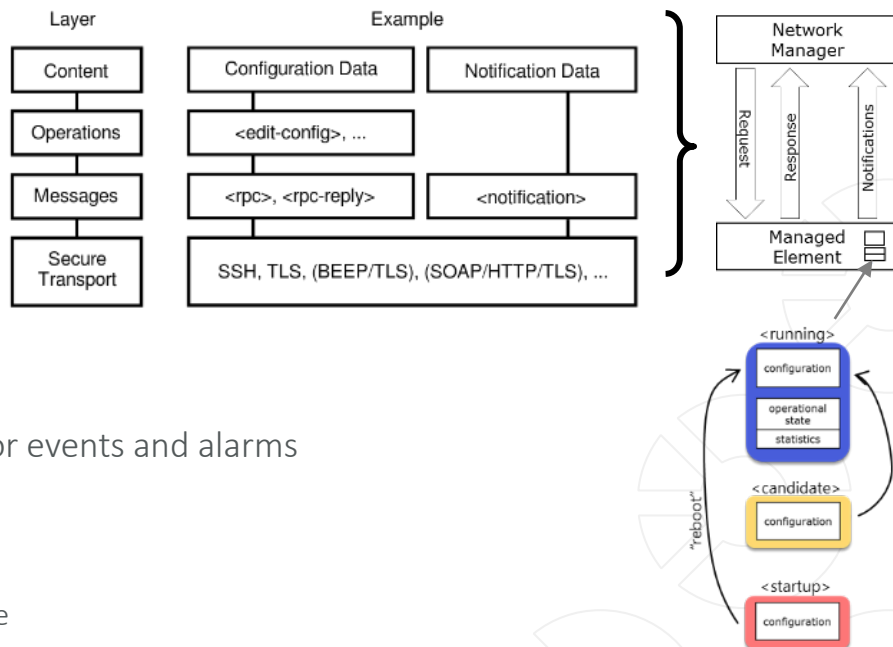
Binary versions of nodal config also supported

Device management via powerful CLI

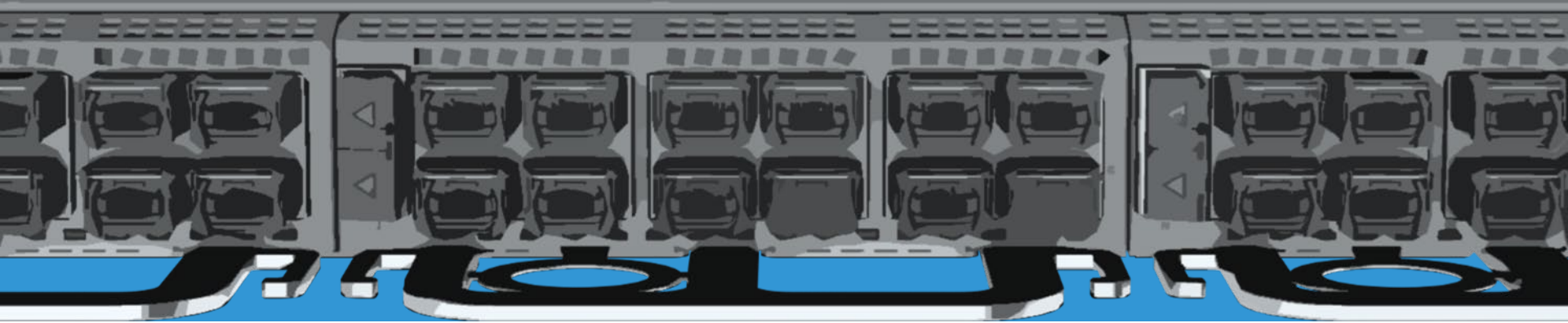
# Netconf Support

## Standardized Device Level API

- NETCONF Protocol support with transactions
- Configuration data bases
  - <running/> and <candidate/>
  - backup and restore (copy)
- Models
  - RFC-6020 YANG model
  - OpenConfig and other models
  - Full coverage (create, read, update, delete)
- Standard NETCONF notification stream (telemetry) for events and alarms
- General session management and base capabilities
  - Start/close session, Get/edit/..., etc.
  - Data exchange, writable-running, rollback-on-error, validate



