4G LTE Solution Introduce

Nokia Shanghai Bell

Oct 2018

Agenda

- DWDM technology and product overview
- DWDM solution and project implementation
- IP technology and product overview
- IP solution

DWDM technology and product overview

Nokia Shanghai Bell

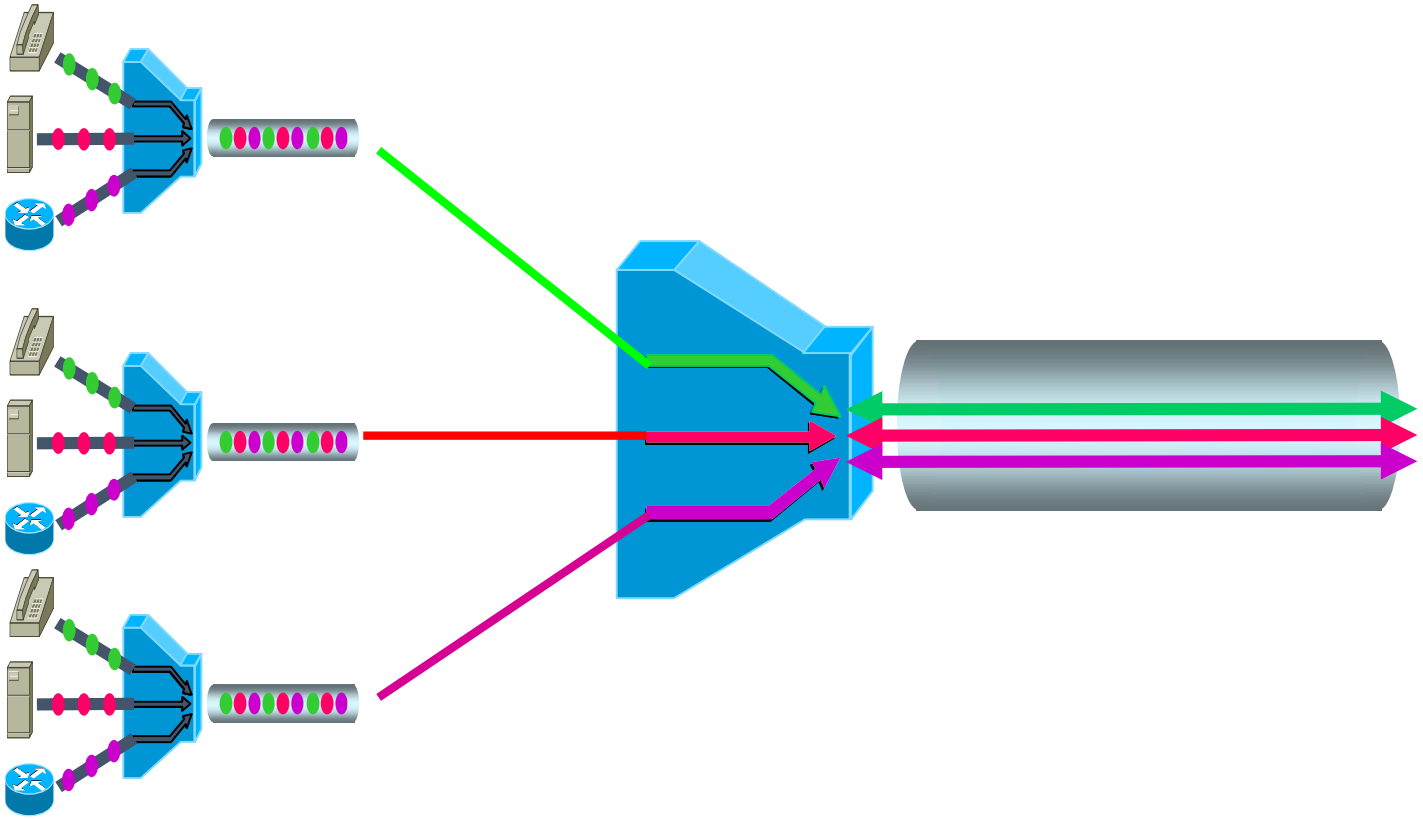
Yang Qingyong

Oct 2018

DWDM Technology Introduction

Why WDM?

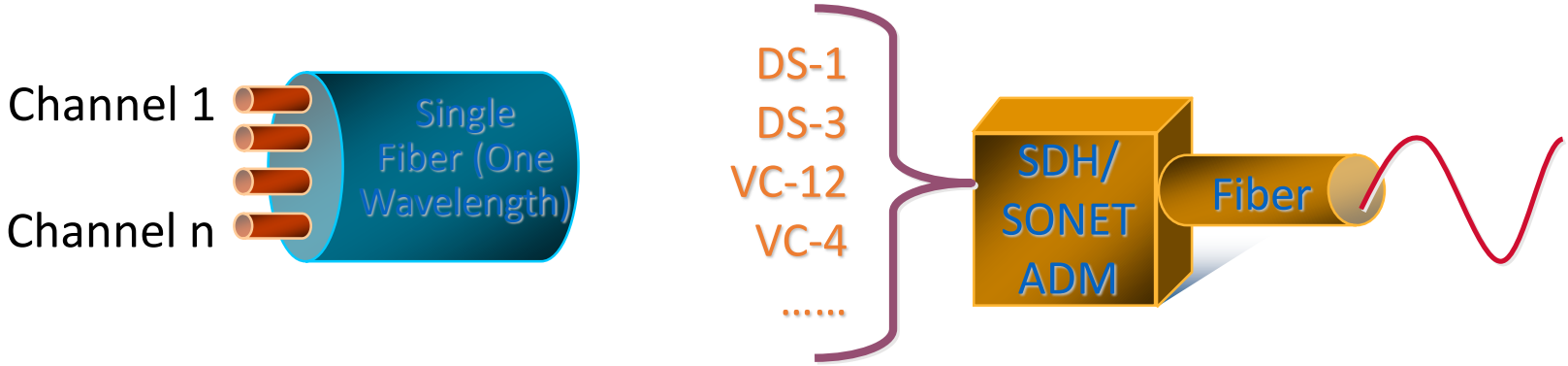
Ability to put multiple wavelength of services onto a pair of Fiber



- WDM provides hundreds of Gbps of scalable transmission capacity today
- Provides capacity beyond TDM's capability
- Supports incremental, modular growth
- Transport foundation for next generation networks

SDH vs WDM

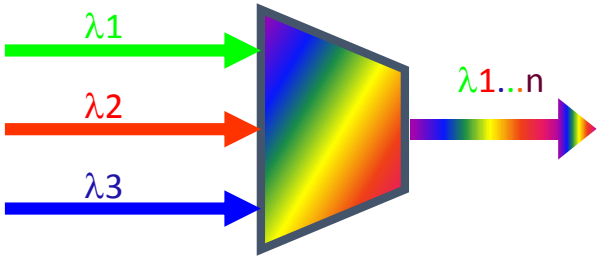
- Time division multiplexing(TDM)
  - Single wavelength per fiber
  - Multiple channels per fiber
  - Takes sync and async signals and multiplexes them to a single higher optical bit rate
  - E/O or O/E/O conversion
  - SDH/S ONET



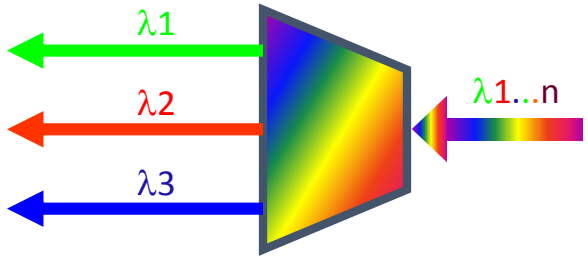
- Wave division multiplexing(WDM)
  - Multiple wavelengths per fiber
  - Multiple channels per fiber
  - Takes multiple optical signals and multiplexes onto a single fiber
  - No signal format conversion

DWDM Components

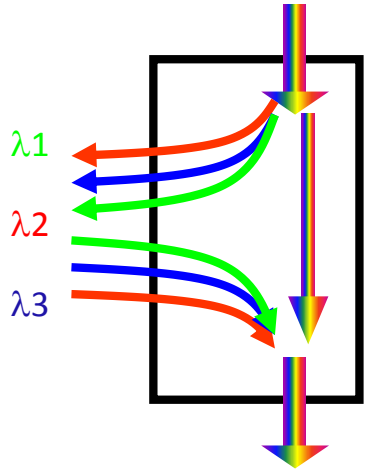
Transponder (OTU)



Optical Multiplexer (MUX)

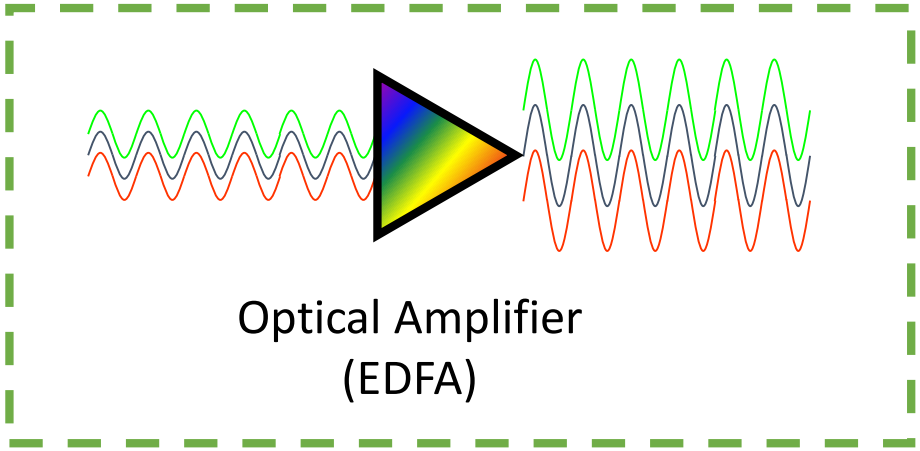


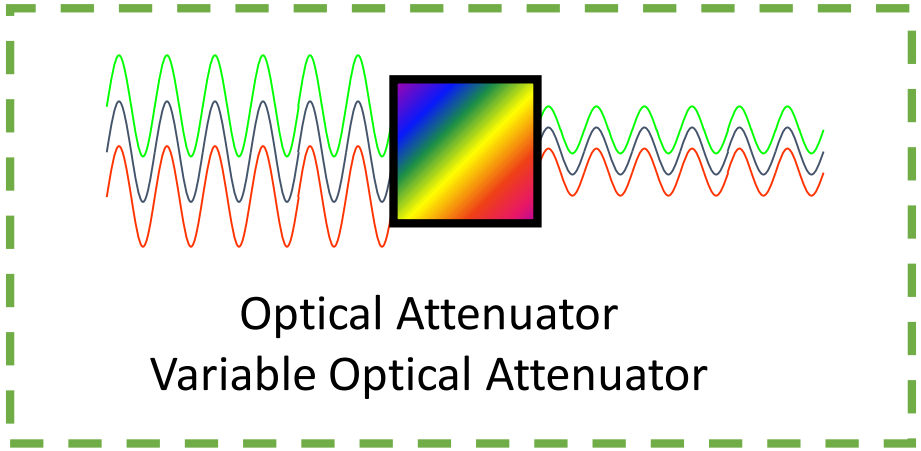
Optical De-multiplexer (DeMUX)

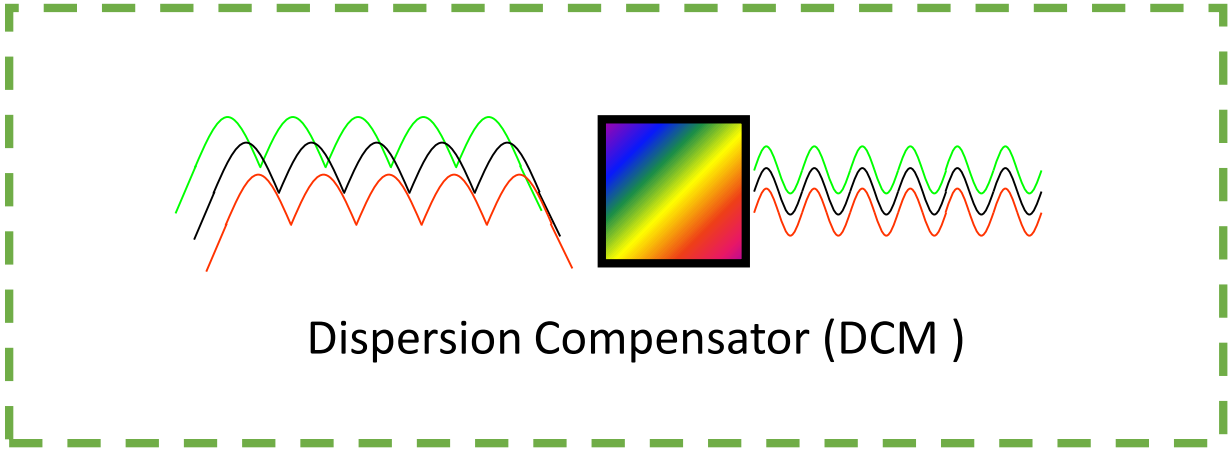


Optical Add/Drop Multiplexer (OADM)

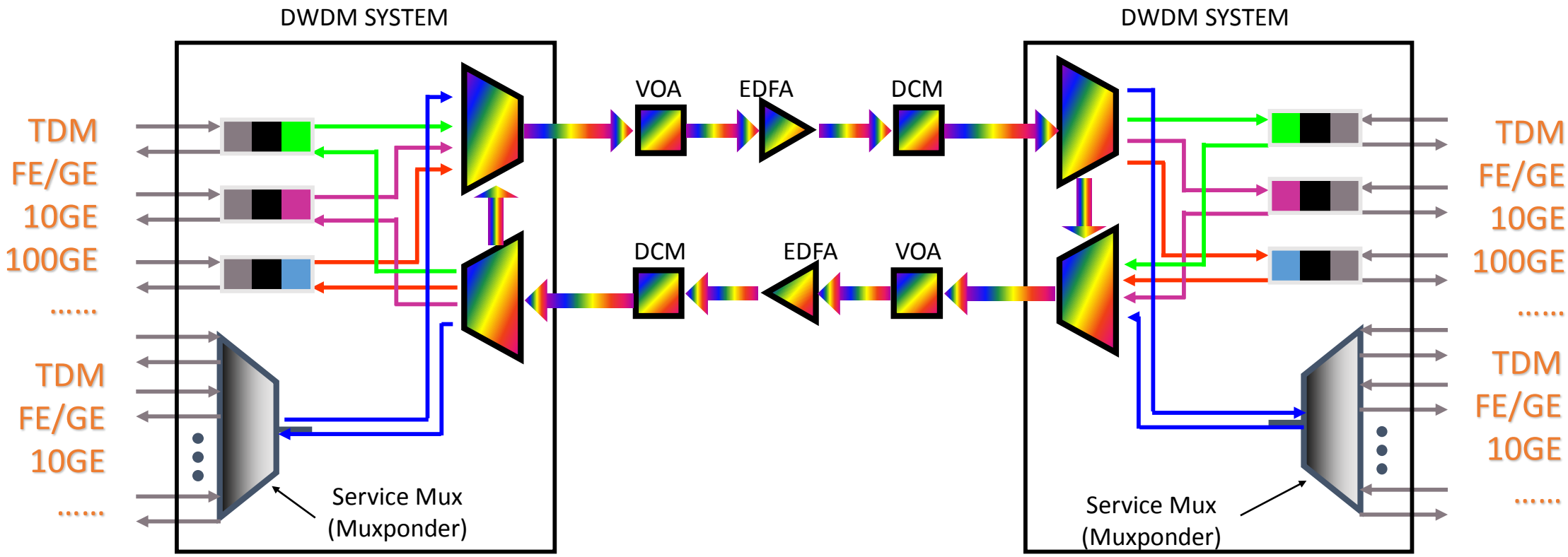
More DWDM Components



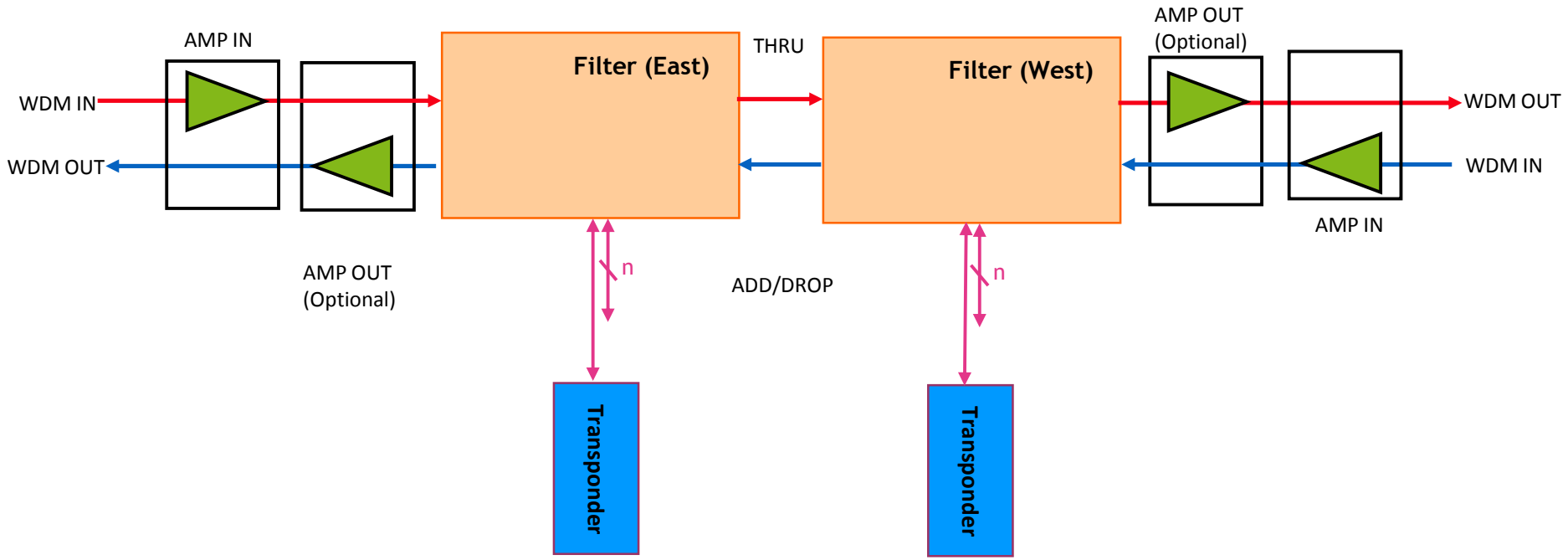




Typical DWDM Network Architecture

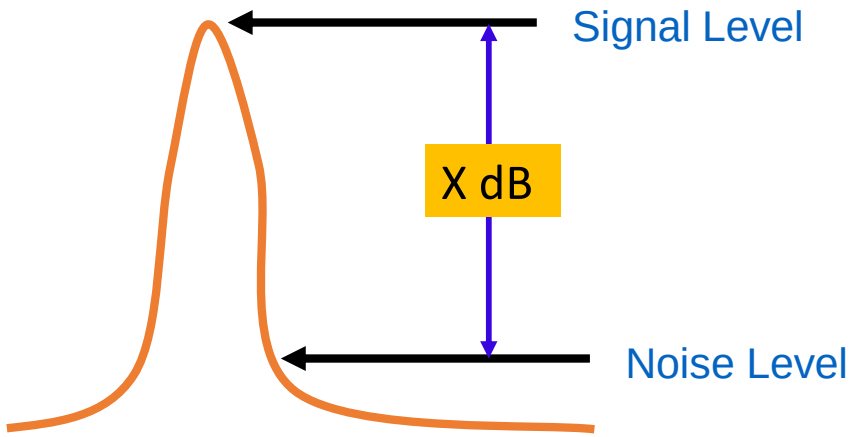


1830 PSS Product DWDM Optical Architecture



- Single/Dual Amplifier Configurations for Metro Applications
- Multiple Filtering (F/R/T) Options support different operational models and price points
- CWDM/DWDM options
- Tunable Transponders / Pluggable Line Side Transponders
- Ethernet / TDM / SAN client signal support
- Wavelength Tracker

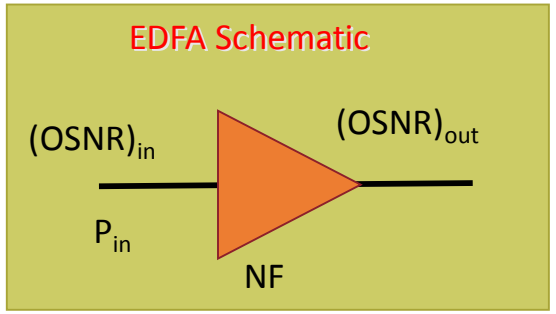
Optical Signal-to Noise Ratio (OSNR)



- Depends on :

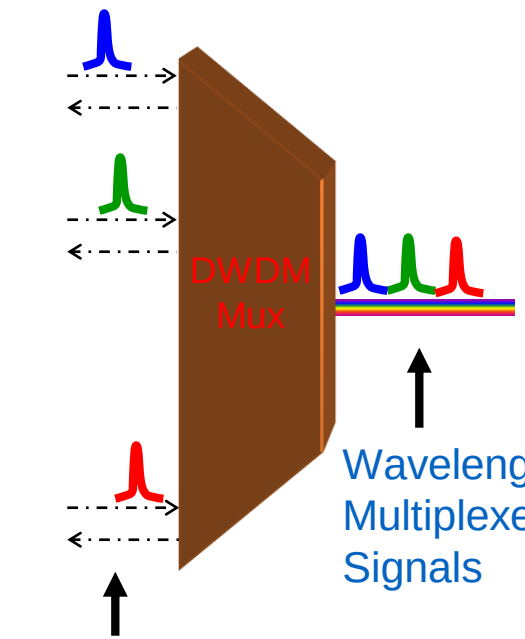
  Optical Amplifier Noise Figure:

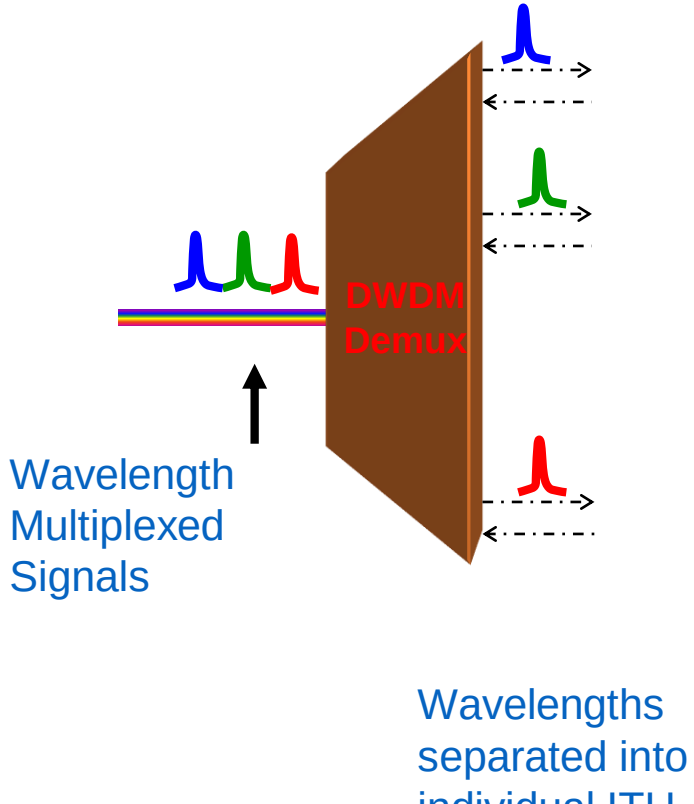
  $(OSNR)_{in} = (OSNR)_{out} NF$



- Target : Large Value for X

Multiplexer / Demultiplexer

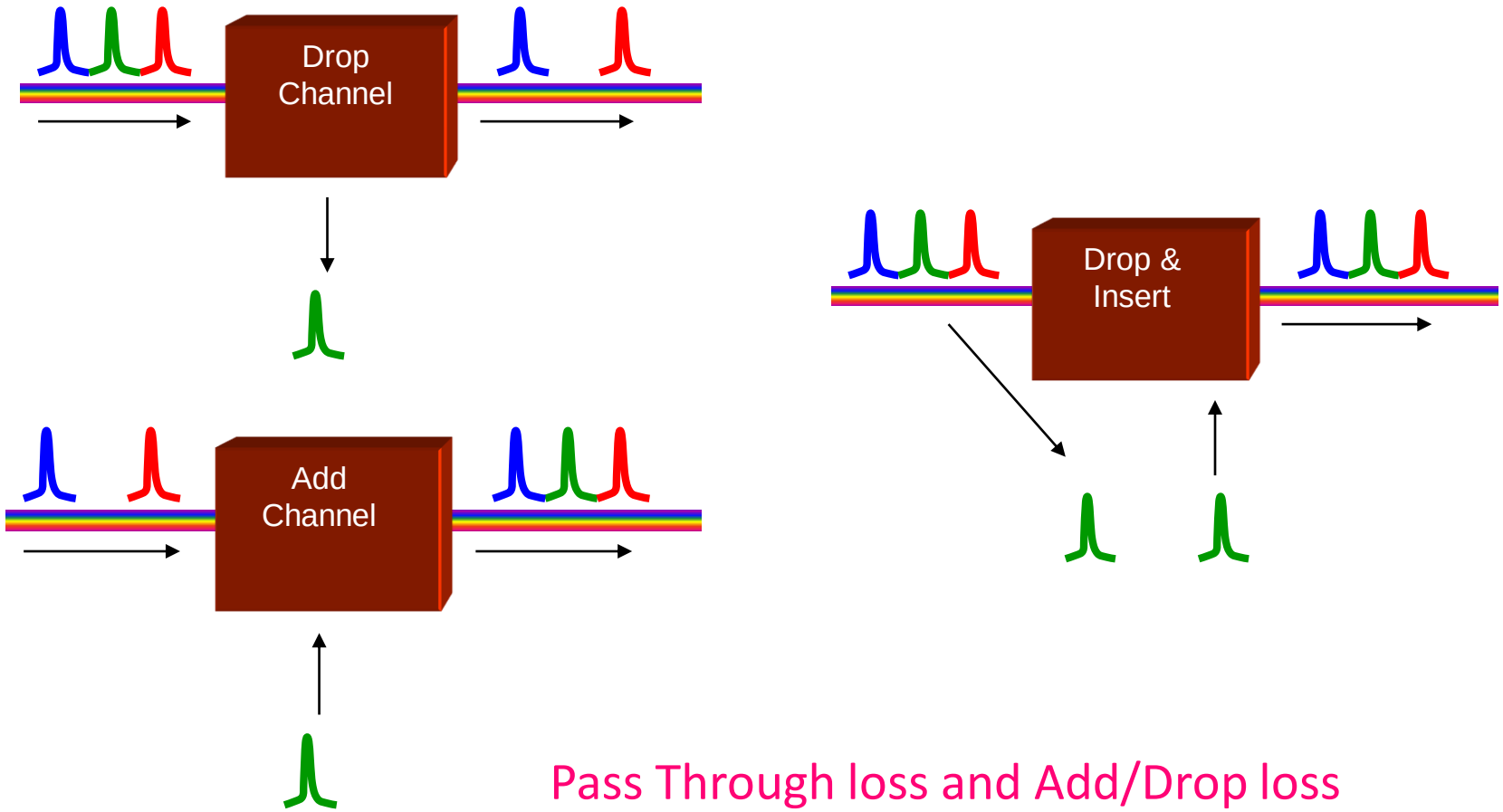




Loss of power for each Lambda

Optical Add/Drop Filters (OADMs)