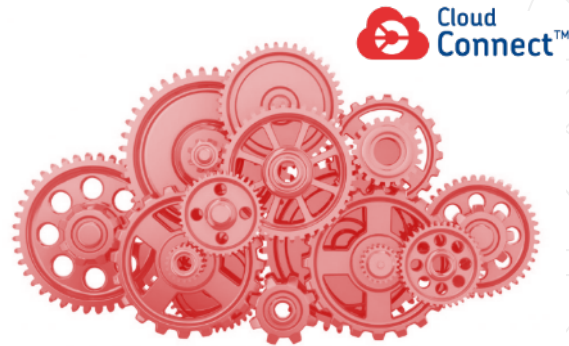
Open API for Device Level



# Zero Touch Provisioning

# Automation and simplicity

- Zero-touch provisioning (ZTP)
  - Fully automated, out-of-the-box boot-and-configure operation
- Simplified local provisioning
  - Local setup of key parameters
- Script-based commissioning (CLI, NETCONF/XML)
- Linux-based containers for custom agent download and execution
- Secure software and configuration management



Automate network services provisioning for your DCI applications

# Simplifying Provisioning

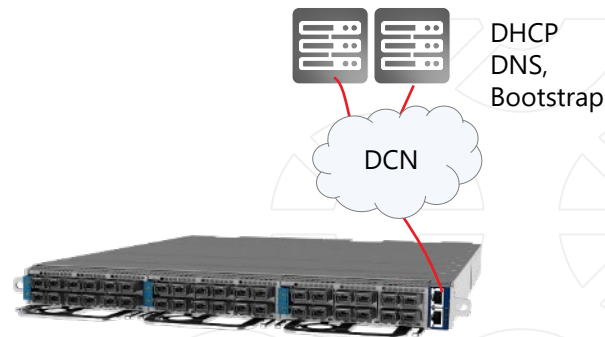
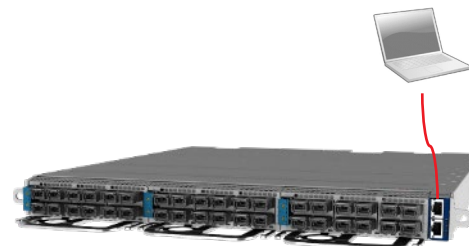
## Operational options

### Simplified local commissioning

- Allow local setup of key parameters (e.g. wavelength)
- DHCP server mode
- Local login from web browser with basic DCN commissioning
- Commission locally or e.g. via Ansible playbooks or push mechanisms

### Zero Touch Provisioning (ZTP)

- Completely automatic, out-of-the-box boot and configure operation
- Auto DCN discovery followed by DHCP request
- Auto download of SW and config files (CLI commands or Netconf directives)





# Zero Touch Provisioning

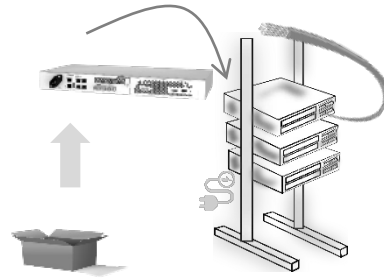
## Process automation

### Manual installation steps:

- Install (rack and stack)
- Power-up
- Connect physical network

### Automated processes:

- **Communicate:** Establish network connectivity
- **Authenticate:** Verify, certify, protect
- **Validate:** Correct software version
- **Initiate:** Load basic configuration
- **Activate:** Load service configuration(s)