OADMs allow flexible add/drop of channels

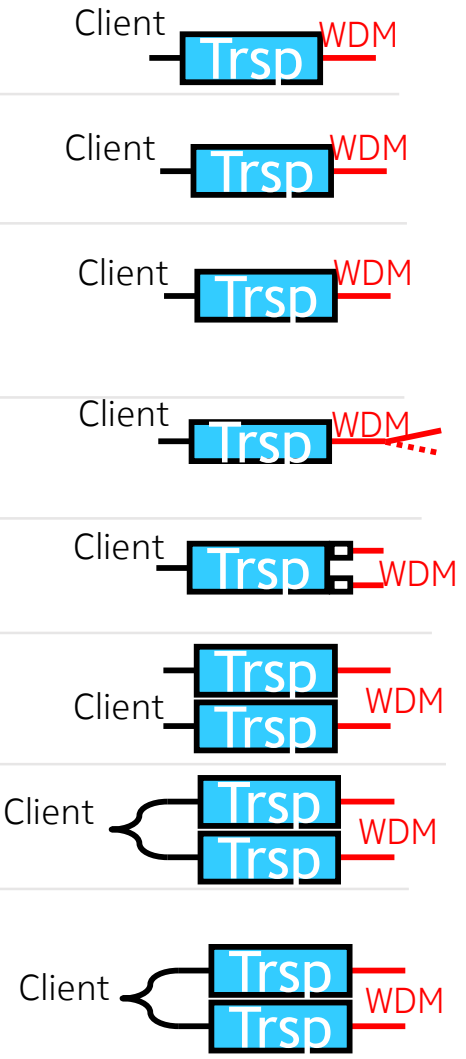


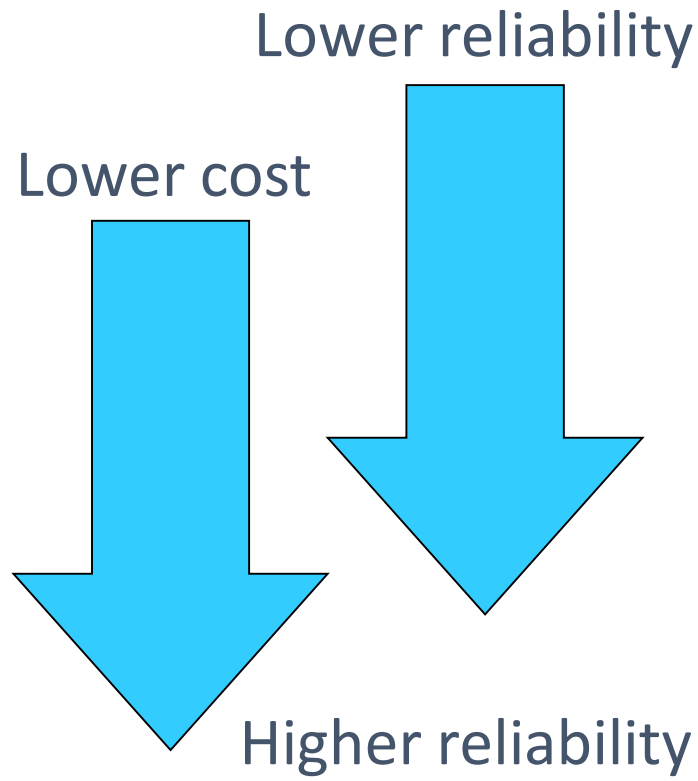
Pass Through loss and Add/Drop loss

DWDM Network protection

Protection:

- **No protection**: « unprotected »
- **OMSP/OLP protection**:
  => not protected transponder
- **SBR & GR protection**
  +Resources for Restoration
  => not protected transponder
- **OCh protection: « WDM 1+1 OPS »**
  => not protected transponder
- **E-SNCP: « WDM 1+1 »**
  => not protected transponder
- **Diverse routing: « Diverse »**
  => protected transponder
- **OSNCP: « Client 1+1 Y cable »**
  => protected transponder
- **PRC Protection: « Client 1+1 Y cable »**
  +Resources for Restoration
  => protected transponder

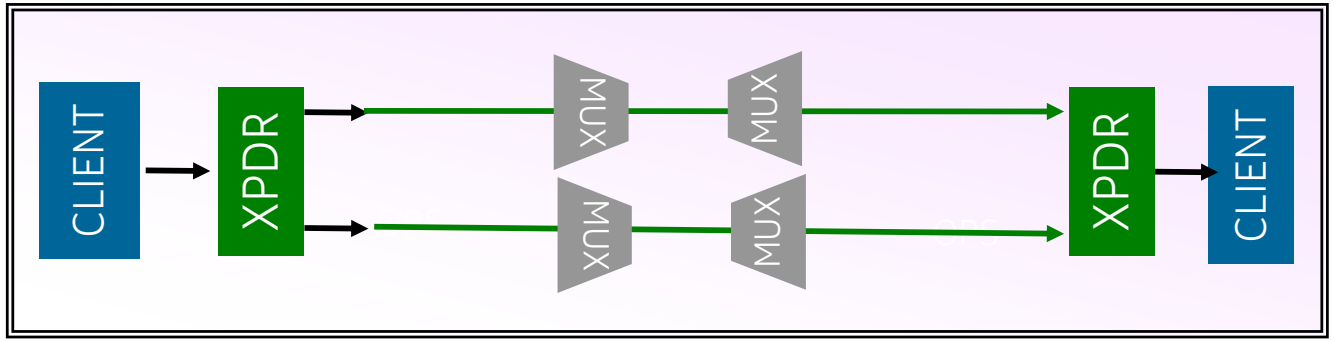




Protection in ETL DWDM Network

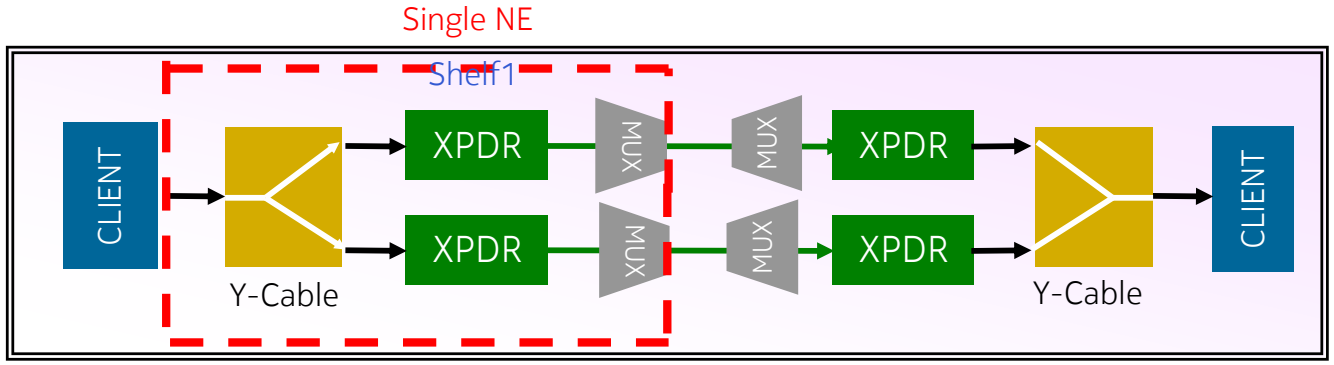
1+1 Electrical Subnetwork Connection Protection(E_SNCP):

- Against fiber, Amplifier and ROADM outage
- Applicable to Pluggable transponders



1+1 Optical Subnetwork Connection Protection (OSNCP with Y-cable) :

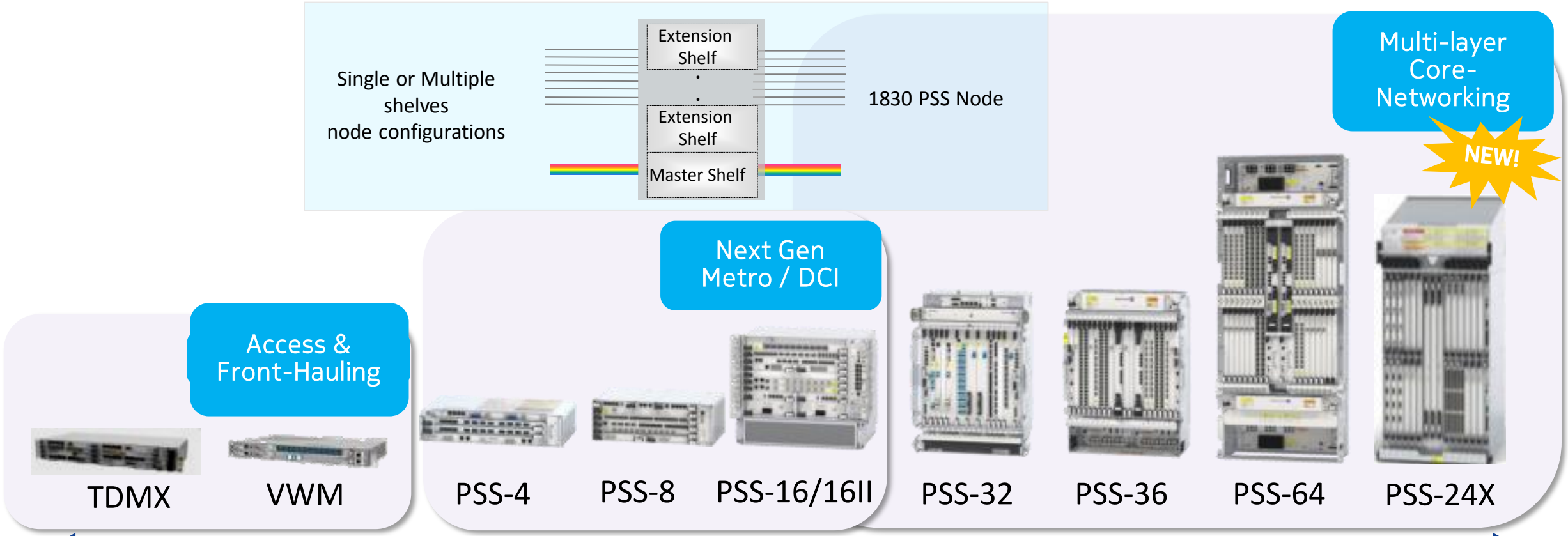
- Against fiber, Amplifier, ROADM, and Transponder outage
- Applicable to Tunable & Pluggable transponders (supported in GMPLS Network)



Nokia 1830 DWDM Portfolio

OPTICS 1830 PSS PRODUCT PORTFOLIO

- ACCESS, METRO, REGIONAL, LONG-HAUL AND CORE SWITCHING SOLUTIONS



End-to-end network management and control of 1830 PSS family with:

Optical Management System (OMS) + NSP Network Service Platform (SDN)

1830 PSS METRO PLATFORMS

- EFFICIENTLY ADDRESSING METRO REQUIREMENTS

2RU

1830 PSS-4

3RU

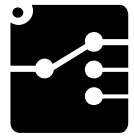
1830 PSS-8

8RU

1830 PSS-16/16II

ROADM D1
ROADM D2
ROADM D3
ROADM D4

4 DEGREE ROADM



200G Line
20x10G I/O
20x10G I/O
200G Line

10G OTN ADM

20x10G I/O
5x100G I/O
500G line
20x10G I/O

10G &100G MUXPONDER

- Right-sized solution for all metro applications
- Compact integrated photonics with IROADM
- Pay as you grow scale (400G to 1.6Tb) with backpanel interconnections
- PSE powered 100G/200G/400G wavelength flexibility

800 Gb/s in 3RU: unique density in the market

2X Capacity Increase

~50% Less Footprint

~40% Power Savings

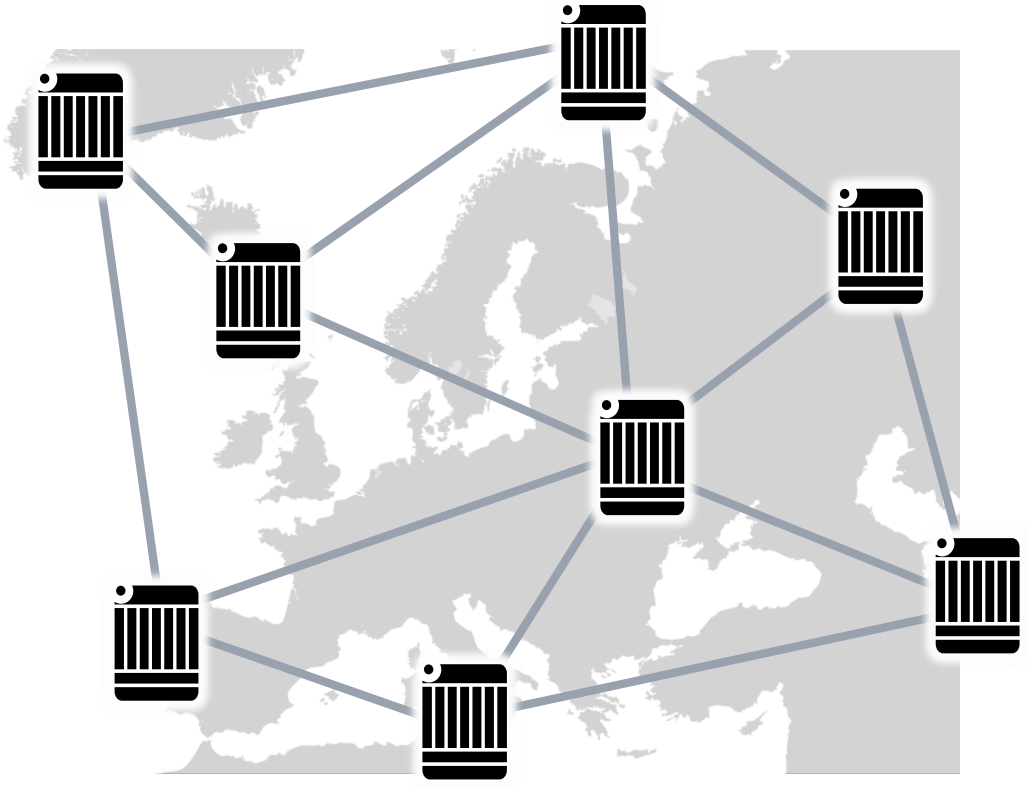
NOKIA OPTICAL NETWORKS INSTALLED BASE

- 50K+ WDM 1830PSS shelves
- 30K+ PTN SYSTEMS
- 900K+ SDH/SONET SYSTEMS
- 15K+ OCS/DCS SYSTEMS
- 500K+ KM SUBMARINE NETWORKS

ALL TOP 10 SERVICE PROVIDERS WORLDWIDE,
1000+ CUSTOMERS, 150+ COUNTRIES

Core / Long Haul

- Service provider transport cores are large complex networks spanning large distances, and supporting service multiplexing, switching, and transport across layers 0, 1, and 2.



- **Focus on:**
- Capital Efficiency
- Operational Efficiency
- Scalability

1830 PSS Core Platforms
Efficiently addressing long haul requirements

OTN/Packet

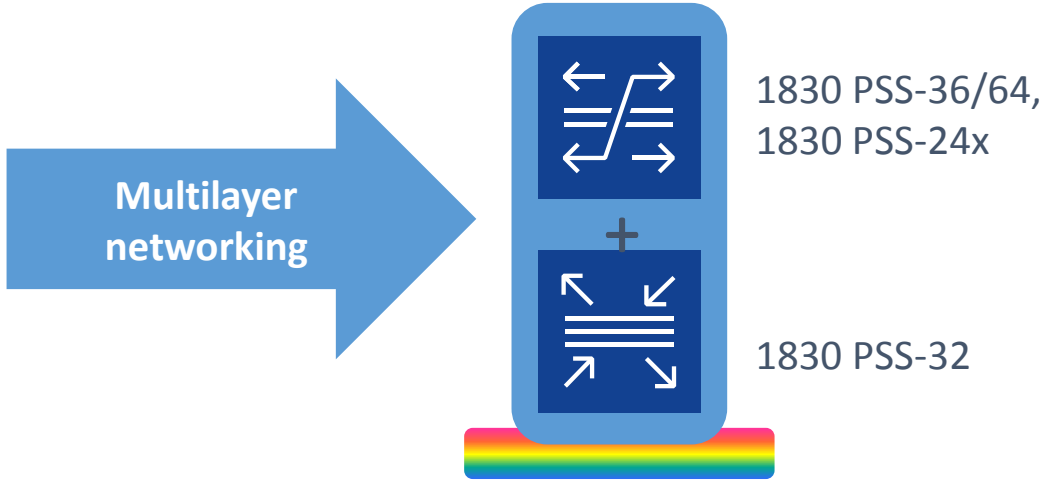
1830 PSS-36/64

1830 PSS-24x

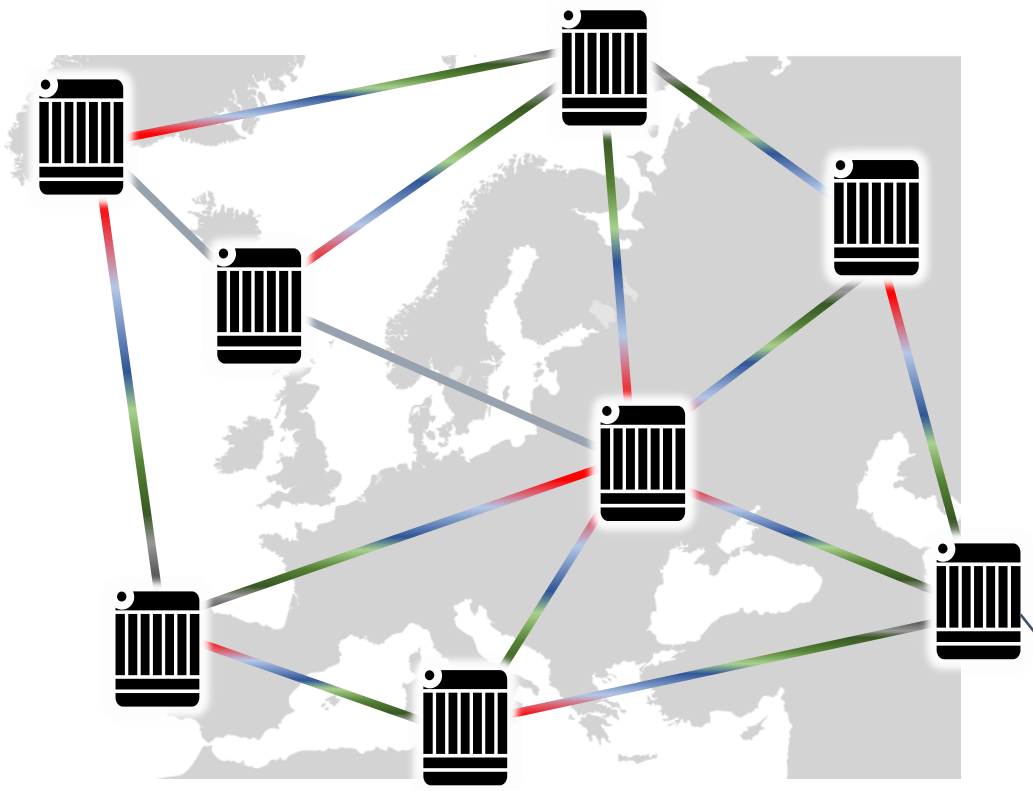
Photonic

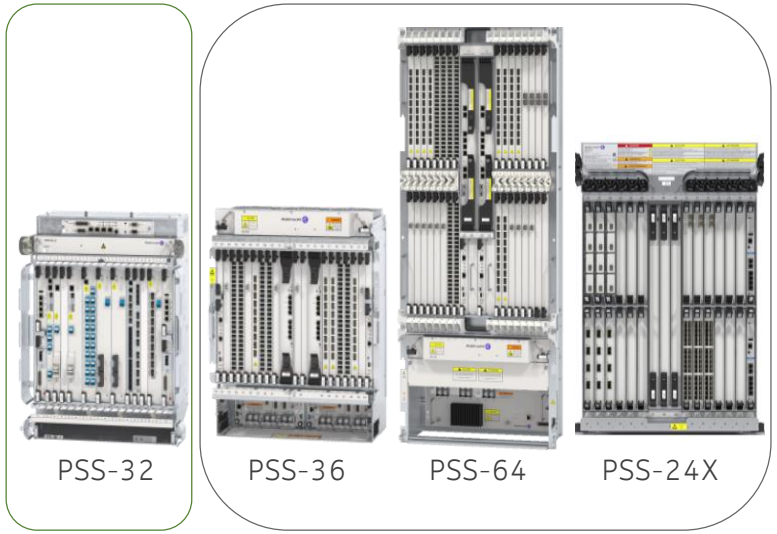
1830 PSS-32

- PSE-2 100G - 500G powered x-ponders and uplinks
- Massive packet/OTN and photonic scale
- Advanced C + L Band CDC-F wavelength routing support



Core / Long Haul – product positioning





WDM

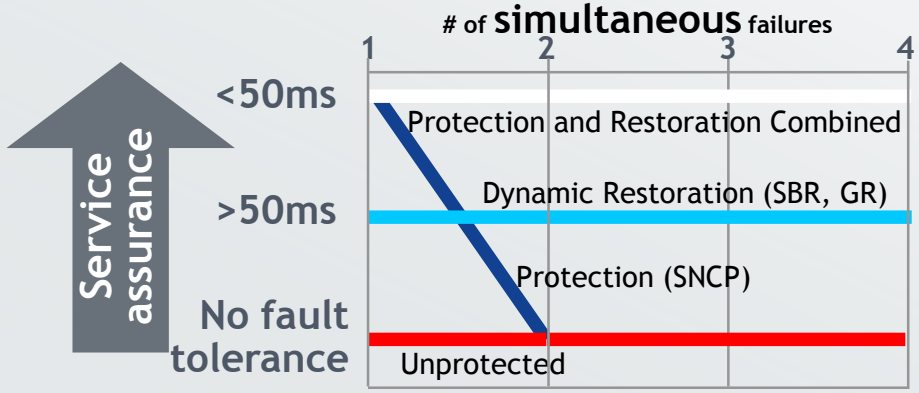
OTN

WDM-> Multiplexing 100G/200G/400G Lambdas over a single fiber pair and optical routing

OTN-> Multiplexing individual ODUx container of each 100G/200G/400G Lambdas

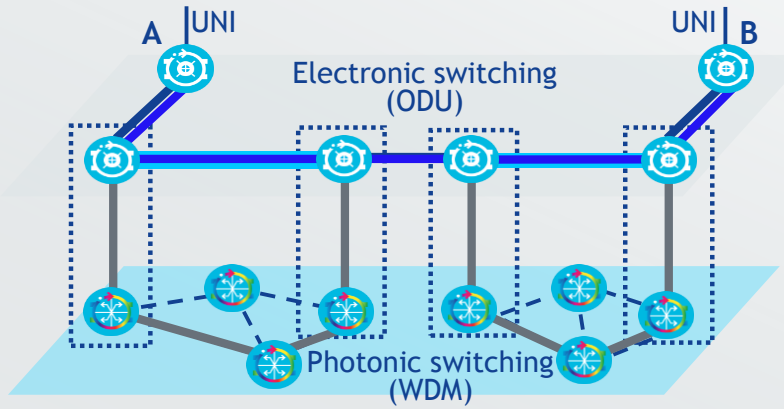
NETWORK INTELLIGENCE
GMPLS BENEFITS

INCREASED RESILIENCE, NETWORK MONETIZATION



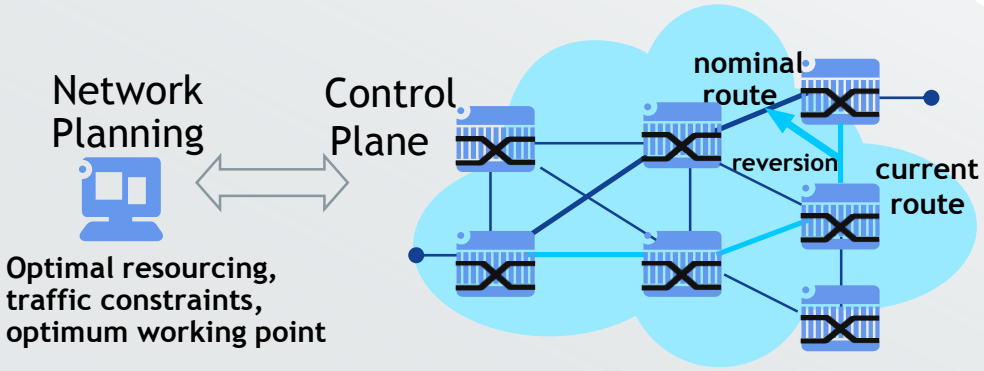
Multiple priority and pre-emption mechanisms