Unpack

Rack and stack

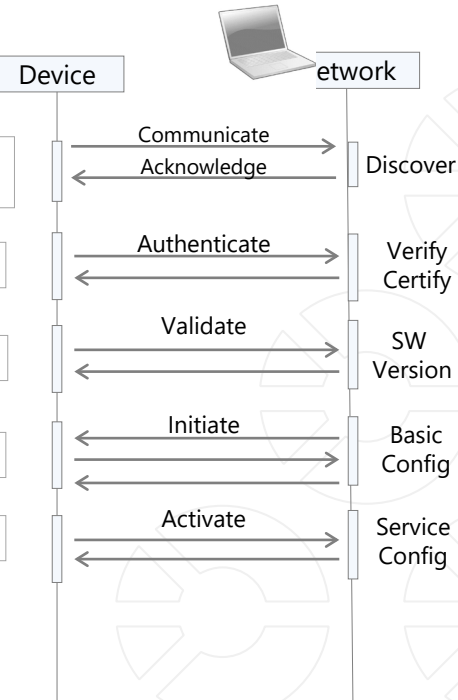
Communication parameters  
(IP address, gateway)

Certificates, Vouchers

Software

Network parameters

Services



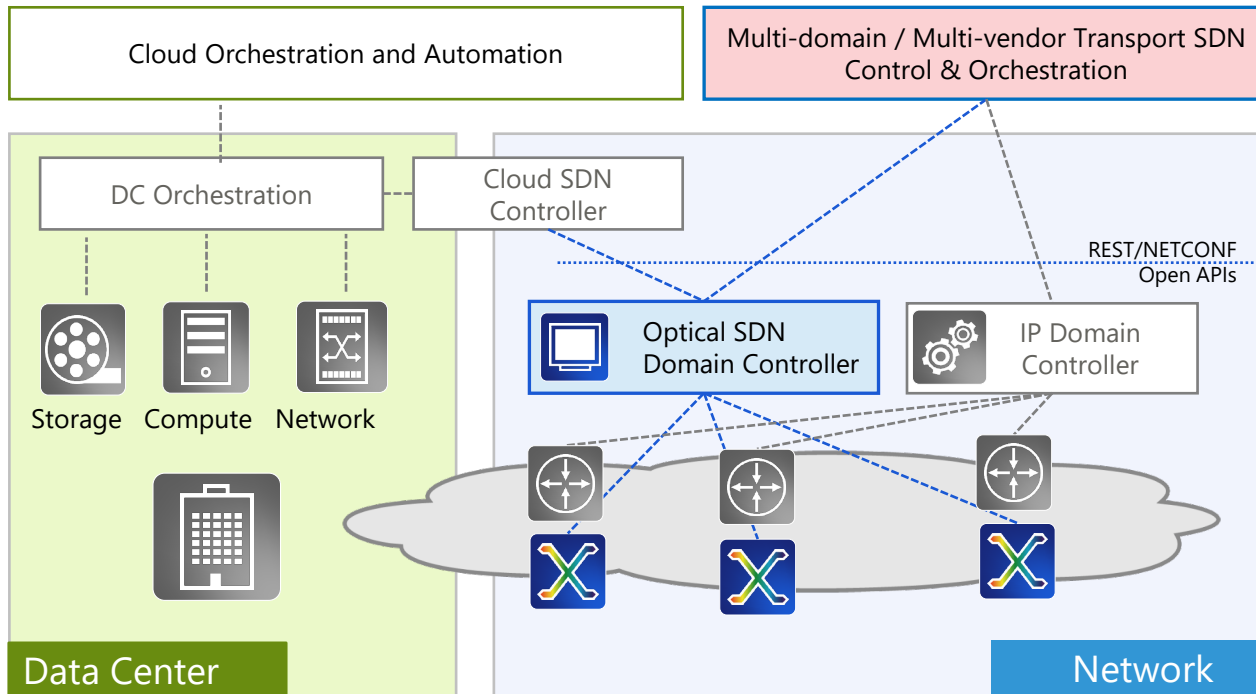
Automated processes save time, effort and mistakes