CROSS-LAYER AUTOMATION



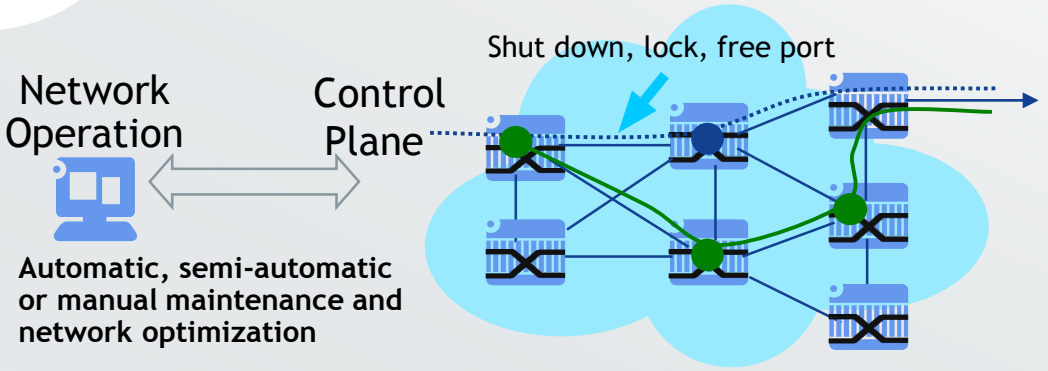
Scalable, coordinated resource usage and control

NOMINAL ROUTING AND REVERSION



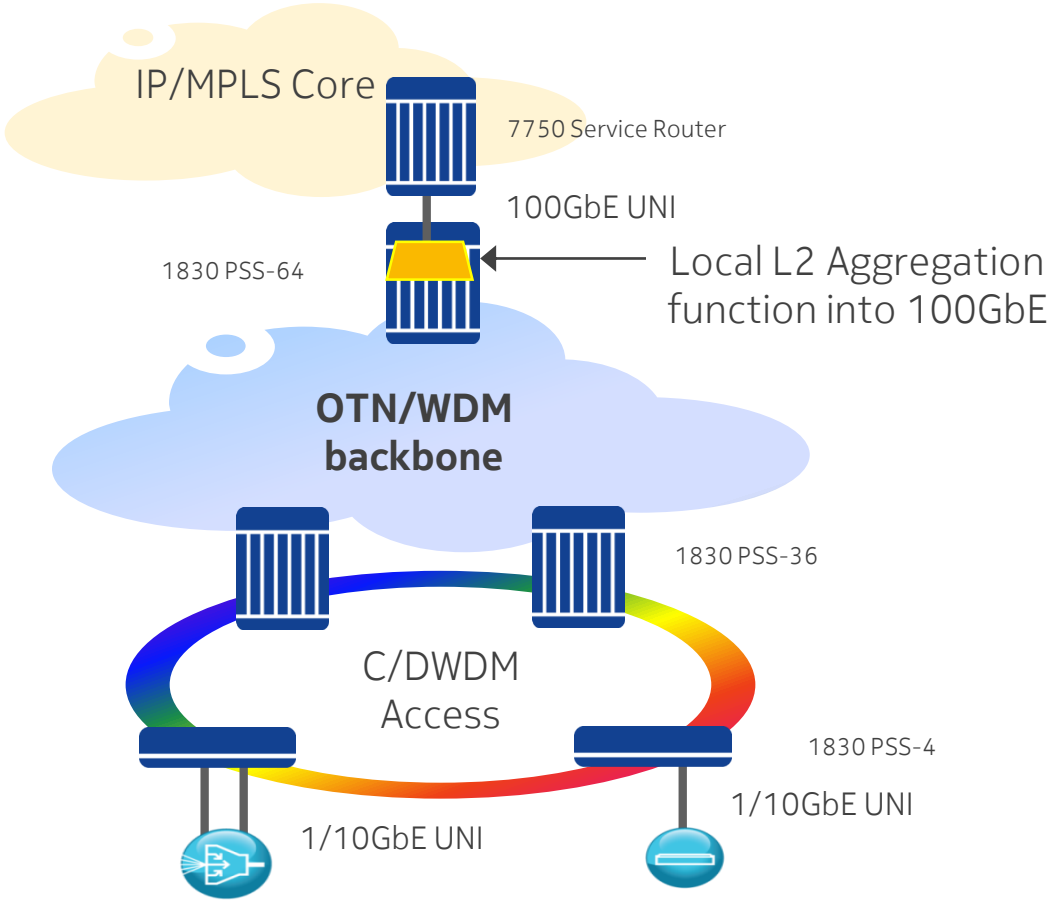
Planning consistency, avoid blocking, ensure optimization

SIMPLIFIED MAINTENANCE

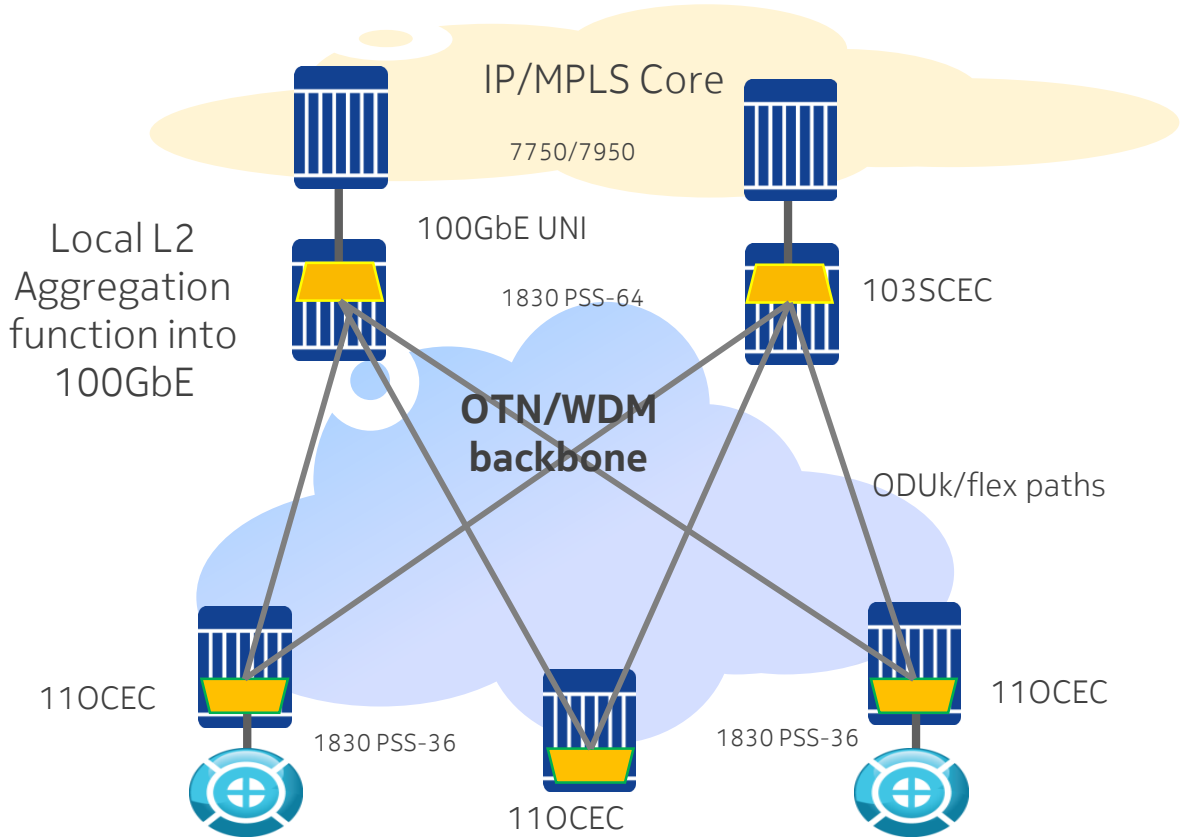


Maintenance activities and network re-optimization

Core Network application example #1
OTN/WDM aggregation and backbone



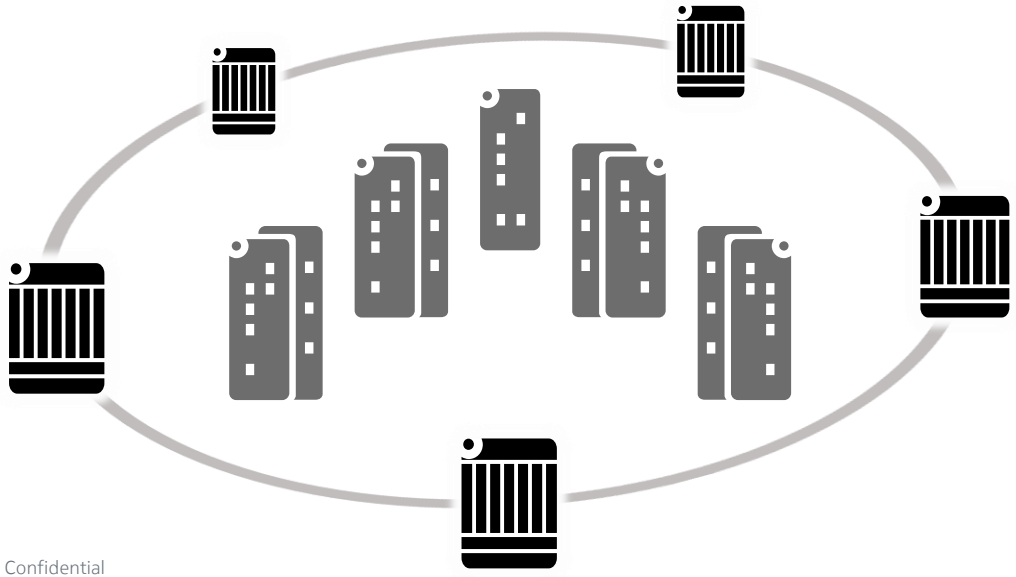
100GbE Aggregation in OTN Core with Packet/WDM in aggregation/access



IP/Optical Integration in Core with PE/P -routers interconnection via OTN

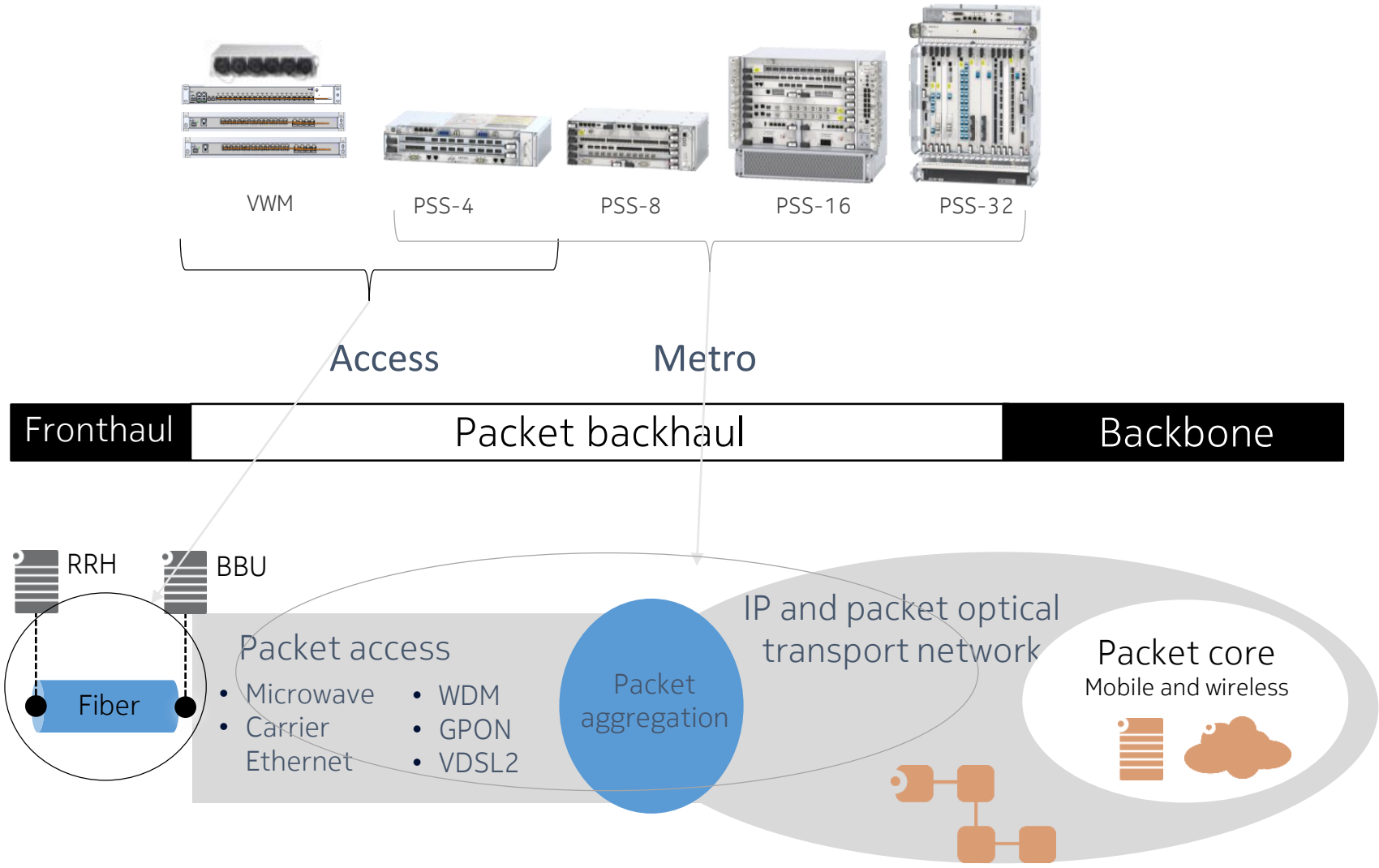
Metro Networks

- Metro networks are characterized by rapidly changing network topologies and services, as customers are churned and new services created. The trend towards cloud IT will further increase the dynamic nature of the demands on the network. Metro networks consist of a changing mix of legacy SONET/SDH and Carrier Ethernet services, with DWDM for data center interconnect and overall scale. Unlike Long Haul networks, the technological challenge of overcoming distance is less of an issue, so systems are purpose-built around compact size, ease of use, low power consumption, and low cost.



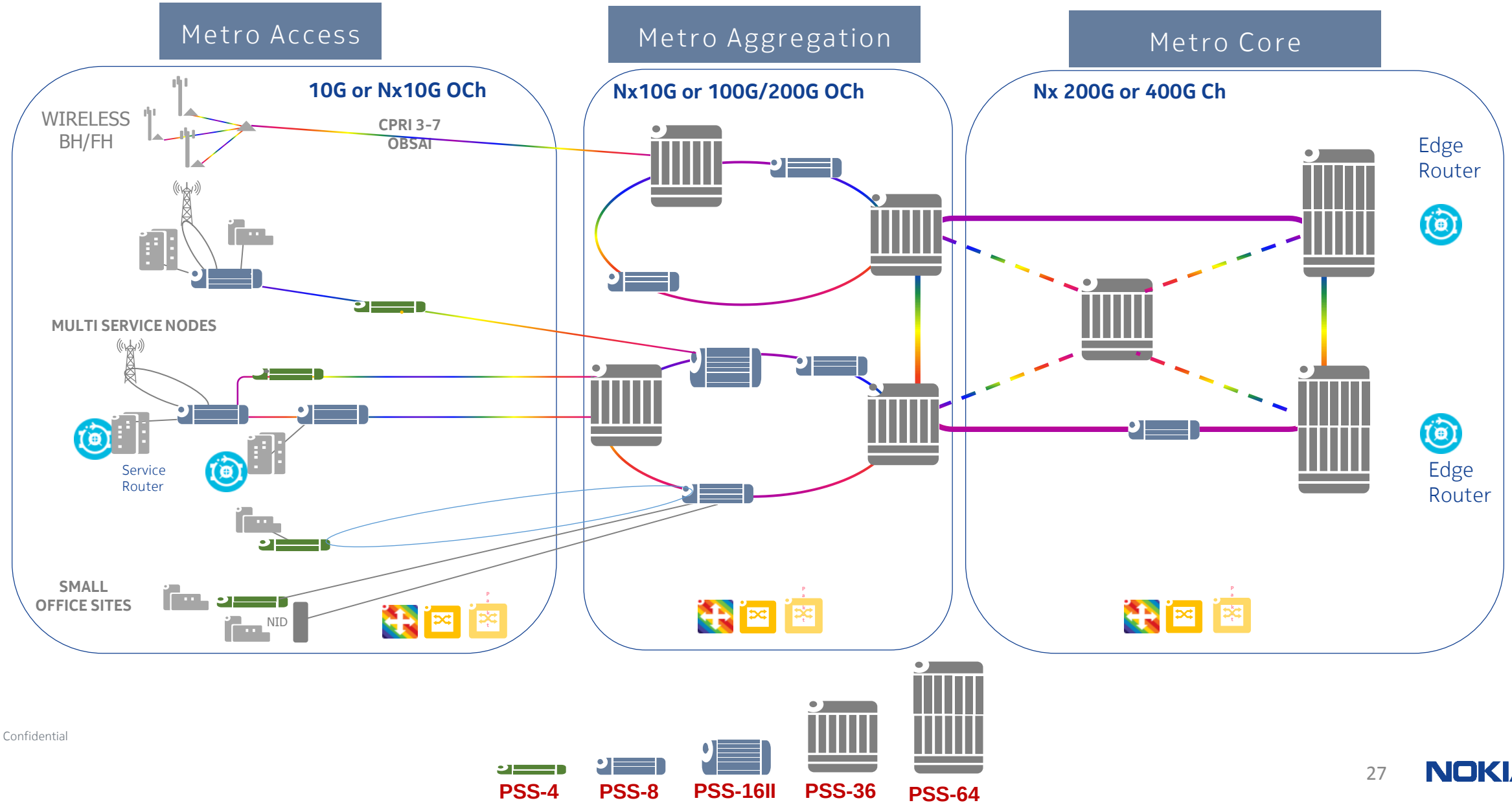
- **Focus on:**
- Space and power efficiency
- Starting small and growing
- Delivering converged, agile services

Access & Metro Portfolio and Solutions for Mobile Networks

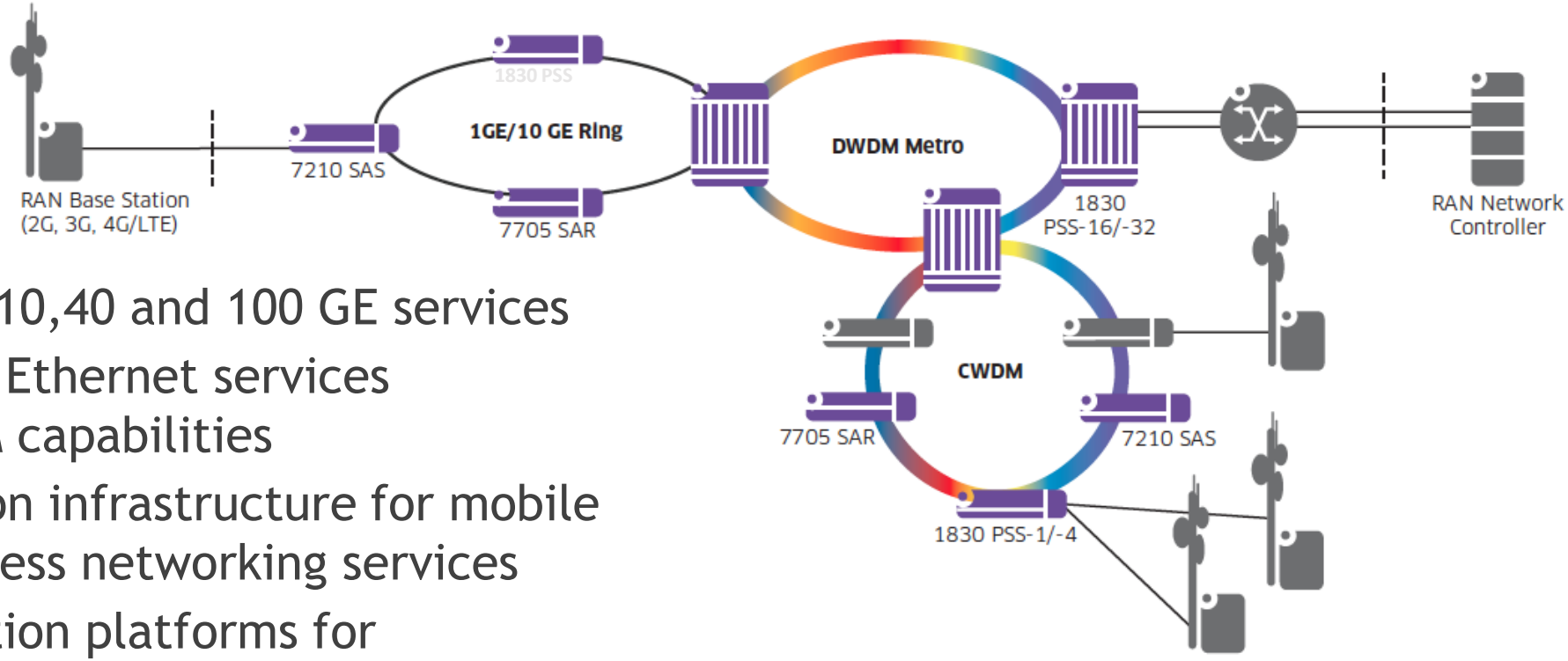


1830 PSS METRO REFERENCE BLUEPRINT

Packet Switched Function
OTN Switched Function
Photonic Switched Function



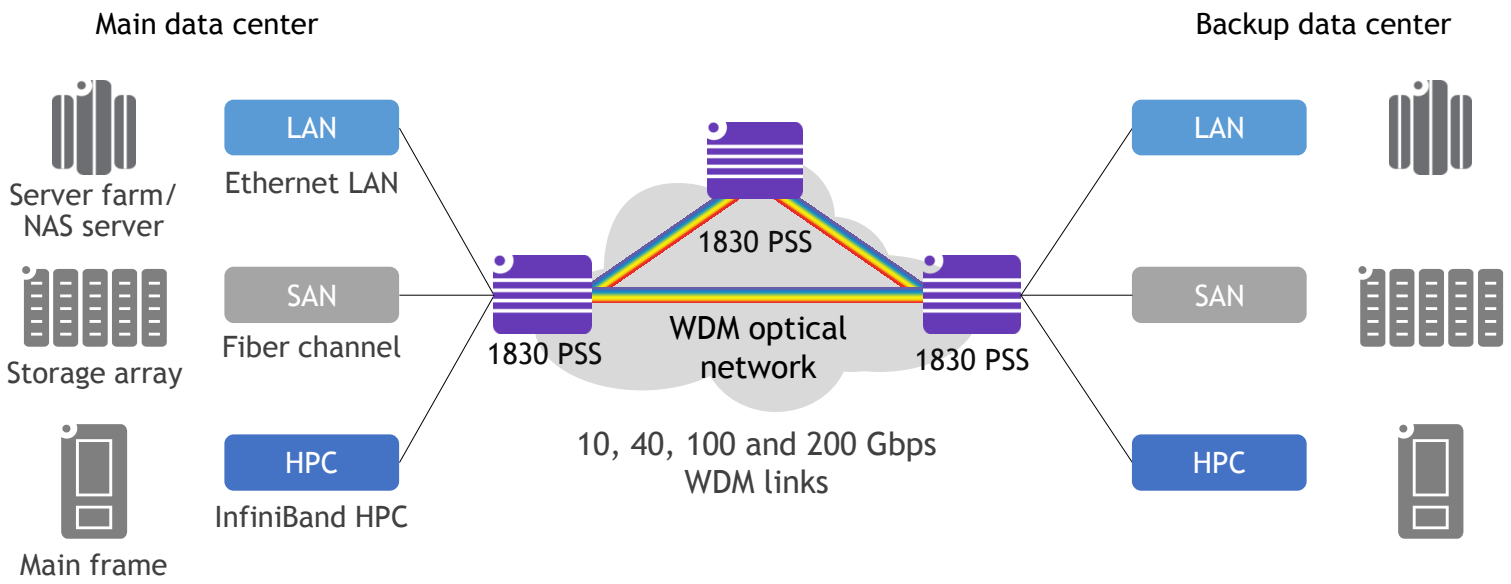
Network application example #1
Metro Aggregation and Transport of Mobile Network



- Massive scaling to 100G+ and high-density 1,10,40 and 100 GE services
- SLA-backed Carrier Ethernet services with advanced OAM capabilities
- Common aggregation infrastructure for mobile transport and business networking services
- Optimized aggregation platforms for Carrier Ethernet, OTN and WDM switching

Scalability, Reliability, Efficiency… plus Fixed-Mobile Convergence

Network application example #2
Data center interconnect



- Support for synchronous and asynchronous DCI applications
- Scalable bandwidth from 10G (CWDM) up to 200G per wavelength (DWDM)
- Low latency with latency optimization
- Transport-grade reliability and protocol independence
- High utilization with flexibility
- Demonstrated support for OpenFlow™ extensions for SDN Transport

HIGH PERFORMANCE OPTICAL

- CWDM or DWDM optical transport
- Short-, medium- and long-reach WDM
- Supports Ethernet, Fibre Channel (FC) and InfiniBand client interfaces

FEATURES AND BENEFITS

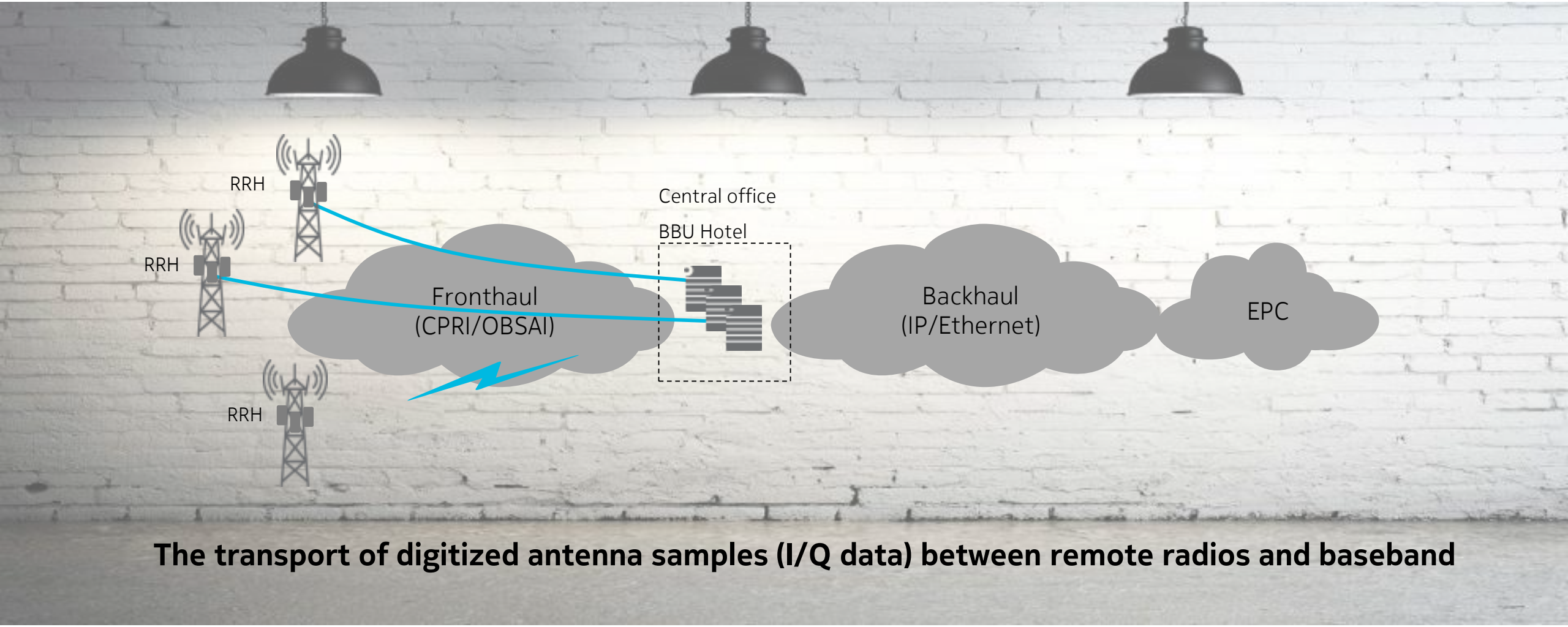
- Efficient λ switching (T-ROADM)
- Full Layer 2 Ethernet services
- Automated provisioning and restoration using G-MPLS lowers OPEX

LATENCY OPTIMIZATION

- Optimizes synchronous DCI depending on distance between sites
- On-demand latency measurement to check end-to-end round trip delay

OPTICAL WDM IS THE TECHNOLOGY OF CHOICE FOR TIER 1 SYNCHRONOUS AND ASYNCHRONOUS DCI APPLICATIONS

Network application example #3
Mobile Fronthaul

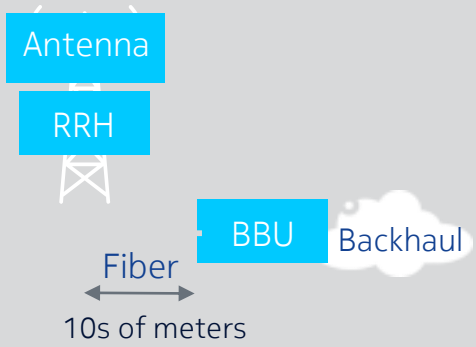


The transport of digitized antenna samples (I/Q data) between remote radios and baseband

Network application example #3
Network migration to Centralized RAN and the need for fronthaul

Distributed base station

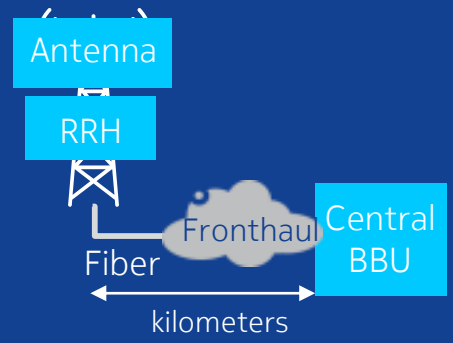
Distributed RAN



- RRHs near antenna reducing loss/power
- IP/Eth backhaul

Centralized base station

Centralized RAN



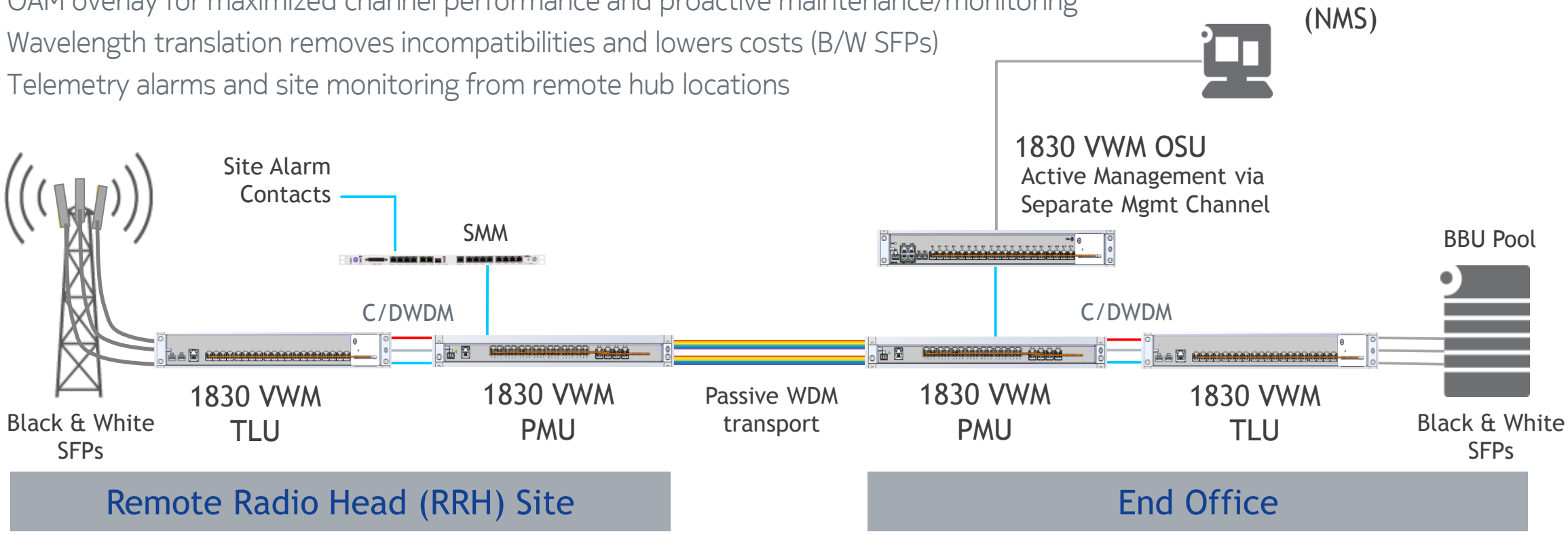
- Centralization of BBU
- BBU pooling (coordinated RAN)
- Fronthaul

Need architectural innovation to drive lower cost, better performance and scale

Network application example #3
Mobile Fronthaul Solution for LTE-Advanced and C-RAN

Versatile Solution Maximizing Fiber Utilization and Performance

- Scalable: supports all CPRI/OBSAI rates with maximum reach and minimal footprint and power
- OAM overlay for maximized channel performance and proactive maintenance/monitoring
- Wavelength translation removes incompatibilities and lowers costs (B/W SFPs)
- Telemetry alarms and site monitoring from remote hub locations



Flexible, scalable and fully managed end-to-end mobile fronthaul solution

Network application example #4
Network Transformation for SDH integration with WDM

1830 PSS-36/64

- 1.2Tb SDH (VC-4n)
- 384 x STM1/4/16
- 160 x STM-64

3G/4G IP-based Controllers/GWs

3G RNC or 2G MSC

n x E1

1830 TDMX

10GbE LAG

1830 PSS-16/32 Head-End Node

1830 PSS-36/64

WDM OTN

1830 PSS-4

1830 PSS-4

y x GbE

1830 TDMXC

n x E1

Data CE

BTS/NodeB or PBX or E1 LL

BTS/NodeB

1830 TDMXC

y x FE/GbE + n x E1

SDH CPE

y x FE/GbE + n x E1

Business Ethernet + E1

Network interface

- 2 x STM-1/4/16

Maximum customer interfaces per chassis

- 252 x E1/T1
- 18 x E3/T3
- 12 x STM-1/4
- 48 x FE
- 6 x GE

1830 TDMX

OMS

Applications: mobile backhaul, business services, SDH migration

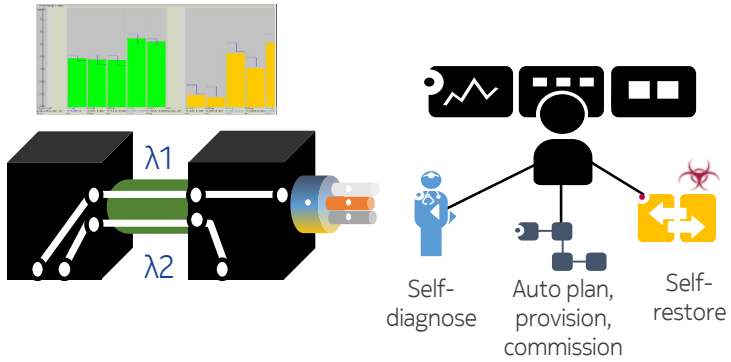
SUMMARY
Nokia KEY DIFFERENTIATOR:
VERTICALIZATION IN-HOUSE INNOVATION IN SILICON & SOFTWARE

PSE

400G PSE COHERENT OPTICS ENGINE

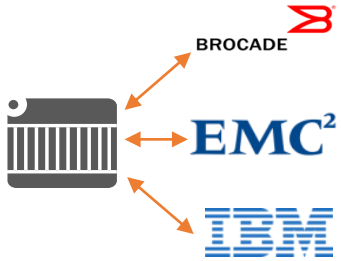
HIGH CAPACITY TB ELECTRONIC SWITCHING (OTN)

FLEXIBLE PHOTONIC SWITCHING (WSS)