# SDN

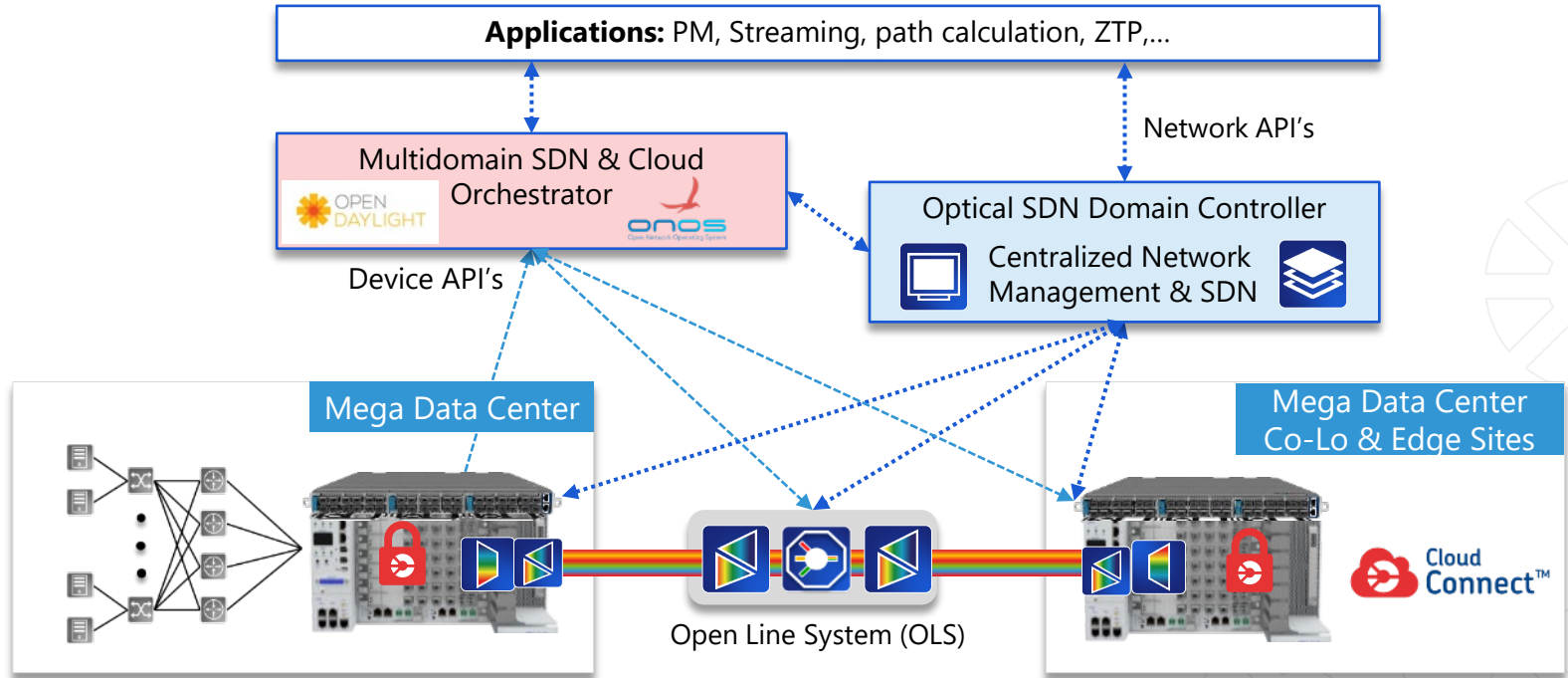
## Network management and SDN

# Cloud & Transport SDN architecture



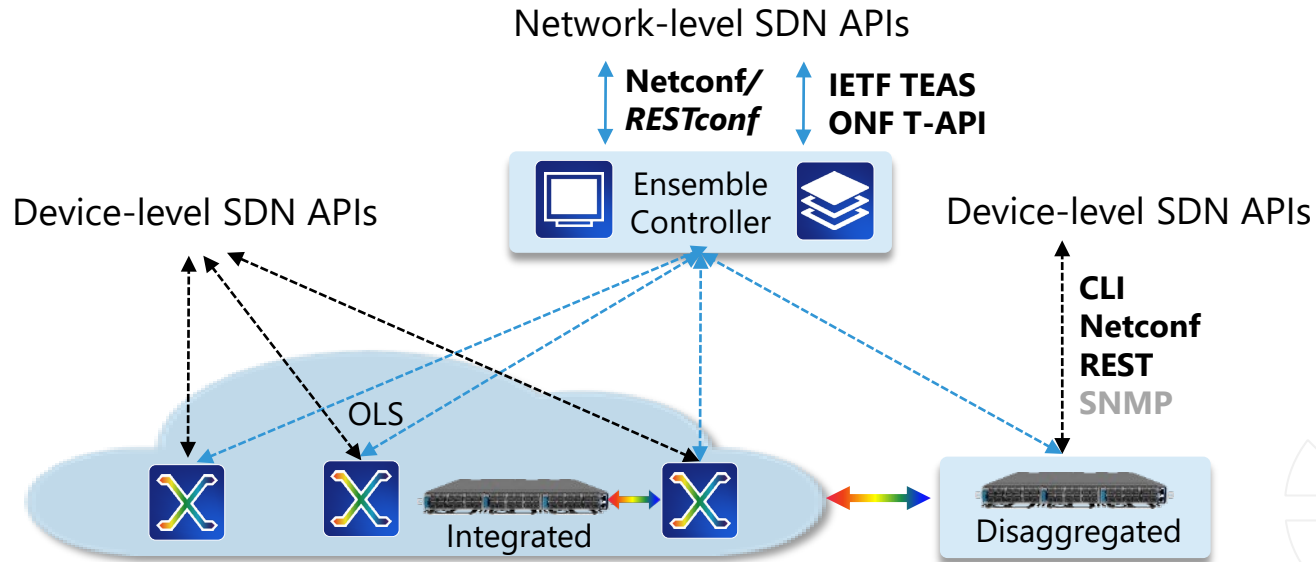
Optical Network Programmability and Automation