INTEGRATED WAVELENGTH TRACKER

GMPLS CONTROL PLANE/SDN



DCI, CPRI, ENCRYPTION & SECURITY

SCALE CAPACITY

MAXIMIZE UTILIZATION

INCREASE AGILITY

NEW SERVICES

FEATURES

COST & RISK

DWDM solution and project implementation

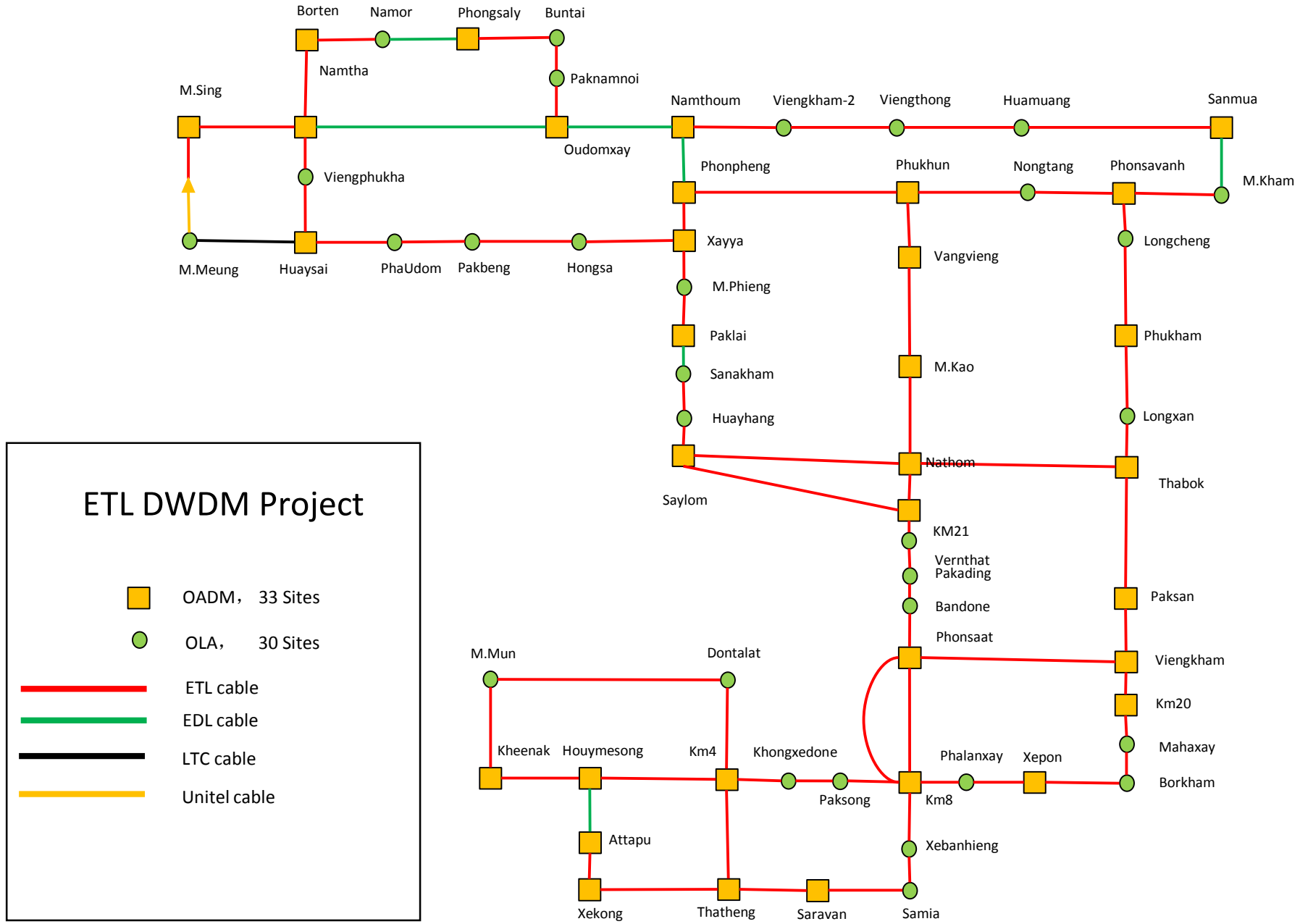
Nokia Shanghai Bell

Wu Xiaobin

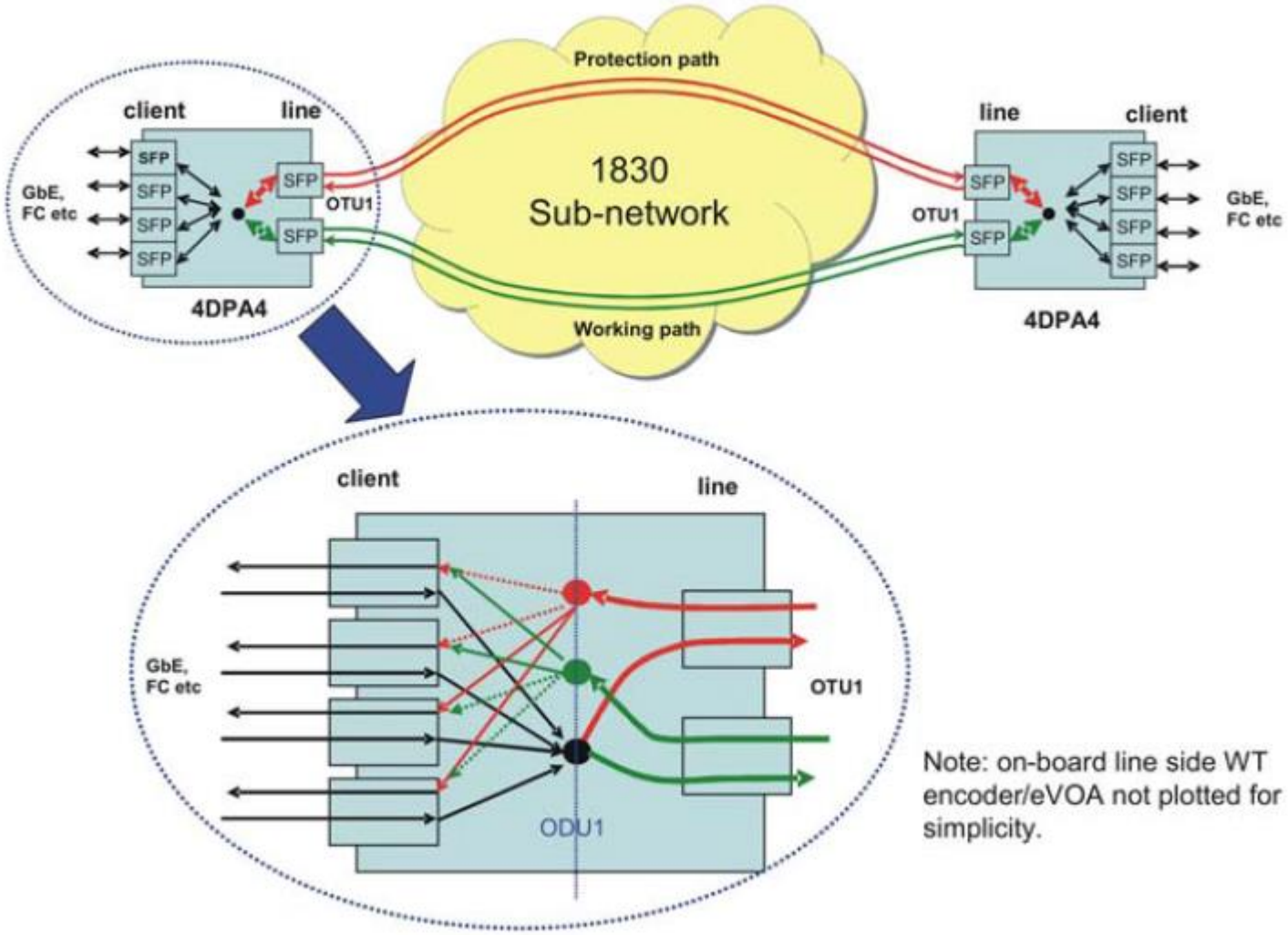
Oct 2018

DWDM solution introduction

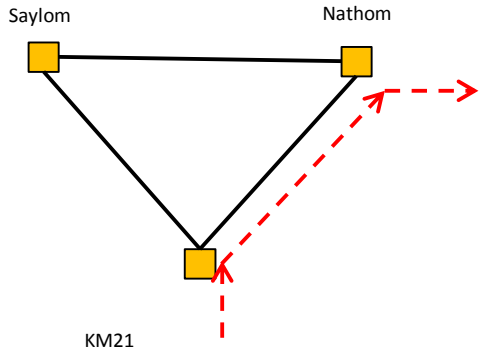
【 Topology Map】



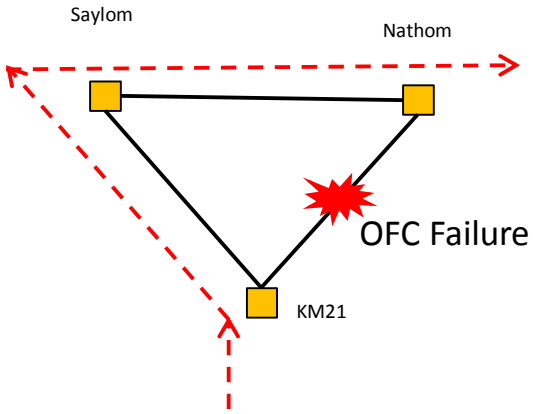
【E-SNCP Protection】



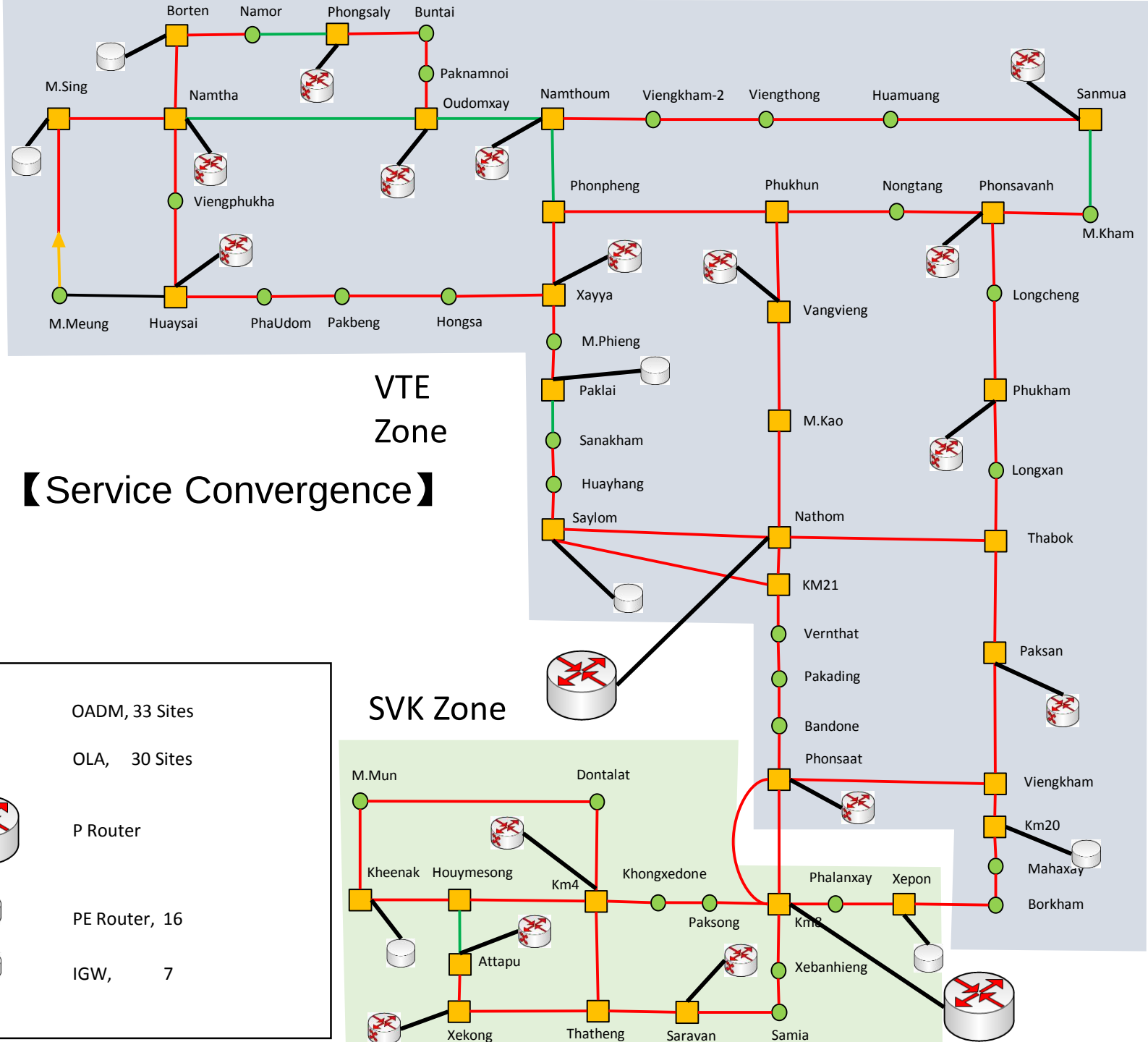
【 E-SNCP Protection Example】



Normal Status



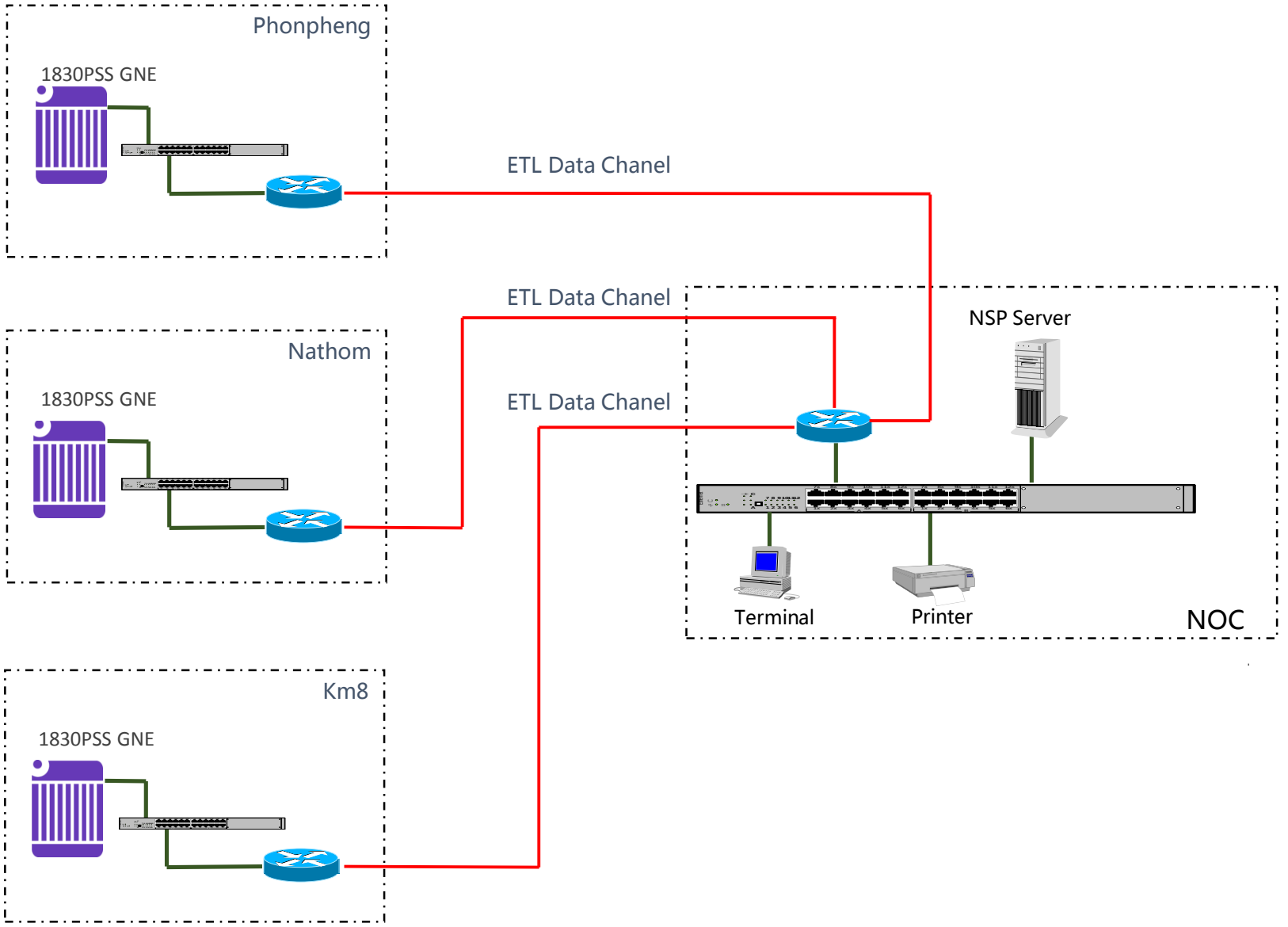
Switching Status



【 Service Requirement】

A		Z	Rate	Quantity
Saylom		Nathom	100G	2
Km8		Nathom	100G	4
M.Sing		Nathom	10G	1
Borten		Nathom	10G	1
M.Phieng		Nathom	10G	1
Saylom		Nathom	10G	1
Km20		Nathom	10G	1
Huaysai		Nathom	10G	2
Namtha		Nathom	10G	2
Phongsaly		Nathom	10G	2
Oudomxay		Nathom	10G	2
Namthoum		Nathom	10G	2
Xayya		Nathom	10G	2
Vangvieng		Nathom	10G	2
Phonsavanh		Nathom	10G	2
Sanmua		Nathom	10G	2
Phukham		Nathom	10G	2
Paksan		Nathom	10G	2
Phonsaat		Nathom	10G	2
Xepon		Km8	10G	1
Kheenak		Km8	10G	1
Saravan		Km8	10G	2
Xekong		Km8	10G	2
Attapu		Km8	10G	2
Km4		Km8	10G	2

【 DCN Design】



DWDM Project Implementation And Cooperation

【Survey phase】-NSB Team

- Survey all sites
- Provide survey report

include:

1. Photos of site view
2. Rack installation location
3. Existing problem of the site
4. Length of the power cable and OFC
5. Site drawing

【Survey phase】-ETL Support

- Provide the detailed data of each span loss
- Provide the support to the NSB team to complete the survey
- Set out to solve the issues that be found during the survey

For example:

1. No spare space for the DWDM rack
2. No spare interface in the power cabinet
3. The problematic cable must be repaired as soon as possible
4. Renovate the existing rack
5. Insufficient number of breaker in the power cabinet
6. The redundancy of power cabinet is insufficient

【Survey phase】-ETL Support

Issue 1:Phonsssat
Solution :remove useless rack

Issue 2:

Issue 3:

【Survey phase】-ETL Support

Issue 4: Phukham

Issue 5:

Issue 6:

【Installation phase】**-NSB Team**

- Transport the equipment to the site
- Equipment installation

1. Fix the rack
2. Insert all of the board following the design
3. Laying the power cable and fiber

- Equipment power on
- Configure NE information

【 Installation phase】**-ETL Support**

- Send a local staff to supervise
- Provide the necessary support to the installation team
- Cooperate the installation team to switch power on
- Solve the OFC issue.

【Installation phase】-Implementation Plan

➢ Regional division

We will have 3 teams to carry out the installation, and the installation will last for 60 days.

Zone	No.	Province	Site Name	Site Type	Equipment Type	Quantity	Total
North	1	PSL	Paknamnoi	OA	PSS4	2	OA:10 OADM:10
			Buntai				
			Phongsaly	OADM	PSS32	1	
	2	LNT	Viengphukha	OA	PSS8	1	
			Borten	OADM	PSS32	3	
			Namtha				
			M.Sing				
	3	BOK	M.Meung	OA	PSS32	1	
			Huaysai	OADM	PSS32	1	
	4	LPB	Viengkham-2	OA	PSS8	1	
			Phonpheng	OADM	PSS32	2	
			Namthoum				
	5	OUX	PhaUdom	OA	PSS8	3	
			Pakbeng		PSS4		
			Namor				
			Oudomxay	OADM	PSS32	1	
	6	XYL	Hongsa	OA	PSS4	2	
			M.Phieng				
			Xayya	OADM	PSS32	2	
			Paklai				

Team 1: Northern Region

Including the following province : PSL, LNT,BOK,LPB,OUX,XYL

Quantity of sites :20

Midland	7	HUP	Huamuang	OA	PSS4	2	OA:10 OADM:13
			Viengthong		PSS32		
			Sanmua	OADM	PSS32	1	
	8	XKH	M.Kham	OA	PSS8	2	
			Nongtang		PSS4		
			Phonsavanh	OADM	PSS32	1	
	9	VTP	Sanakham	OA	PSS4	3	
			Longcheng				
			Longxan				
			M.Kao	OADM	PSS32	4	
			Vangvieng				
			Phukhun				
			Phukham				
	10	BLX	Vernthat	OA	PSS4	2	
			Pakading				
			Thabok	OADM	PSS32	4	
			Paksan				
			Viengkham				
			Km20				
	11	VTE	Huayhang	OA	PSS4	1	
			Saylom	OADM	PSS32	3	
			Nathom				
			KM21				

Team 2: Central Region

Including the following province : HUP,XKH,VTP,BLX,VTE

Quantity of sites :23

South	12	KHM	Bandone	OA	PSS4	2	OA:10 OADM:10
			Mahaxay		PSS32		
			Phonsaat	OADM	PSS32	1	
	13	SVK	Borkham	OA	PSS8	4	
			Xebanhieng				
			Paksong		PSS32		
			Phalanxay				
			Xepon	OADM	PSS32	2	
			Km8				
	14	SRV	Samia	OA	PSS4	2	
			Khongxedone				
			Saravan	OADM	PSS32	1	
	15	CPS	Dontalat	OA	PSS4	2	
			M.Mun				
			Kheenak	OADM	PSS32	3	
			Km4				
			Houymesang				
	16	XEK	Xekong	OADM	PSS32	2	
			Thateng				
	17	ATP	Attapu	OADM	PSS32	1	

Team 3: Southern Region

Including the following province :KHM,SVK,SRV,CPS,XEK,ATP

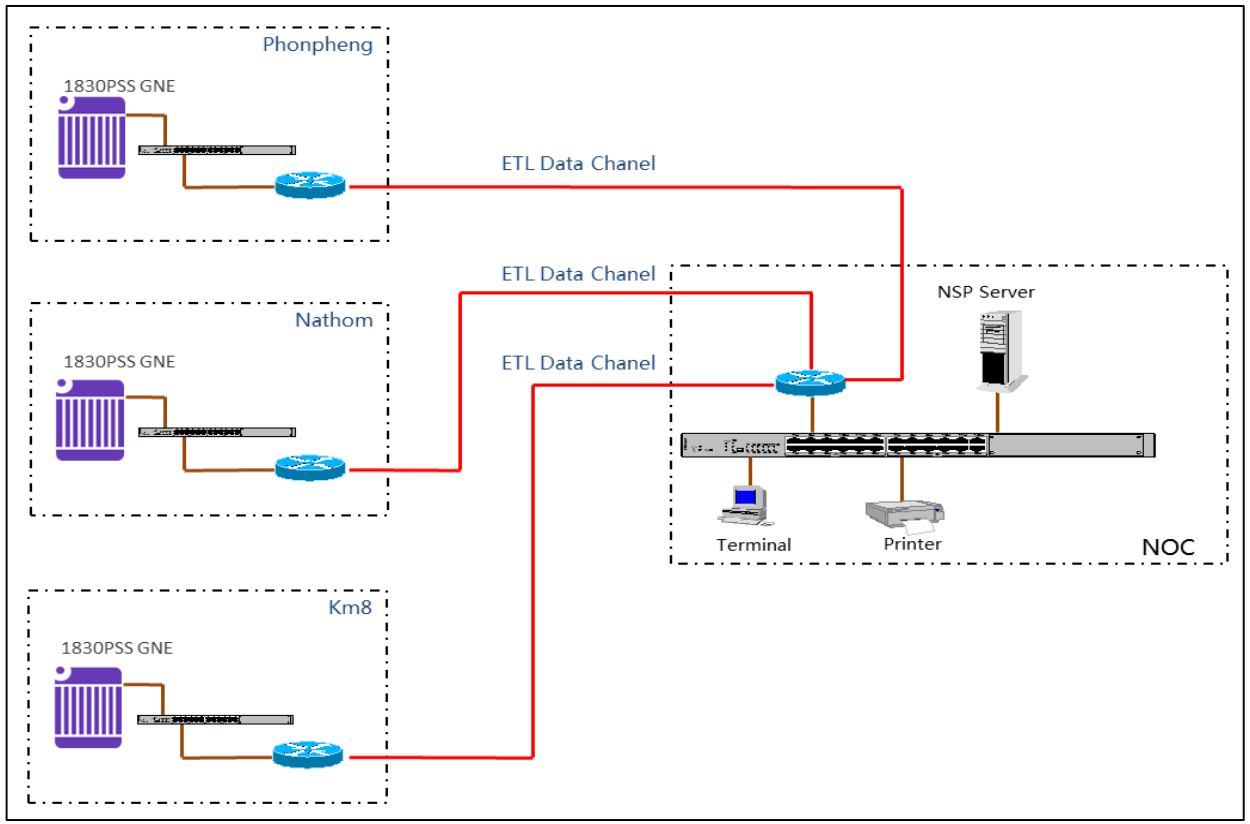
Quantity of sites :20

【Commissioning phase】-NSB Team

- Install Nokia Network Services Platform(NSP) in NOC
- Planning the route of the OTU2&OTU4 channel
- Configure the OTU2&OTU4 channel between PE site and P&IGW site on NSP
- Test the performance of the OTU2&OTU4 channel
- Upload the service to the DWDM equipment
- Handling the remaining issue during the installation phase

【 Commissioning phase】-ETL Support

- Provide the location of the server and workstation
- Provide the LAN ports and IP address of GNE sites



- Ensure the routings between GNE and server are working well
- Cooperate the NSB team to test the OTU2&OTU4 channel

【Acceptance phase】**-NSB Team**

- Make the final rectification of the remaining issues
- Organize the relevant ETL staff to attend the training of the 1830PSS and NSP
- Issue the Provisional Acceptance Test

【 Acceptance phase】**-ETL Support**

- Attend the training of 1830PSS and NSP daily operation
- Sign the Provisional Acceptance Test

IP technology and product overview

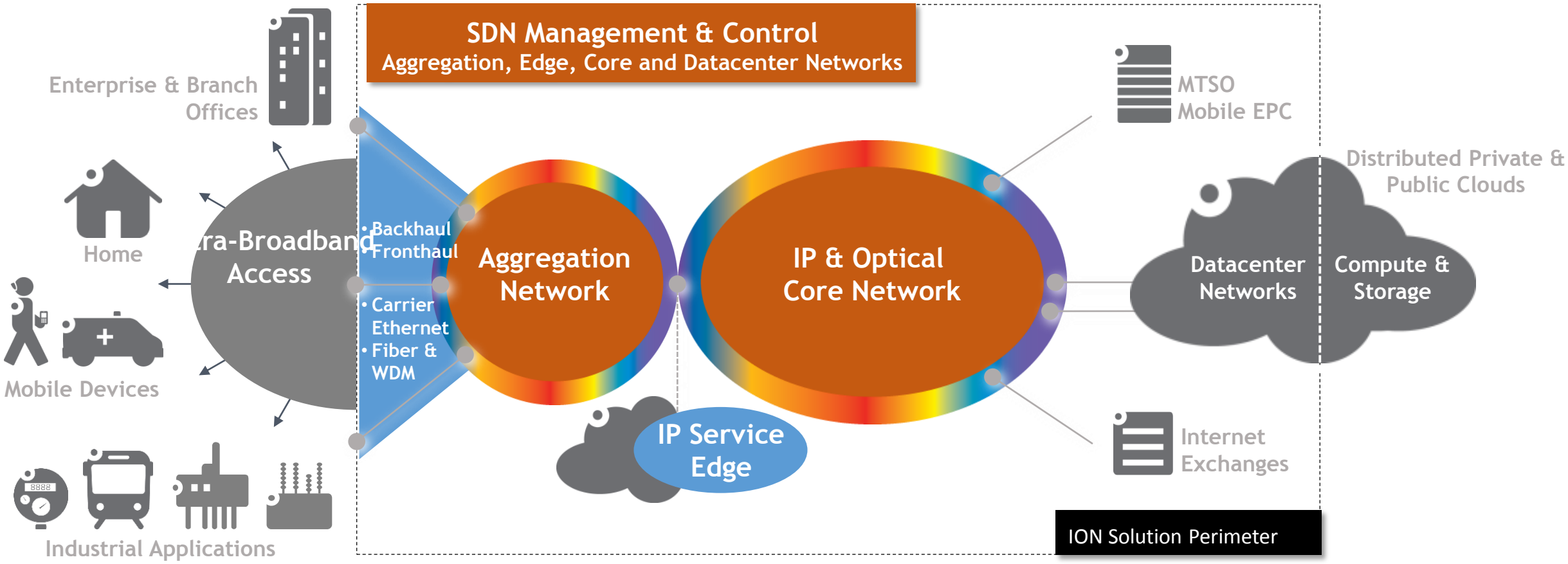
Nokia Shanghai Bell

Chen Chuanxiang

Oct 2018

IP & Optical Network Infrastructure

IP & Optical Network Infrastructure



Secure and reliable connections amongst users, devices, datacenters, 'things' and their content and applications in the cloud

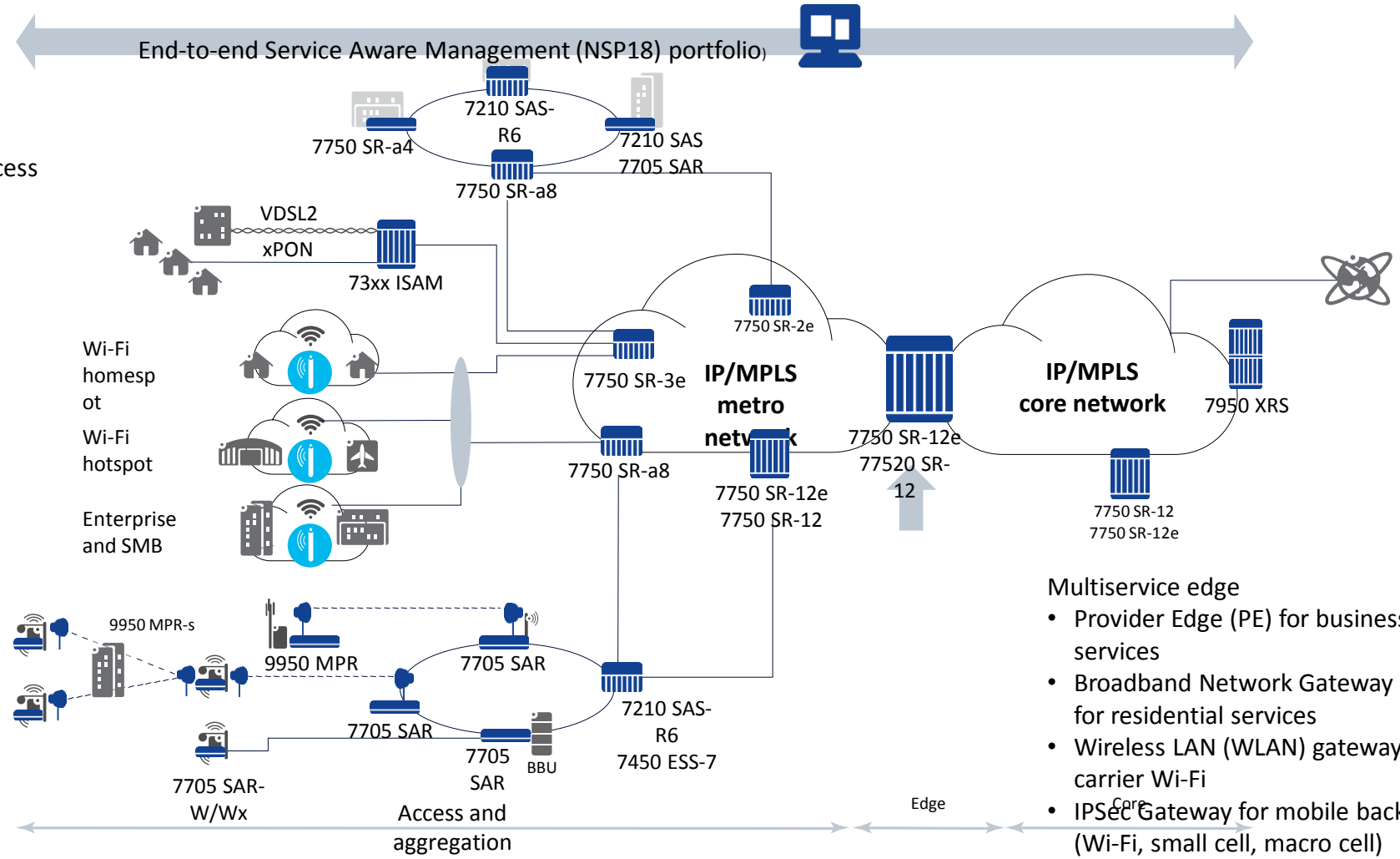
Deployed by Service Providers, Cable/MSOs, Webscale Providers, Large-tech Enterprise and any organization with 'carrier grade' requirements

Reference Architecture

Carrier Ethernet
Layer 3 VPN
Dedicated Internet Access (DIA) services
IPTV
High-speed Internet (HSI) services

Carrier Wi-Fi

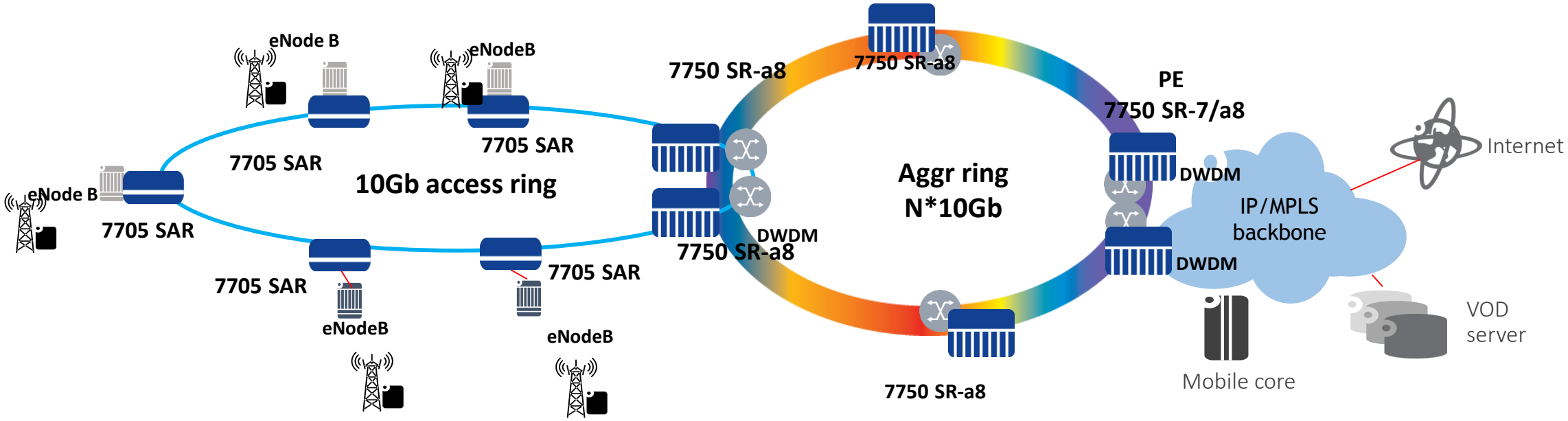
Mobile backhaul



Multiservice edge

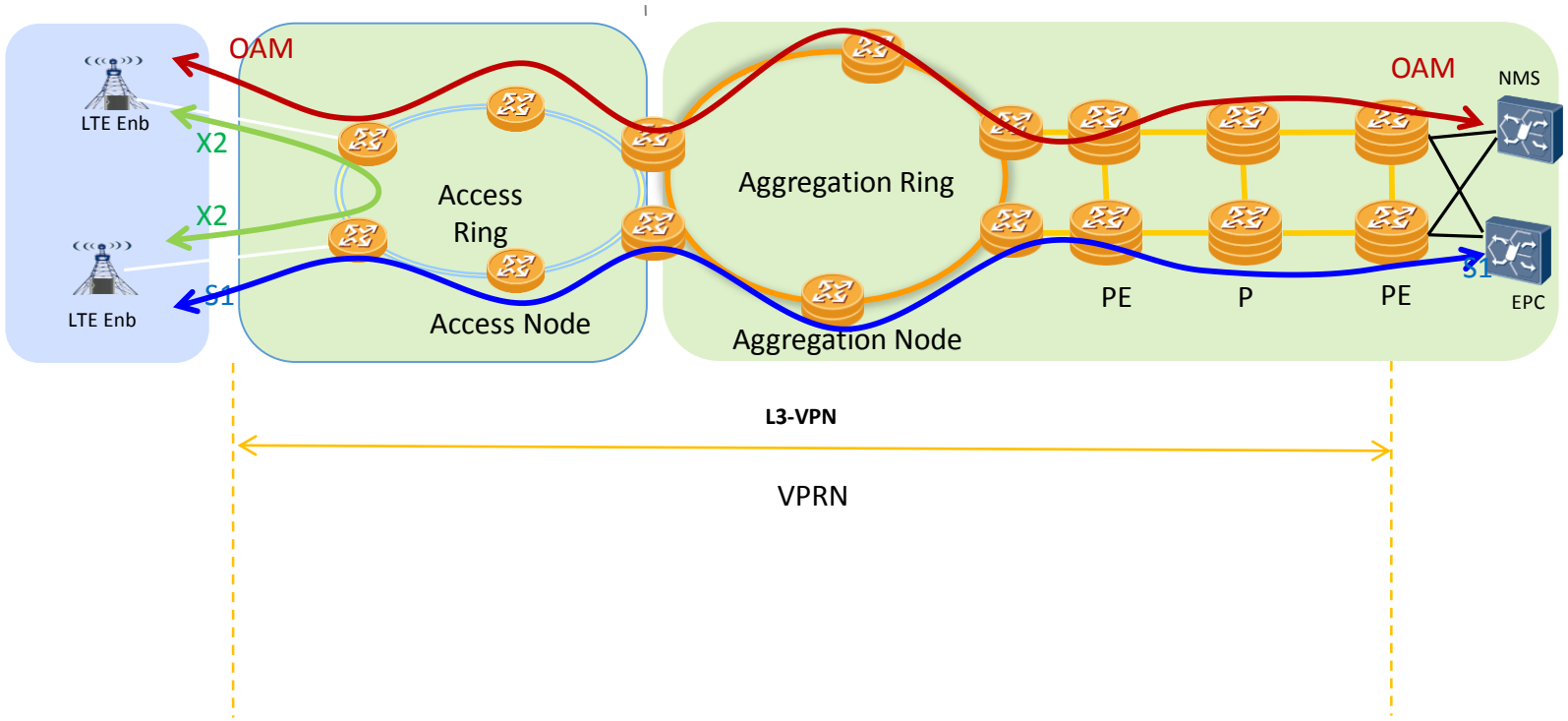
- Provider Edge (PE) for business services
- Broadband Network Gateway (BNG) for residential services
- Wireless LAN (WLAN) gateway for carrier Wi-Fi
- IPSec Gateway for mobile backhaul (Wi-Fi, small cell, macro cell)

ETL IP RAN topology



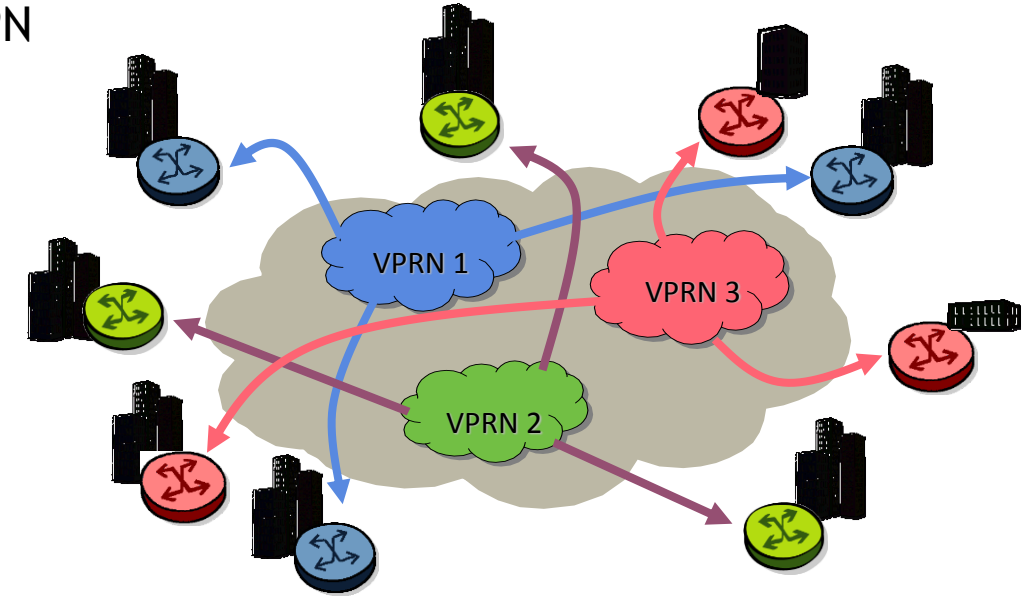
- Access ring: 10G ring ， Each ring connect 15-20 access router (7705 SAR-X).
- Access router interface eNodeB by GE interface and E1 interface.
- Each Access ring will connect to 2 Aggr router to improve the safety.
- Several Aggr router by N*10G ring interface connect to PE router in province.