# DCI Transport SDN Architecture



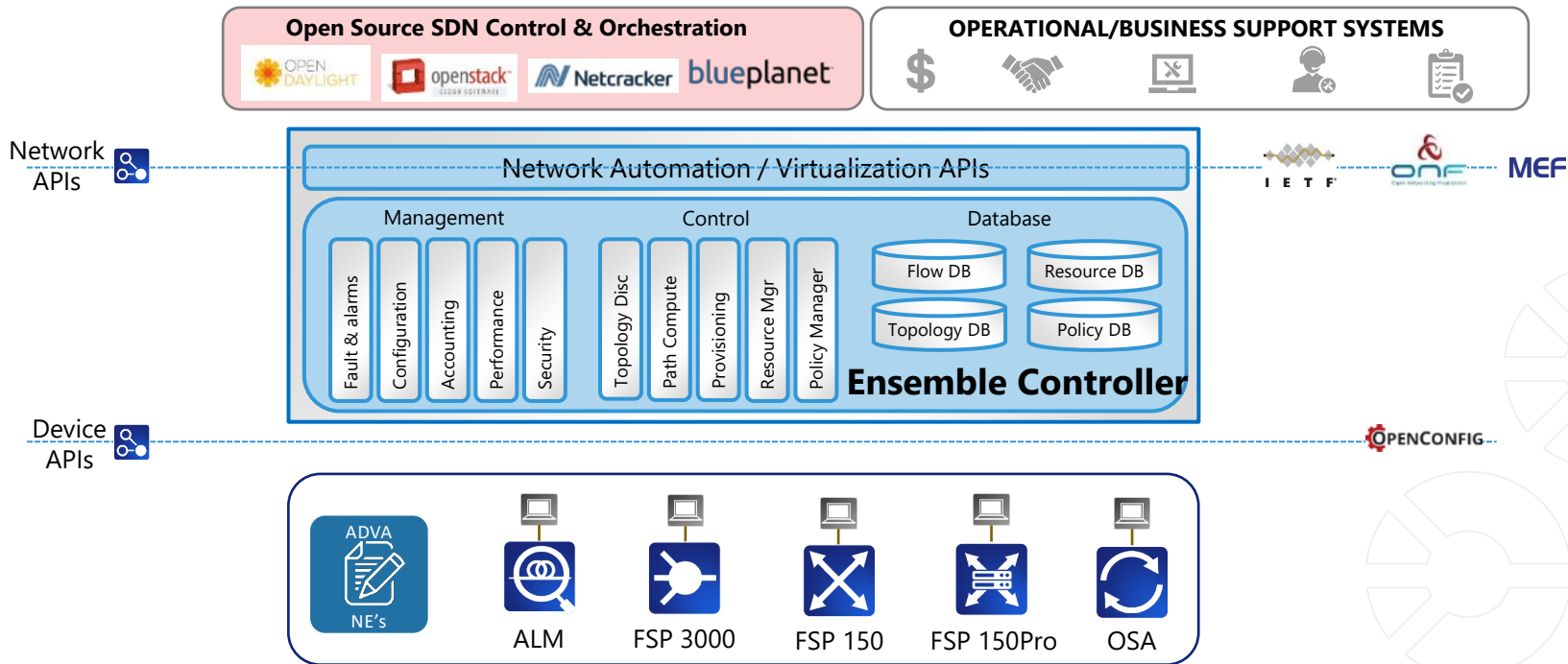
# Ensemble Controller Support

## Network Management and SDN APIs



Ensemble Controller acts as domain controller with service abstraction

# Ensemble Controller – SDN based Network Management



One Future Proof Network Management Solution for all Technologies

# Supported YANG Data Models

Network Scope

## IETF TEAS TE Topology



- Focus on IP over Optical
- Released FSP 3000 AgileConnect product feature
- Existing customers
- Partner integration: Cisco NSO/WAE, Juniper/NorthStar

## ONF Transport-API



- Focus on Carrier Transport Networks
- Several customer RFIs
- Ongoing Interops and Demos
  - ONF T-API Interop 2018
  - ONF ODTN (Open Disaggregated Transport Networks)
- Partner intergration: Ciena Blue Planet, NEC/Netcracker, Sedona

## MEF LSO Presto



- Based on ONF Core Model
- Uses ONF Transport API
- Adds Service API for Ethernet & OTN

Device Scope

## OpenConfig



- IP / Ethernet / **Streaming telemetry** device level configuration
- Direct device API
- Used by many DCI / Web 2.0 providers
- (Partially) supported by CloudConnect

## AT&T OpenROADM



- Full disaggregation
- Small community (current AT&T vendors)

*under consideration*

## ONF Core Model



- Focus on Device Scope
- Large SDO support  
ITU-T G.874.1/G.8052, BBF, MEF, IEEE, IETF
- Few contributors for Optical / Ethernet

*under consideration*



# TeraFlex: Summary

Entering a new era of disaggregated networking