ETL IP MPLS L3 VPN



MPLS VPRN
Technology Overview
MPLS VPRN

- A VPRN allows multiple customer sites to communicate securely at the IP level over a provider-managed MPLS network
- Customer sees each site as connected to an isolated routed L3 network managed by a service provider
- Service provider may share the IP/MPLS core to provide multiple services to multiple customers
- Also referred to as Layer 3 Backbone VPN, BGP/MPLS-based VPN, or MPLS-based IP-VPN



VPRN Benefits

VPRN advantages:

- Simplifies the routing topology at customer sites
- Allows the service provider to manage the core network and the customer routes separately
- Provides customers with redundancy benefits designed into the provider core
- Securely isolates customer traffic, similar to existing layer 2 technologies (ATM or Frame Relay)
- Operates independent of Layer 2 to allow different technology connectivity at customer sites
- Permits overlapping private IP address spaces between different customers

VPRN technology Overview

VPRN is the Nokia Implementation of an MPLS Layer 3 VPN

- MPLS Layer 3 VPN specifications in RFC 4364 describe:
  - Distributing the customer's routing information between sites
  - Forwarding customer packets according to their routed network
  - Providing secure Layer 3 connectivity between multiple customer sites

- Utilizes MPLS label stacking with two labels
  - The top (LSP) label allows traffic to transit across the MPLS network
  - The bottom (VPN) label is used to determine the customer's VPRN
  - Push, Pop, and Swap operations adds, removes and replaces the top label in the MPLS-based core, respectively

VPRN Terminology

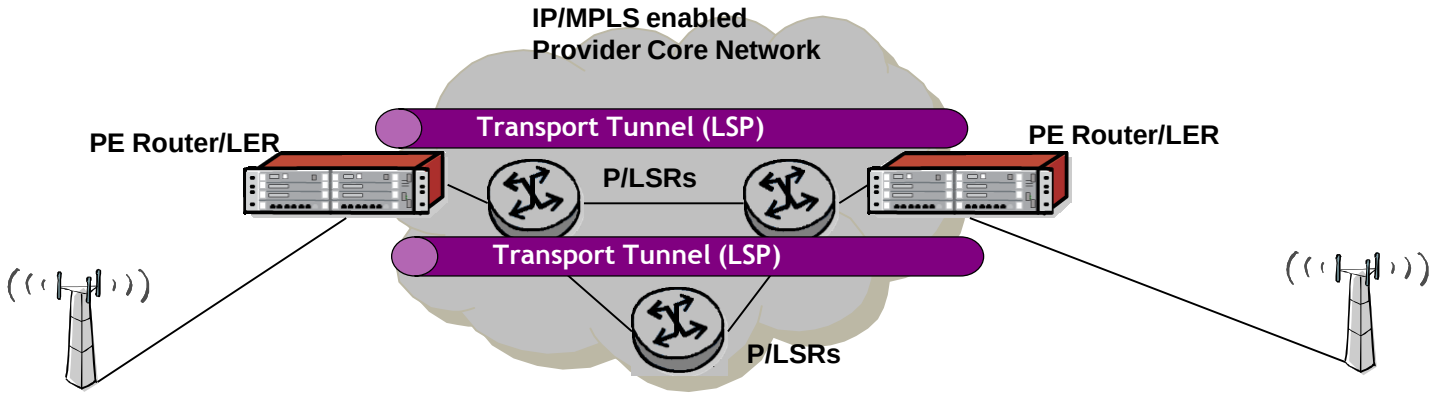
- Provider Edge (PE) Device is the interface between the customer and the service provider networks
  - Directly connected to one or more CE devices
  - Owned and managed by the Provider

- PE Router Functions
  - Exchange provider core IP routing information with other provider routers by means of a core protocol
  - Exchange IP routing information with customers by running a common routing protocol with each CE
  - Exchange each customer's routes (VPRN routes) with other PEs by running a common routing protocol with other PEs
  - Share MPLS information and are VPRN-aware
  - Establish MP-BGP sessions with other PE devices

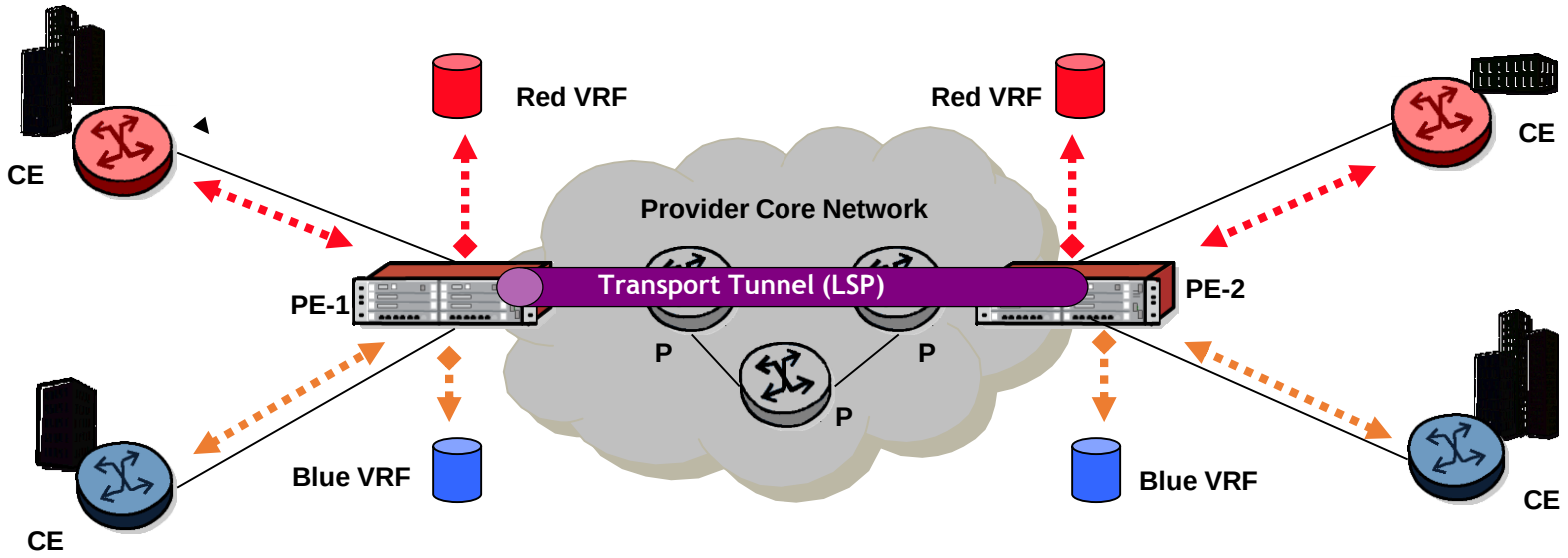
VPRN Terminology

MPLS Domain

- Label Edge Router (LER)
  - Role of the PE devices
  - Receive unlabeled packets from the customer and forward labeled packets into the provider core
  - Receive labeled packets from the provider core and forward unlabeled packets towards the customer
- Label Switch Router (LSR)
  - Role of the P devices
  - Swap packet labels and transmit across the provider core based on the received label towards a PE



VPRN Terminology



- VPRN provides an end-to-end service between customer sites through transport tunnels across provider core
- MPLS LSPs must be configured between PEs to build the customer VPRN service
- PEs may provide different VPRN services to CEs and customers

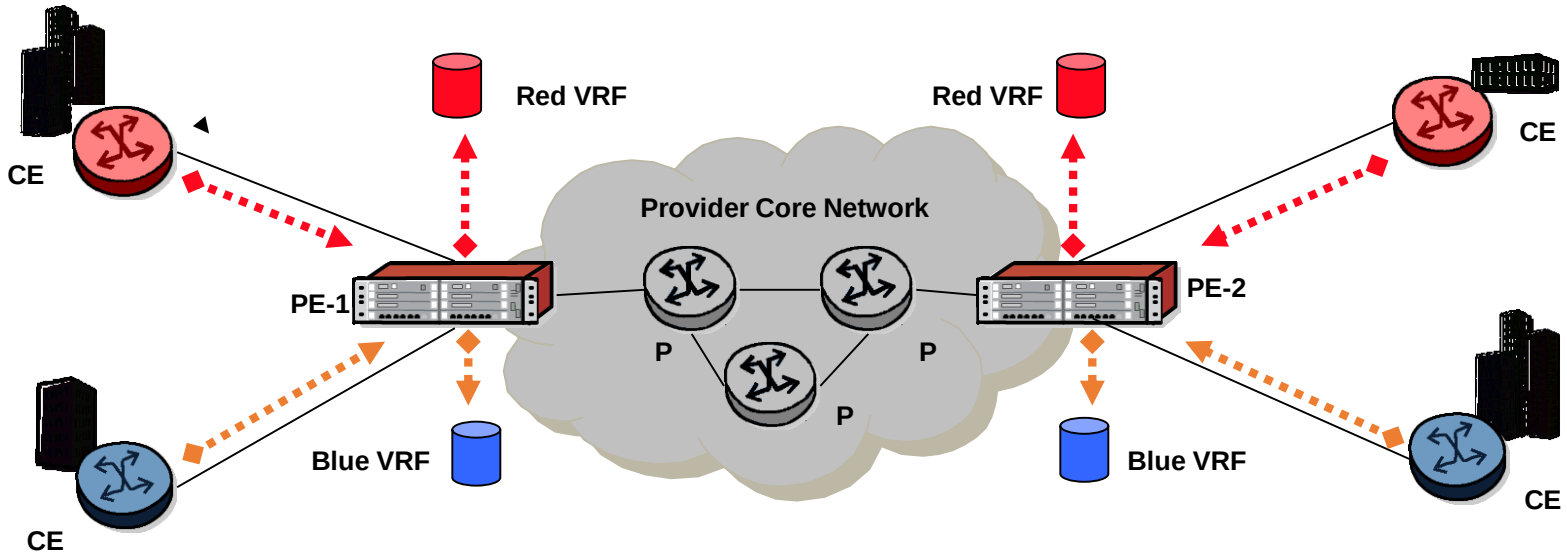
VPRN Control Plane Functions

VPRN Control Plane

- VPRN-aware devices exchange routing information and labeling
  - Each PE maintains a specific VRF for each VPRN
  - Learning routes
    - Prefixes learned from the CE will populate into the VRF for that customer
    - Prefixes learned from a remote PE will populate into a VRF based on parameters associated with the received route
  - Propagating routes
    - Prefixes learned from the CE will propagate to other PEs across the provider core
    - Prefixes in a VRF table that did not originate from the local CE will be propagated to locally connected CEs in the same VPRN
  - Label signaling enables transport tunnels to be built across the provider core network

VPRN Control Plane Routing Functions

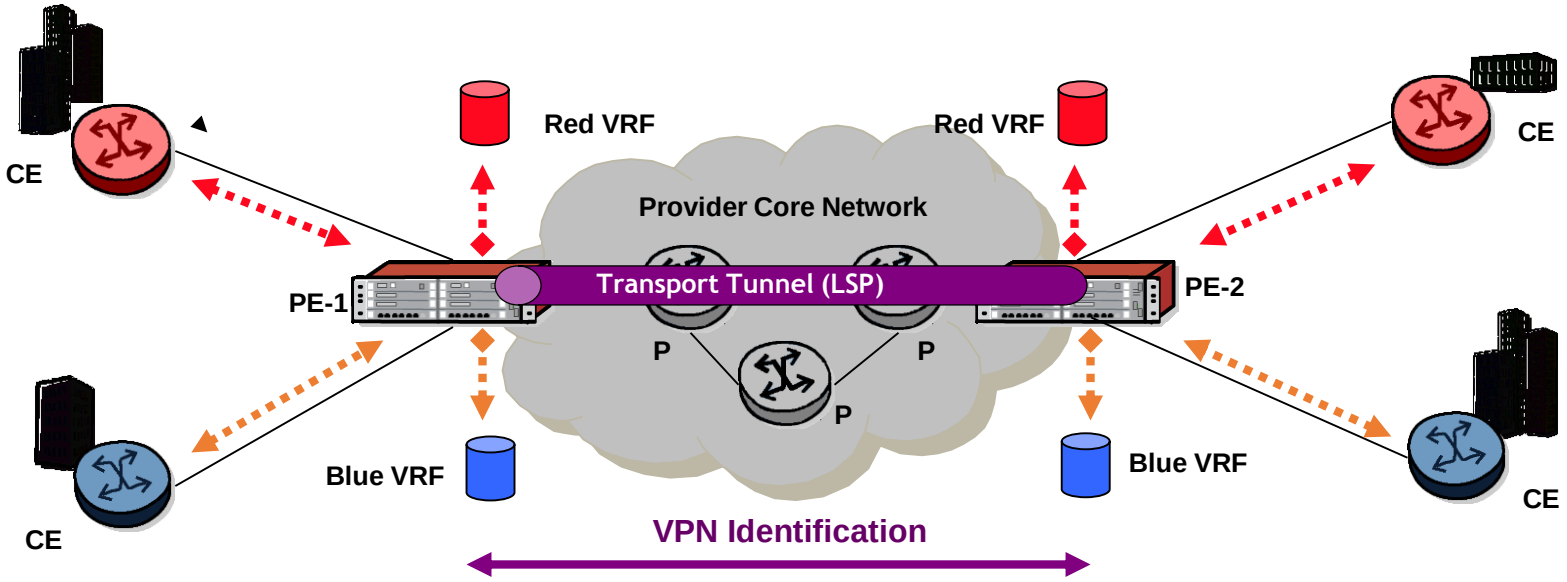
- CE to PE Routing Control
  - Locally reachable prefixes are stored in the appropriate VRF corresponding to the PE interface on which they were received



- PE to PE Routing Control Plane
  - Customer VPRN routes are exchanged between PE routers across the provider core infrastructure
- PE to CE Routing Control Plane
  - PE routers propagate customer routing information received from the far end PE to the local CE, based on the VRF

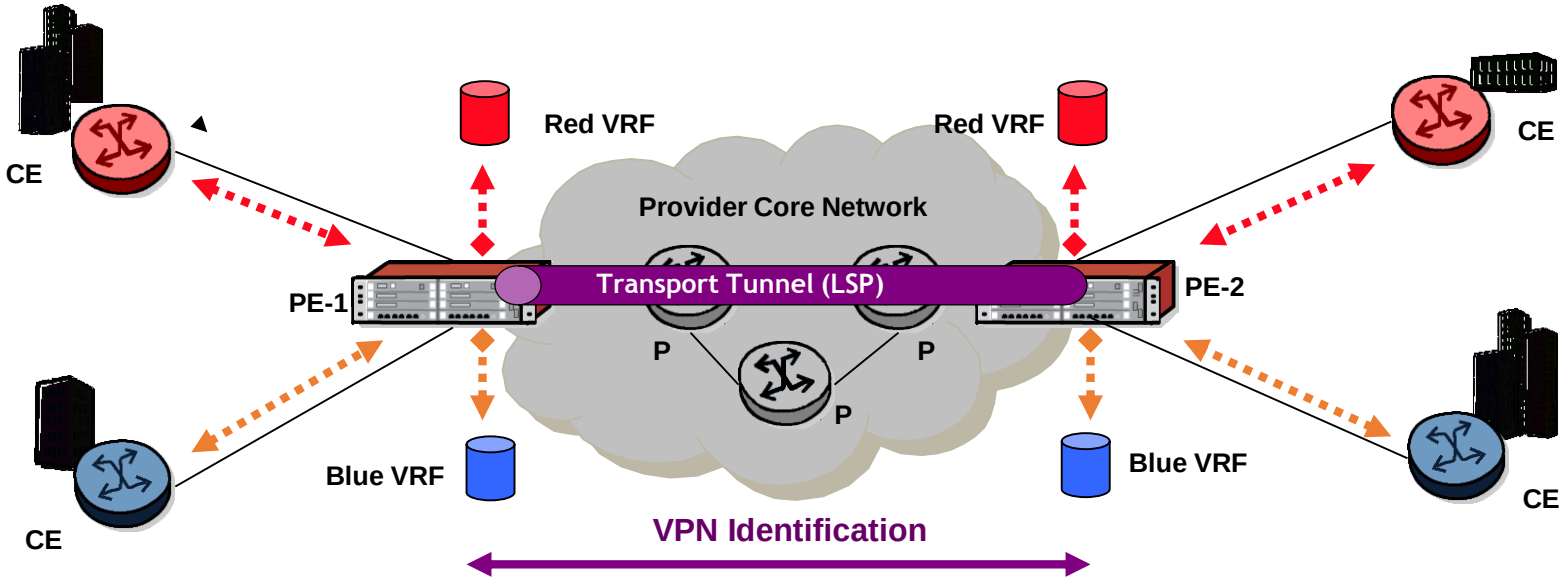
VPRN Control Plane Label Switching Functions

- PE to PE Label Switching Data Plane
  - LSP labels are signaled between PE devices to build a transport tunnel across the provider core network
  - LSP Label
    - Establish LSPs between PE devices
    - Identifies the next-hop towards the egress PE in the MPLS domain



VPRN Control Plane Label Switching Functions

- VPRN Label Switching Control Plane
  - VPN labels are signaled between PE devices to differentiate between the specific customer destination networks
  - VPN Label
    - Identifies the VPRN to which the prefix belongs
    - Identifies the customer network on the egress PE



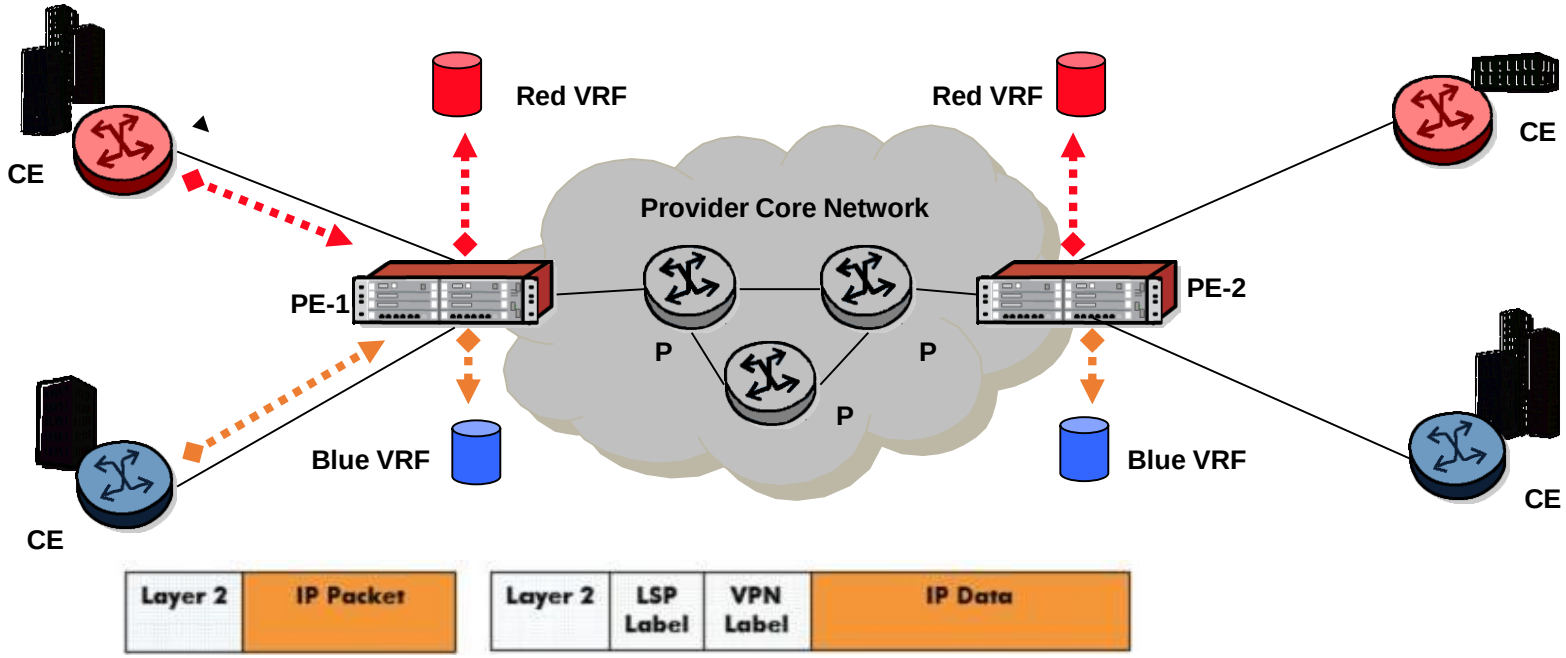
VPRN Data Plane Functions

VPRN Data Plane

- A customer's data packets received from a CE will be forwarded across the service provider's network to the remote CE

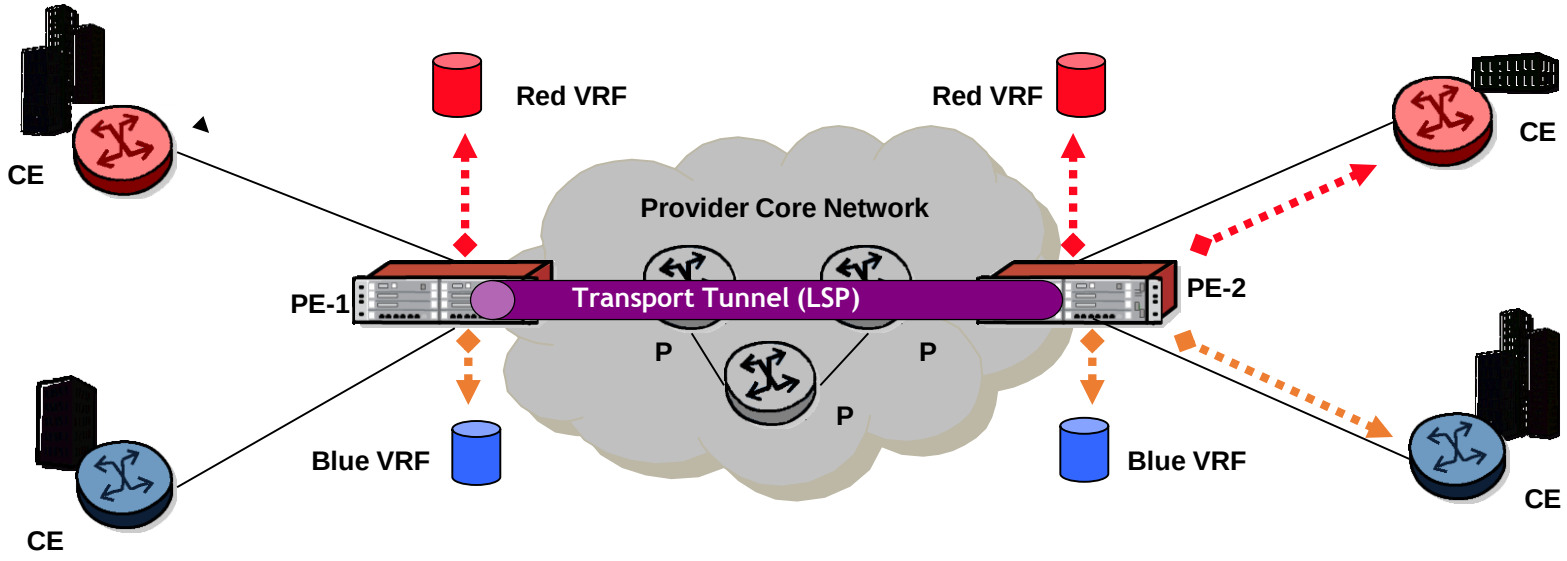
Packet Forwarding

- CE to Ingress PE (VPRN Data Plane)
  - CEs forward unlabeled packets from the customer site to the PE
  - The ingress PE pushes a label stack onto each customer packet



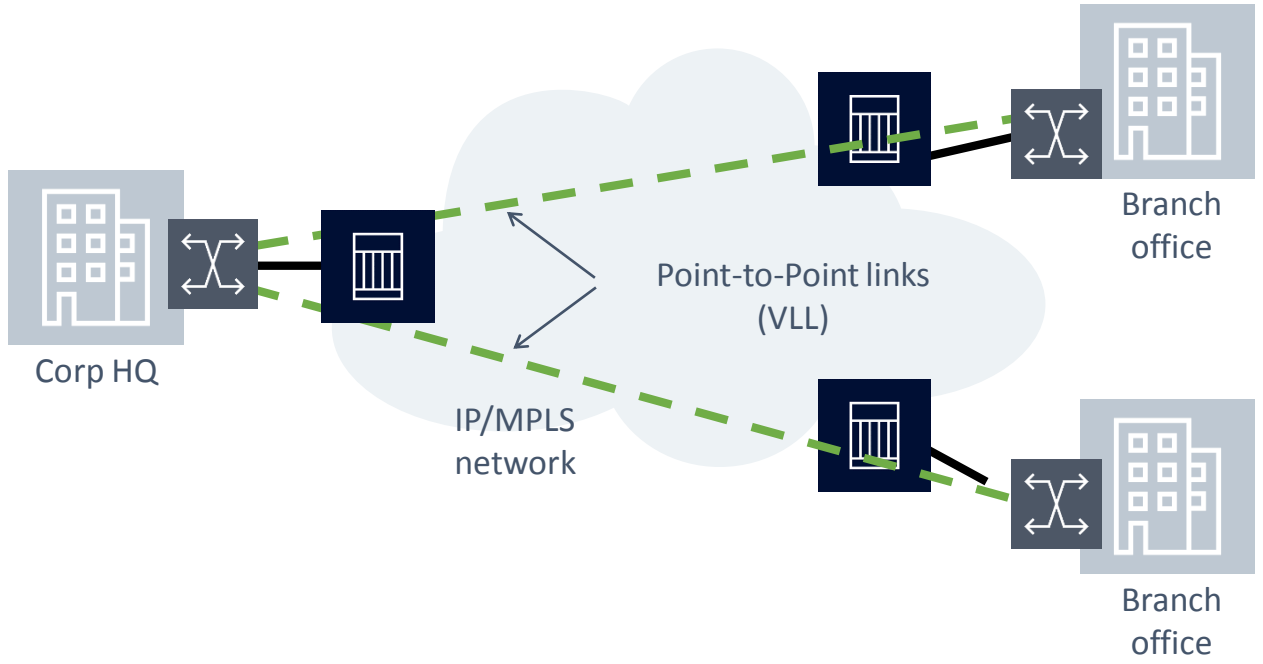
VPRN Data Plane Functions

- PE to PE
  - The ingress PE sends the labeled packets to the provider core
  - Provider core P devices label-switch the packets to the correct egress PE
- Egress PE to CE
  - The egress PE receives label stacked packets from the provider core
  - The egress PE forwards unlabeled packets to the customer based on the VPN label



Virtual Leased Lines (VLL)

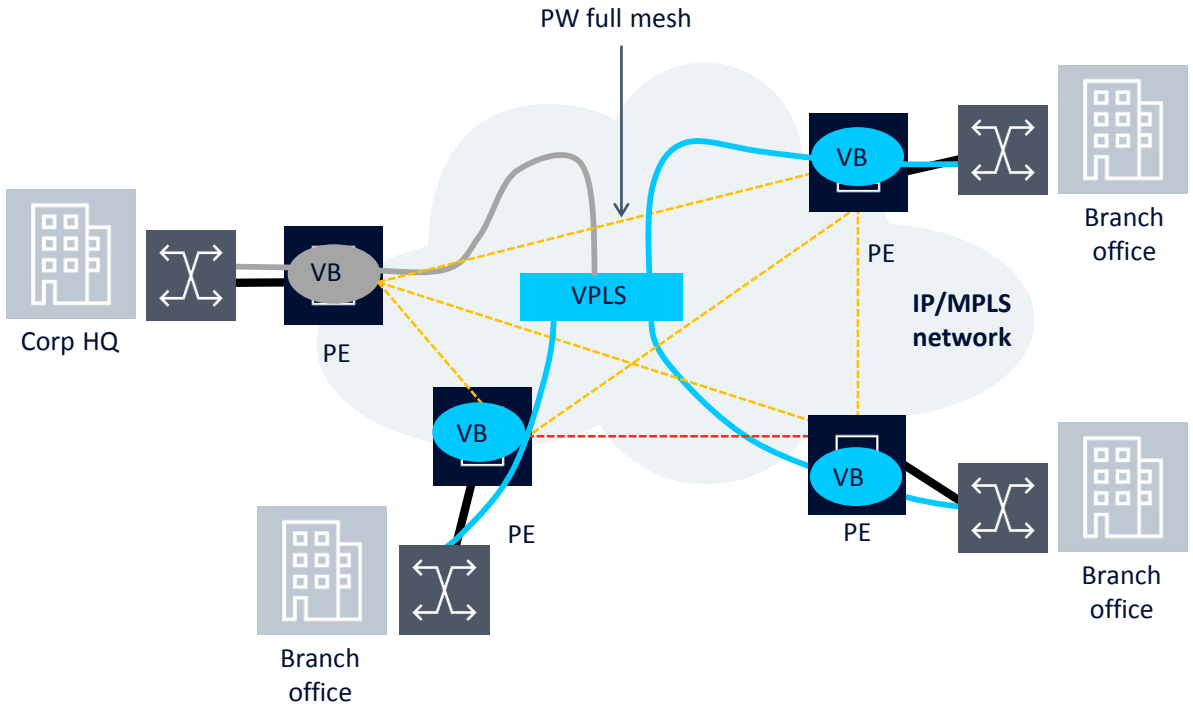
- Provide Point-to-Point (P2P) services
- This service is known by many different names:
  - Pseudowires (PWE3)
  - Virtual Private Wire Service (VPWS)
- Various different VLL types
- Fully transparent service
  - No end user address learning



Confidential

Virtual Private LAN Service (VPLS)

- Layer 2 multipoint-to-multipoint (MP2MP) Virtual Private Network (VPN) service
  - Allows the connection of multiple sites in a single bridged domain over an IP/MPLS network
    - Customer sites in a VPLS instance appear to be on the same LAN, regardless of their location
- Two variants:
  - RFC 4761: Virtual Private LAN Service (VPLS) using BGP for Auto-Discovery and Signaling
  - RFC 4762: Virtual Private LAN Service (VPLS) using Label Distribution Protocol (LDP) Signaling
- Ethernet access
- Protocol independent



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7750 SR-12/SR-7

Nokia 7750 Service Router (SR) portfolio overview








7750 SR-12e	7750 SR-12	7750 SR-7	7750 SR-3e	7750 SR-2e	7750 SR-1e	7750 SR-a8	7750 SR-a4
9.6 Tb/s (HD)	4 Tb/s (HD)	2 Tb/s (HD)	1.2 Tb/s (HD)	800 Gb/s (HD)	400 Gb/s (HD)	400 Gb/s (HD)	200 Gb/s (HD)
400G per slot (FD)	200G per slot (FD)	200G per slot (FD)	200G per IOM (FD)	200G per IOM (FD)	200G per IOM (FD)	100G per IOM (FD)	100G per IOM (FD)
(9) IOM/IMM slots 1/2 rack 22 RU	(10) IOM/IMM slots 1/3 rack 14 RU	(5) IOM/IMM slots 8RU	(3) IOM slots 4 MDA-e per IOM 13 RU	(2) IOM slots 4 MDA-e per IOM 10RU	(1) IOM slot 4 MDA-e per IOM 6RU	(2) IOM slots 4 MDA-a per IOM 7RU	(1) IOM slot 4 MDA-a per IOM 5RU
Terabit IP/MPLS Multiservice Edge Router	Terabit Ethernet, IP/MPLS Edge Router	Mid-scale Ethernet, IP/MPLS Edge Router	Fabric-less, Mid-Scale Edge Router	Fabric-less, Mid-Scale Edge Router	Fabric-less, Small-scale Edge Router	Fabric-less, Mid-Scale Access Router ETSI 300mm compliant	Fabric-less, Small-Scale Access Router ETSI 300mm compliant

IP edge routing

Delivering residential, enterprise and mobile services without compromise

7750 SR

ENTERPRISE	Carrier Ethernet -VPLS, VLL services, IP VPNs, Internet access, Application Assurance, Datacenter Interconnect, Managed services
RESIDENTIAL	Residential Broadband, Carrier Wi-Fi, Advanced services Video Delivery (eg Ad insertion, Fast Channel Change)
WIFI	Carrier Wi-Di, Community Wi-Fi, Hybrid access
MOBILE	Mobile Aggregation, security
INFRASTRUCTURE	IP/MPLS Routing, DPI, BGP Route Reflector

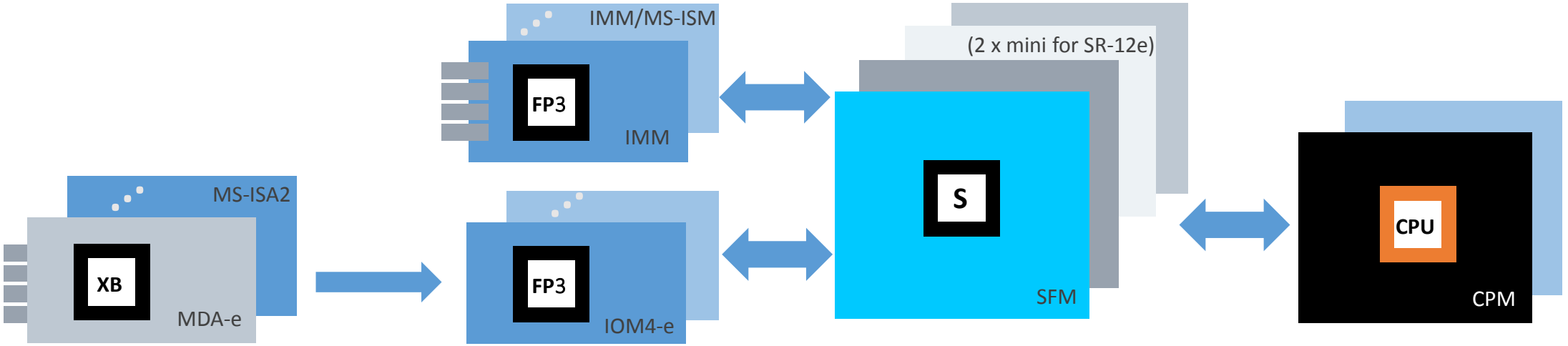
Common platform for the efficient delivery of multiple IP applications & services

Confidential

Nokia 7750 SR-7, 7750 SR-12, 7750 SR-12e: System overview

	7750 SR-7	7750 SR-12	7750 SR-12e
Height (RU)	8	14 (1/3 rack)	22 (1/2 rack)
System capacity (HD)	2 Tb/s	4 Tb/s	7.2 Tb/s (redundant)
Slot capacity (FD)	200 Gb/s (redundant)	200 Gb/s (redundant)	400 Gb/s (redundant)
Resiliency	Redundant CPM, fabric, power and fans	Redundant CPM, fabric, power and fans	Redundant CPM, fabric, power and fans
Slots	5 line card slots	10 line card slots	9 line card slots
GE/10GE/40GE/100GE ports	800/100/30/20	1600/200/60/40	1440/360/54/36

7750 SR-7, SR-12 and SR-12e: System architecture



Media Dependent Adapter (MDA)	Integrated Services Adapters (ISAs)	Integrated Media Module (IMM)	Input/Output Module (IOM)	Switch Fabric & Control Processor Module (SFM, CPM)
Provides physical layer termination	ISA's are a resource platform for Layer 4-7 service processing	Slot-level control, memory and interconnect	Slot-level control, memory and interconnect	CPM provides system-level control, routing and processing
Supports a wide range of types, interfaces, densities, service options	MS-ISM provides higher capacity resources, with combo IMM option	Provides physical layer termination	IOM4-e supports up to 2 MDA-e cards and MS-ISA2s, MDA's only supported on IOM1/2/3	Switch Fabric: SR-7/ SR-12: 1+1 redundant SR-12e: 3+1 redundancy

7750 SR-7: Chassis overview

Front view

19” rack width

8RU height
1/6 rack

- 1+1 redundancy with switch fabrics (SFM5)
- 2 Tb/s (HD) forwarding capacity
- 200 Gb/s (FD) per slot throughput

Rear view

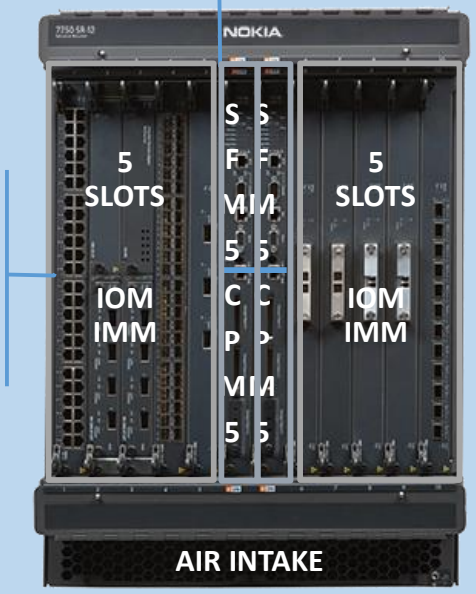
- Redundant cooling with coaxial stacked fans
- Right side-to-back airflow

- 1+1 DC power inputs
- AC through external 1RU rectifiers

7750 SR-12: Chassis overview

- 1+1 redundancy with switch fabrics (SFM5)
- 4 Tb/s (HD) forwarding capacity
- 200 Gb/s (FD) per slot throughput

- 10 input/output line card slots with 20, 50, 100 or 200 Gb/s slots



Front view

19” rack width

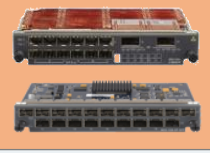
14RU height
1/3 rack

Rear view

- N+1 cooling redundancy
- Front-to-back airflow

- 1+1 DC power inputs
- AC through external 1RU rectifiers

7750 SR-7, SR-12 and SR-12e: Key hardware elements

Switch Fabric / Control Processor Modules (SF/CPM)		• Modular switch fabric design with pluggable CPM and advanced timing ports (SFM5 + CPM5) or integrated switch fabric and CPM design (SF/CPM4) • Multi-core CPM runs routing, switching and centralized OAM protocols • FP chipset protects CPM from DoS and provides commonality with the data plane • Fully hot-swappable
Input/Output Modules (IOM)		• Full slot card supports up to 2 x MDA, 2 x MDA-e, 2 x MS-ISA2 • Network processor complex/forwarding plane logic • IOM4-e/IOM3-XP-C provides 200 Gb/s (FD) wire-rate forwarding • Traffic forwarding, L2/L3 encapsulation, distributed control plane • Fully hot-swappable
Media Dependent Adapters (MDA-e, MDA)		• Physical layer termination (connector, PHY, MAC) • MDA-e adds OTU, FEC and ITU-T G.709 support • Ethernet, POS and ASAP options • Fully hot-swappable
Integrated Media Modules (IMM)		• Full slot card with FP3 network processor complex with integrated physical ports, with embedded ISA2 capability option • 100, 200 and 400 Gb/s (FD) per card models • L2, Basic L3, or Full L3 service support (RTU-based) • Fully hot-swappable
Integrated Service Adapters (ISA)		• Resource blades (no physical ports), includes, MS-ISM with ISA2 + IMM option, MS-ISA2 • Provide specialized processing and buffering • Applications include IPSec, Application Assurance (DPI), Network Address Translation (NAT), L2TP Network Server (LNS), WLAN Gateway, Security Gateway, video services (FCC, RET) • Fully hot-swappable

7750 SR-7/SR-12/SR-12e: 100GE IMMs

High-performance interfaces with full services support

- Powerful FP3 network processor technology provides speed and functionality with a low cost of ownership
  - Single T3 fabric interface chip with full 100 Gb/s flow capacity
  - 4-port 100GE IMM: 400 Gb/s FP3, 10-core CPU
  - 2-port 100GE IMM: 200 Gb/s FP3, 10-core CPU
  - 1-port 100GE IMM: 100 Gb/s FP3, 10-core CPU
- Flexible, tiered feature and license options (L3BQ, L2HQ, and L3HQ)
  - Scalable IPv4/IPv6 OSPF, IS-IS, BGP routing and MPLS label edge router (LER)/label switch router (LSR) functionality supports IP/MPLS edge and core applications
  - Advanced Layer 2 VLL and Layer 3 VPN services with up to 128,000 queues per port for customer aggregation
- Wide range of supported IEEE modules with DDM for extended OAM
  - CFP = 100GBase-SR10, 100GBase-LR4, 100GBase-ER4, 100GBase-ZR, 100G DWDM Coherent tunable (future)
  - CXP = 100GBase-SR10
  - CFP4 = 100GBase-LR4

4-port 100GE CXP IMM
(for 7750 SR-12e)

2-port 100GE CFP IMM

1-port 100GE CFP IMM

7750 SR-7/SR-12/SR-12e: GE and 10GE IMMs

High-performance interfaces with full services support

- Powerful network processor technology provides speed and functionality with a low cost of ownership
  - 160-port GE IMM: 200Gb/s FP3, 10-core CPU
  - 40-port 10GE IMM: 400Gb/s FP3, 10-core CPU (for SR-12e)
  - 20-port 10GE IMM: 200Gb/s FP3, 10-core CPU
  - 12-port 10GE IMM: 200Gb/s FP3, 10 core CPU
- Flexible, tiered feature and license options (L3BQ, L2HQ, and L3HQ)
  - Scalable IPv4/IPv6 OSPF, IS-IS, BGP routing and MPLS LER/LSR functionality supports IP/MPLS edge and core applications
  - Advanced Layer 2 VLL and Layer 3 VPN services with up to 128,000 queues per port for customer aggregation

160-port GE CSFP/SFP IMM

40-port 10GE SFP+ IMM (for 7750 SR-12e)

20-port 10GE SFP+ IMM

7750 SR-7/SR-12/SR-12e: Packet over SONET/SDH (POS) MDA-XP/MDA

- Feature highlights:
  - Support for services on SDH/SONET network uplinks
  - Flexible timing support options – loop- or node-timed
  - Wide variety of interface densities and speeds from OC-3c/STM-1c to OC-192c/STM-64c

SDH/SONET	Port densities	Optics reach
OC-3c/STM-1c or OC-12c/STM-4c (multirate)	16 ports	Up to 85 km SFPs
OC-48c/STM-16c	4 ports	Up to 85 km SFPs
OC-192c/STM-64c	2 ports	Up to 80 km

2-port Chan. OC-192c/STM-64c POS MDA-XP

16-port Chan. OC-3c/OC-12c/
STM-1c/STM-4c POS MDA

4-port OC-48c/STM-16c POS MDA

Facilitating integration to existing SONET/SDH infrastructure

7750 SR-7/SR-12/SR-12e: IMM summary

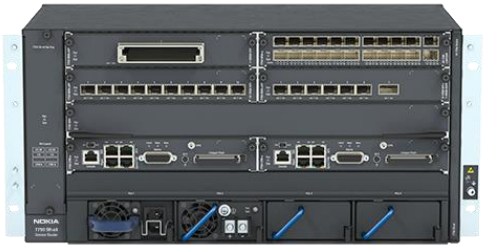
IMM TYPE	PORTS	CONNECTOR TYPE	SYNC-E/ 1588v2	MAXIMUM DENSITY		
				SR-12e	SR-12	SR-7
10/100/1000BASE	160 or 80	CSFP or SFP	Yes/No	1440 or 720	1600 or 800	800 or 400
10/100/1000BASE	48	SFP	Yes/No	432	480	240
10GBASE	40	SFP+	Yes/No	360	—	—
10GBASE/100/100BASE (combination)	10/20	SFP+/SFP	Yes/Yes	90/180	100/200	50/100
10GBASE + 7x50 ISA2 (combination)	10	SFP+	Yes/Yes	90	100	50
10GBASE	12, 20	SFP+	Yes/Yes	108, 180	120, 200	60, 100
40GBASE	6	QSFP+	Yes/No	54	60	30
40GBASE/100/100BASE (combination)	3/20	QSFP+/SFP	Yes/Yes*	27/180	30/200	15/100
100GBASE	4	CXP and CFP4**	Yes/Yes**	36	—	—
100GBASE	1, 2	CFP	Yes/No	9, 18	10, 20	5, 10
100GBASE/10GBASE (combination)	1/10	CFP/SFP+	Yes/Yes*	9/90	10/100	5/50
100GBASE + 7x50 ISA2 (combination)	1	CFP	Yes/No	9	10	5
100GBASE IMM (Integrated DWDM optics)	1	LC	Yes/No	9	10	5

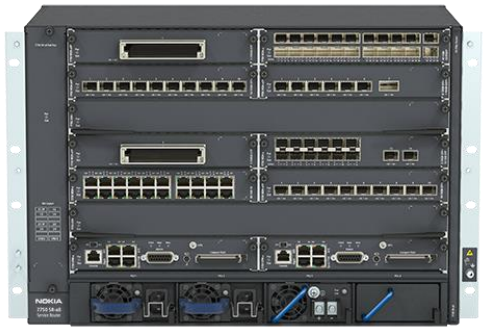
Support 10G tunable SFP+ for DWDM applications with 10GE IMMs

* Note: IEEE 1588v2 is supported only on GE and 10GE interfaces.