# TeraFlex: Market leading device figures

## Performance

Highest reach in the market  
with >3dB benefit @ 400G and  
record submarine distances



## Density

Highest density in the market:  
3.6Tb/s per 1RU



## Speed

Highest capacity per  
wavelength 600Gb/s driving  
down transmission cost



## Power Efficiency

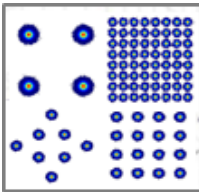
Lowest power per bit in the  
market 0.16W/Gb/s



TeraFlex is the most powerful terminal solution on the market

# TeraFlex: Optimum services through unique features

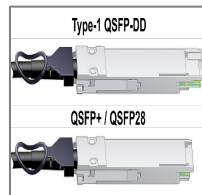
Highest interface **FLEXIBILITY** : Ultra variable modulation with symbol inter leaving, tunable Bd rate and shaping



Most flexible operational **ADAPTATION**: modern APIs, data models, 3<sup>rd</sup> party agents, security protocols, ZTP



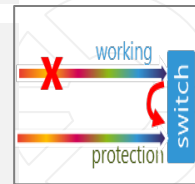
**SERVICE** migration at same density: 10GE to 100GE with MicroMux, 400GE support with LLDP monitoring



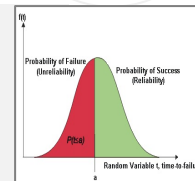
Trusted layer-1 **ENCRYPTION** solution with highest security key exchange and security management



Highest service **AVAILABILITY** by < 50ms line protection, suppression of router flapping and ultrafast polarization control.



Maximized **RELIABILITY** with in-service replaceable controller



TeraFlex easily adapts to any network and operational environment



Спасибо за внимание

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