7750 SR-a8

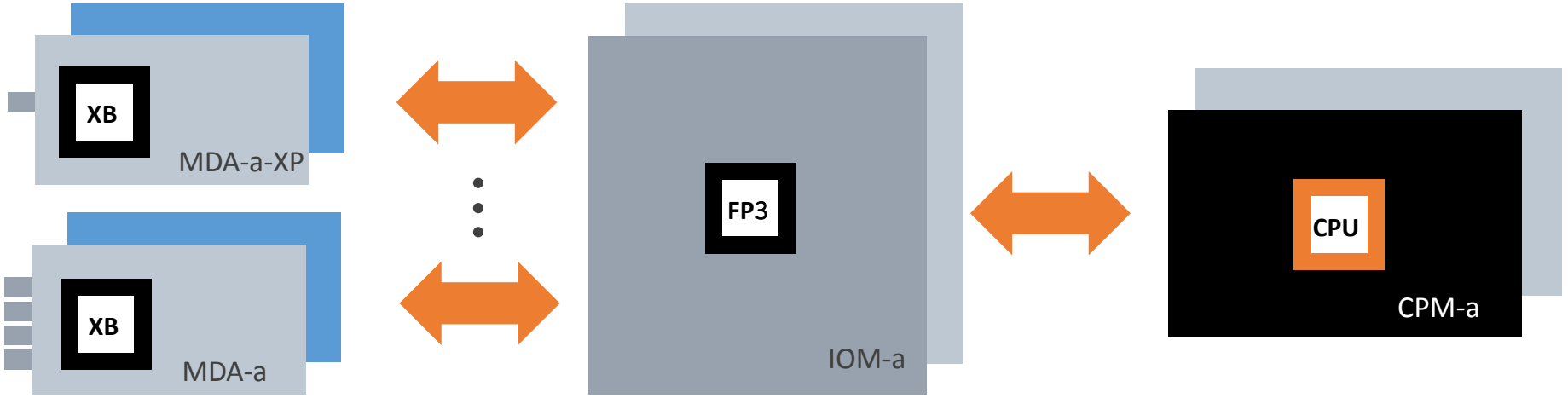
Nokia 7750 SR-a: System overview





	7750 SR-a4	7750 SR-a8
Height/depth	5RU/240 mm	7RU/240 mm
System capacity (HD)	200 Gb/s	400 Gb/s
Resiliency	Redundant CPM, power and fans	Redundant CPM, power and fans
MDA-a slots	4	8
IOM-a slots	1	2
GE/10GE/100GE ports	176/40/4	352/80/8

7750 SR-a: System architecture



Media Dependent Adapter (MDA-a, MDA-a-XP)	Input/Output Module (IOM-a)	Control Processor Module (CPM-a)
Provides physical Ethernet connectivity	Supports up to 4 x MDA-a/MDA-a XP	System-level control, routing and processing
Available in a wide range of Ethernet interfaces up to 4 per IOM-a	Provides up to 100 Gb/s (FD) connectivity to MDA-a, MDA-a XP and IOM-a (for SR-a8)	Fully redundant: provides timing, alarm and management ports

Specialized design delivers optimal balance of performance, features and cost

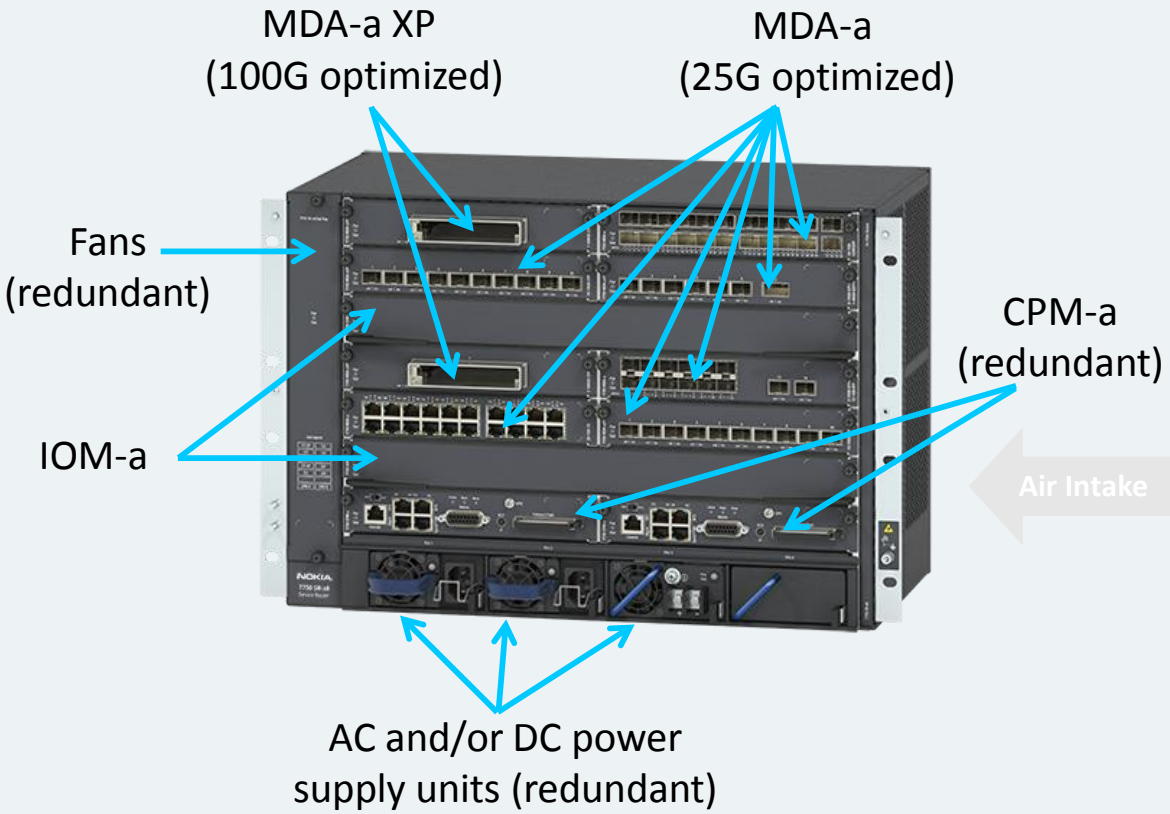
7750 SR-a: Key hardware elements

Control Processor Module-a* (CPM-a) 	• Provides intelligent control and processing functionality and offers optional 1+1 redundancy • Redundant CPM-a cards operate in a hitless, stateful, failover mode • Central processing and memory are intentionally separated from the forwarding function on the interface modules to ensure utmost resiliency • Multi-core control processor runs routing and OAM protocols • Hot-swappable
Input/Output Module-a* (IOM-a) 	• Provides up to 200 Gb/s (HD) connectivity to MDA-a and MDA-a-XP cards • Uses multi-core processor complex/forwarding plane logic • Provides forwarding and service functions along with high-end traffic management capabilities • Contains FP3 silicon chipset; P3 chip performs all forwarding and service functions; Q3 chip delivers high-end traffic management capabilities
Media Dependent Adapter (MDA-a XP and MDA-a)* 	• MDA-a's and MDA-a XPs provide physical Ethernet interface connectivity • Physical layer termination (connector, PHY, MAC) • MDA-a XPs provide up to 100Gb/s performance over 100GE, 40GE and 10GE interfaces • MDA-a cards provide up to 25 Gb/s performance over 10GE and GE interfaces • Different port densities available with pluggable optics, hot-swappable

*Note: Not portable to other 7750 SR variants

7750 SR-a8: Chassis overview

- 400G (HD, max) system capacity, fabric-less design
- 7RU, fits in a 300-mm ETSI cabinet compliant
- Enhanced standard operating temperature range support of -5°C to +55°C
- Vertical mounting option, cabinet available where extended temperature is required
- Highly resilient, full system redundancy with hot-swappable components
- 2 x IOM-a slots (FP3-based) - Up to 100 Gb/s (FD) each
- 8 x MDA-a/MDA-a XP slots – 1 x 100G and 3 x 25G per IOM-a
- Side-to-side airflow with variable speed fans



Leverages proven 7750 SR hardware architecture

7750 SR-a: Media Dependent Adapter-a (MDA-a)

- High density for a range of oversubscription scenarios
- Full range of Carrier Ethernet interfaces
- Supports ITU-T Sync-E

MDA-a XPs (up to100 Gb/s extended performance)

1-port 100GE CFP

1-port 100GE CFP2

1-port 100GE CFP4

10-port 10GE SFP+

1-port 40GE QSFP+ and 6-port 10GE SFP+ (combo)

MDA-a cards (up to 25 Gb/s performance)

4-port 10GE SFP+

2-port 10GE SFP+ and 12-port GE SFP (combo)

44/22-port GE CSFP/SFP

20-port 10/100/1000BASE -TX RJ-45

1–port 100GE CFP MDA-a XP

10–port 10GE MDA-a XP

1–port 100GE CFP2 MDA-a XP

20–port GE MDA-a

1–port 100GE CFP4 MDA-a XP

2-port 10GE + 12-port GE MDA-a

High-density, high-performance Carrier Ethernet connectivity

7750 SR-a: MDA-a summary

MDA-a TYPE	PORTS	CONNECTOR TYPE	SYNC-E/ 1588v2	MAXIMUM DENSITY	
				SR-a8	SR-a4
MDA-a					
10/100/1000BASE	44 or 22	CSFP or SFP	Yes/Yes	352 or 176	176 or 88
10/100/1000BASE-TX	20	RJ-45	No/No	160	80
10GBASE/1000BASE (combination)	2/12	SFP+/SFP	Yes/Yes	16/96	8/48
10GBASE	4	SFP+	Yes/Yes	32	16
MDA-a XP					
10GBASE	10	SFP+	Yes/Yes	80	40
40GBASE/10GBASE (combination)	1/6	QSFP+/SFP+	Yes/Yes*	8/48	4/24
100GBASE	1	CFP, CFP2, CFP4	Yes/No	8	4

Support 10G tunable SFP+ for DWDM applications with 10GE MDA-a's

*Note: IEEE 1588v2 is only supported on the 10GE interfaces

7705 SAR

For mobile backhaul and IP transformation

Scalability and flexibility

- Ethernet, VPLS
- IP and IP VPN
- TDM
- ATM
- Serial data, E&M, FXS/FXO
- Teleprotection
- Frame Relay
- HDLC

7705 SAR

- nxDS1/E1
- SONET/SDH
- GE, 10GE
- microwave
- xDSL
- CWDM

7705 SAR Portfolio


7705 SAR-X


7705 SAR-W


7705 SAR-Wx


7705 SAR-Ax


7705 SAR-Hc


7705 SAR-O


7705 SAR-A


7705 SAR-M


7705 SAR-H


7705 SAR-8


7705 SAR-18

Any interface & SLA

Any network access

Any scale, any location

Reliable service delivery

Supports new and legacy services

- Full suite of IP/MPLS and Carrier Ethernet services
- Secure tunnels for legacy services

End-to-end consistency and control

- Rich service and OAM feature set
- Consistent across Nokia Service Router portfolio

Superior QoS

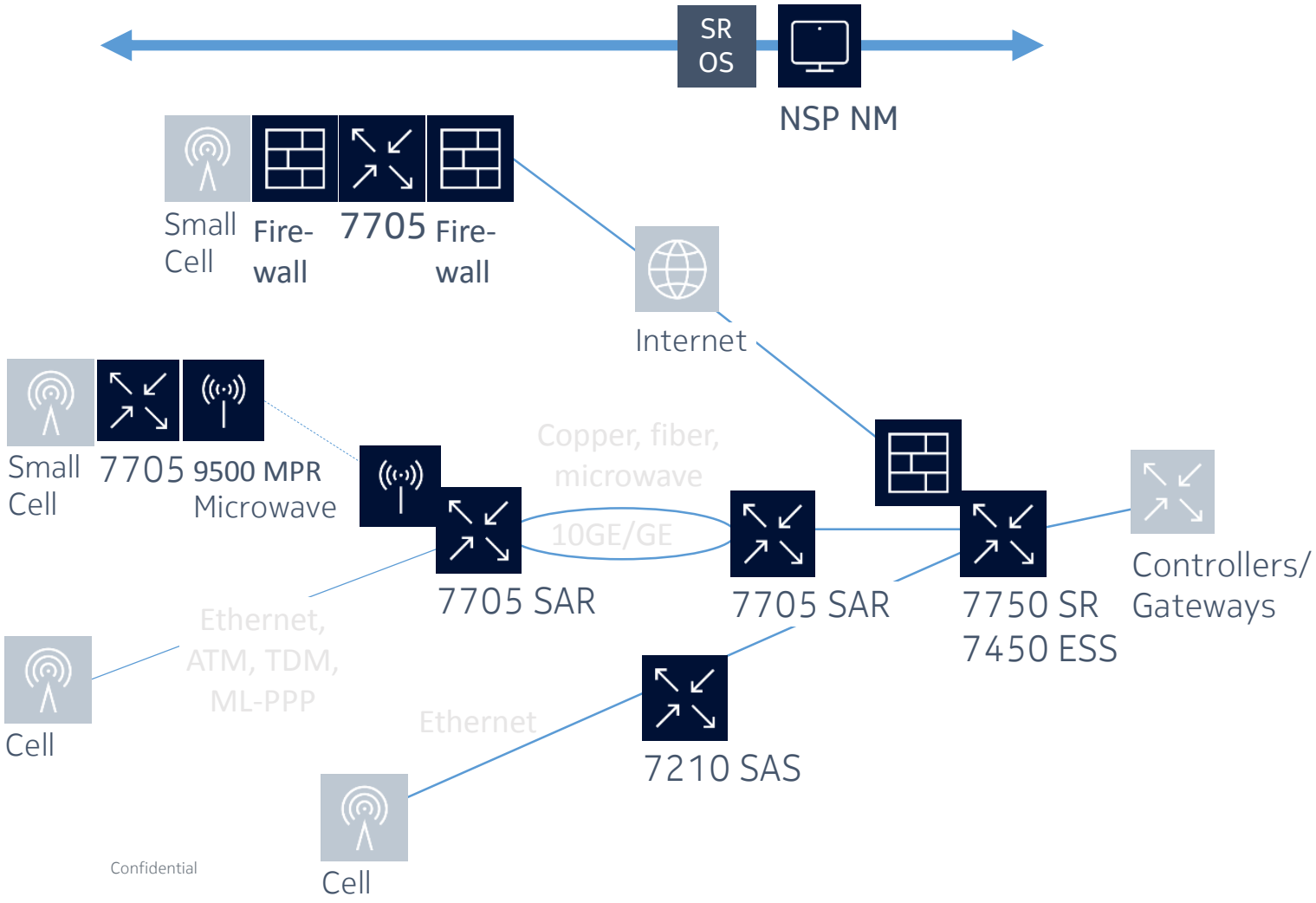
- Service-aware prioritization
- Deep buffers with ingress and egress shaping

Redundancy
Fast recovery

- Redundant hardware, networking elements
  - e.g. LAG, redundant pseudowires
- Fast reroute protocols

5620 SAM

Mobile backhaul



Features

- IP and MPLS scalability
- Timing and synchronization support
- Deep buffers, ingress and egress buffering and shaping
- Any interface, uplink, location

Benefits

- Scales for future bandwidth, RAN needs
- Legacy services supported
- Quickly and economically deployed
- Secure from cyber attacks

Confidential

7705 product family

Purpose-built for mobile backhaul and mission critical

Chassis systems
Redundant switch fabrics
Multiple interface cards

7705 SAR-18

7705 SAR-8 - Electric utility compliance

Multipurpose systems
Targeted at specific applications

7705 SAR-X - high throughput, 10GE ports

7705 SAR-M - modules

7705 SAR-A - Ethernet

New

7705 SAR-Ax – small cells

Utility focussed
Advanced security

7705 SAR-H also used in small cell

7705 SAR-Hc

Passive CWDM

7705 SAR-O

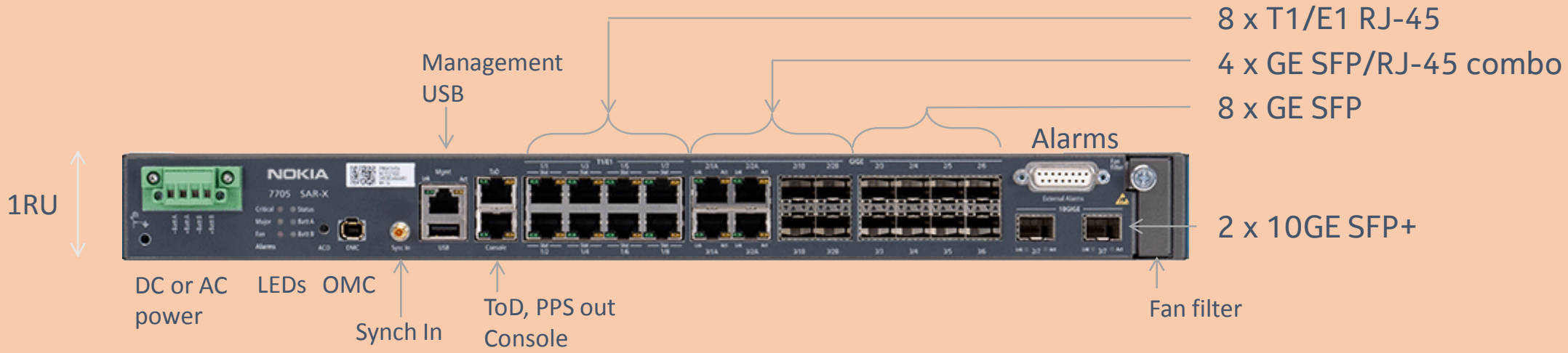
Outdoor small cell
Pole, strand mount
PoE, GPS, xDSL

7705 SAR-W

7705 SAR-Wx

7705 SAR-X

Unmatched IPv4, IPv6, label BGP route and MPLS scalability



- Full 10 Gb/s line rate
- Deep buffering : Up to 50 ms of burst absorption at ingress & egress
- Ingress shaping
- Hardware enabled encryption IPSec/NGE & NAT
- IEEE 1613 Class 2 and 61850-3 for electrical utilities

54 Gb/s (HD) throughput

IP solution

Nokia Shanghai Bell

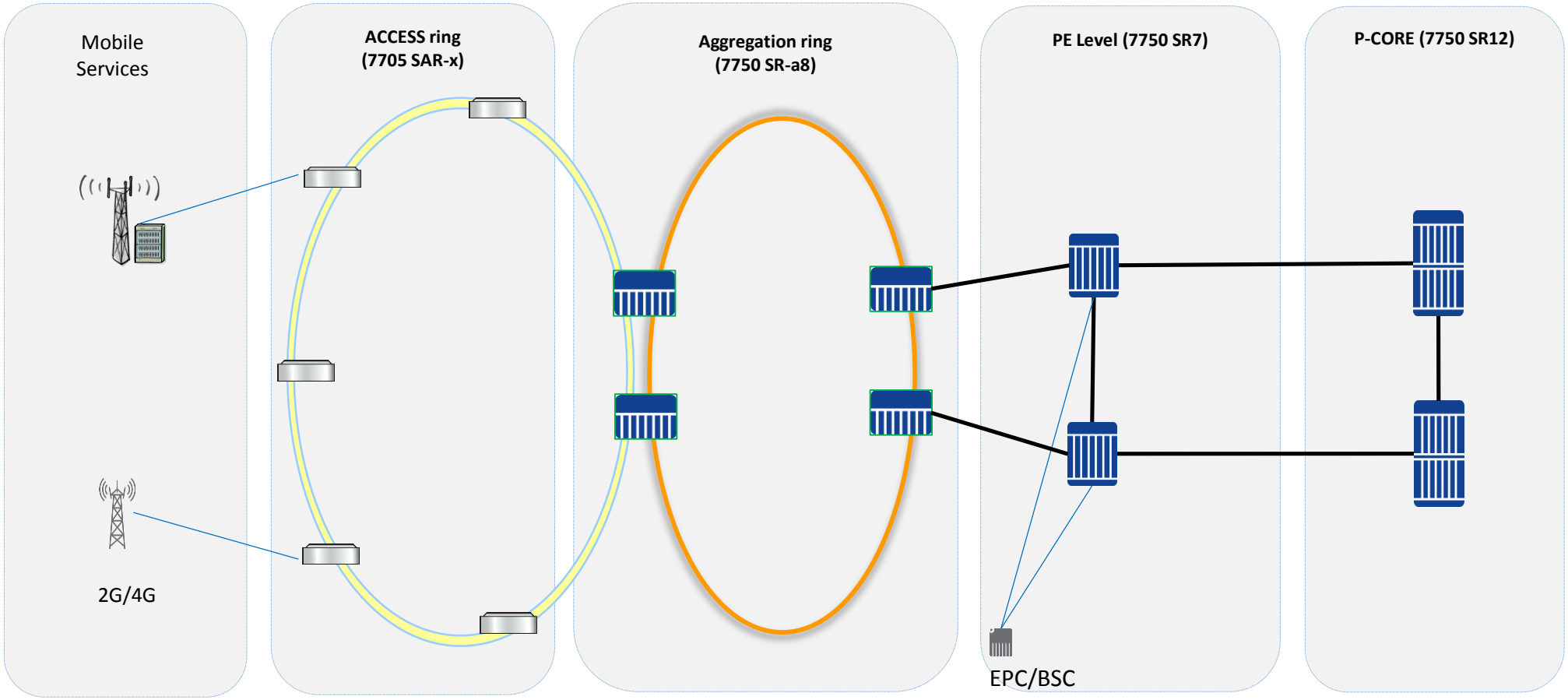
Yang Yi

Oct 2018

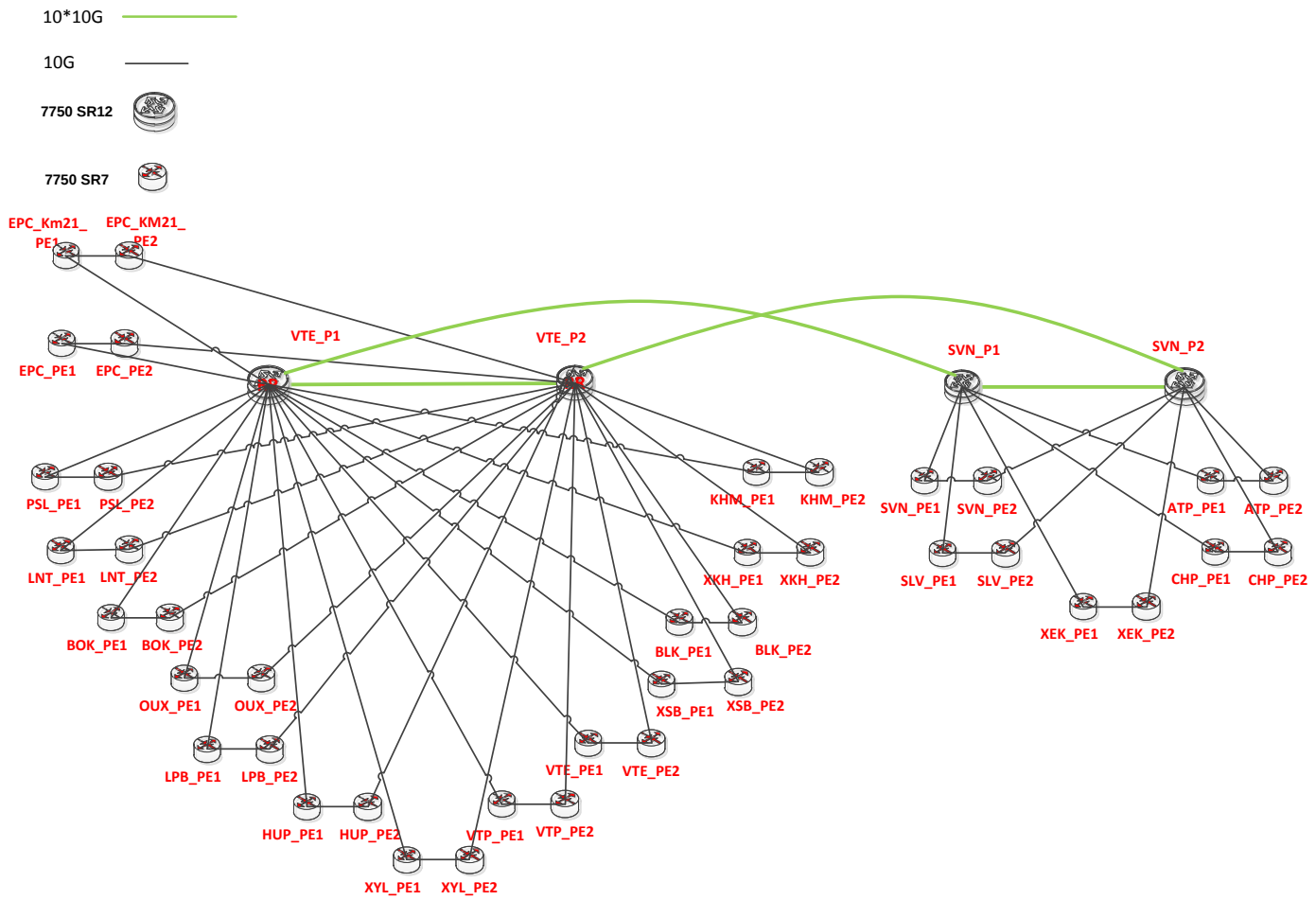
IP solution introduction

Network Architecture Overview

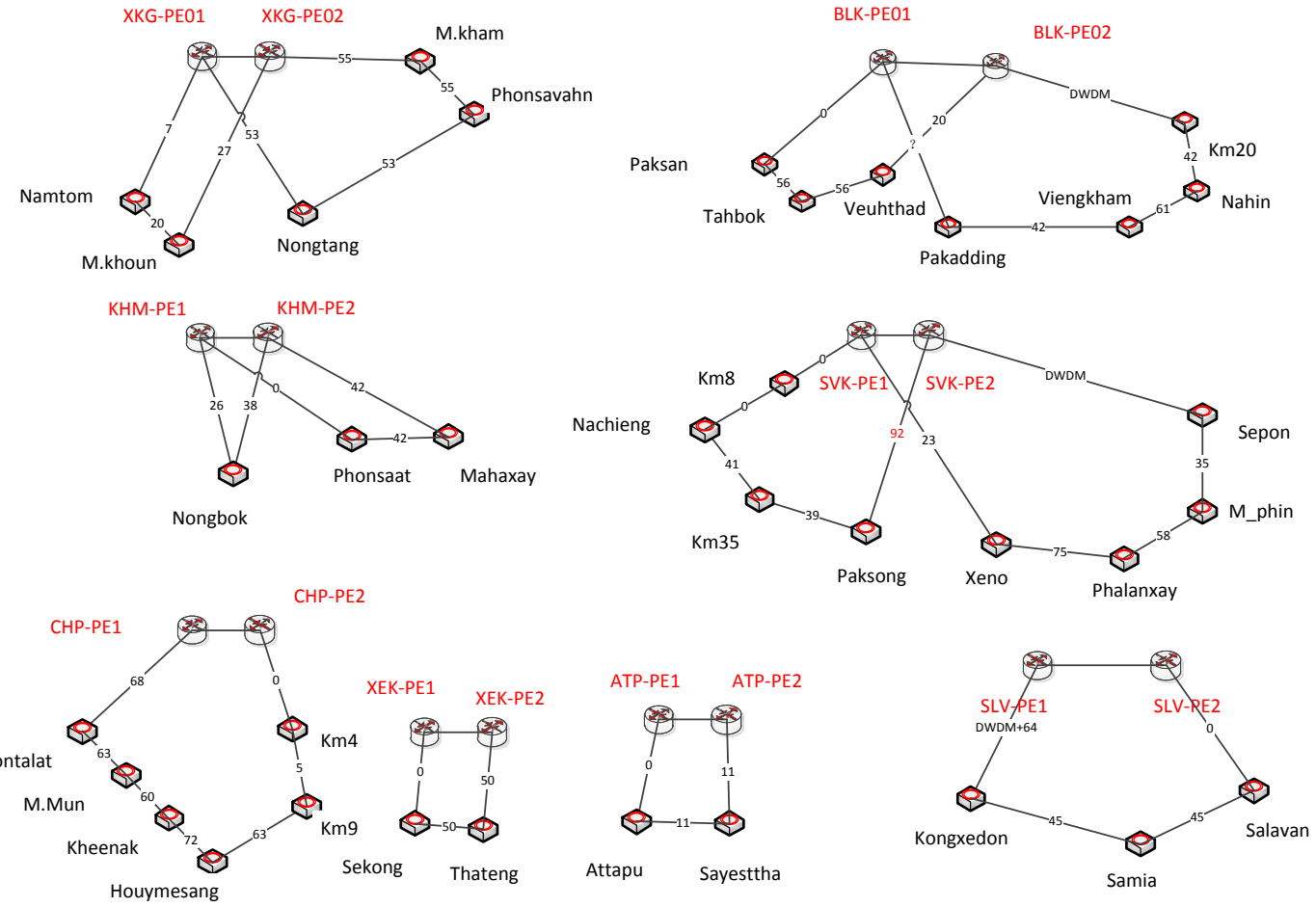
- The high-level network architecture for the network is depicted in the following figure:



P router and PE router design



Aggregation Router design

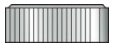


Product List

P Router : 7750 SR-12

PE Router : 7750 SR-7

Aggregation: 7750SR-a8



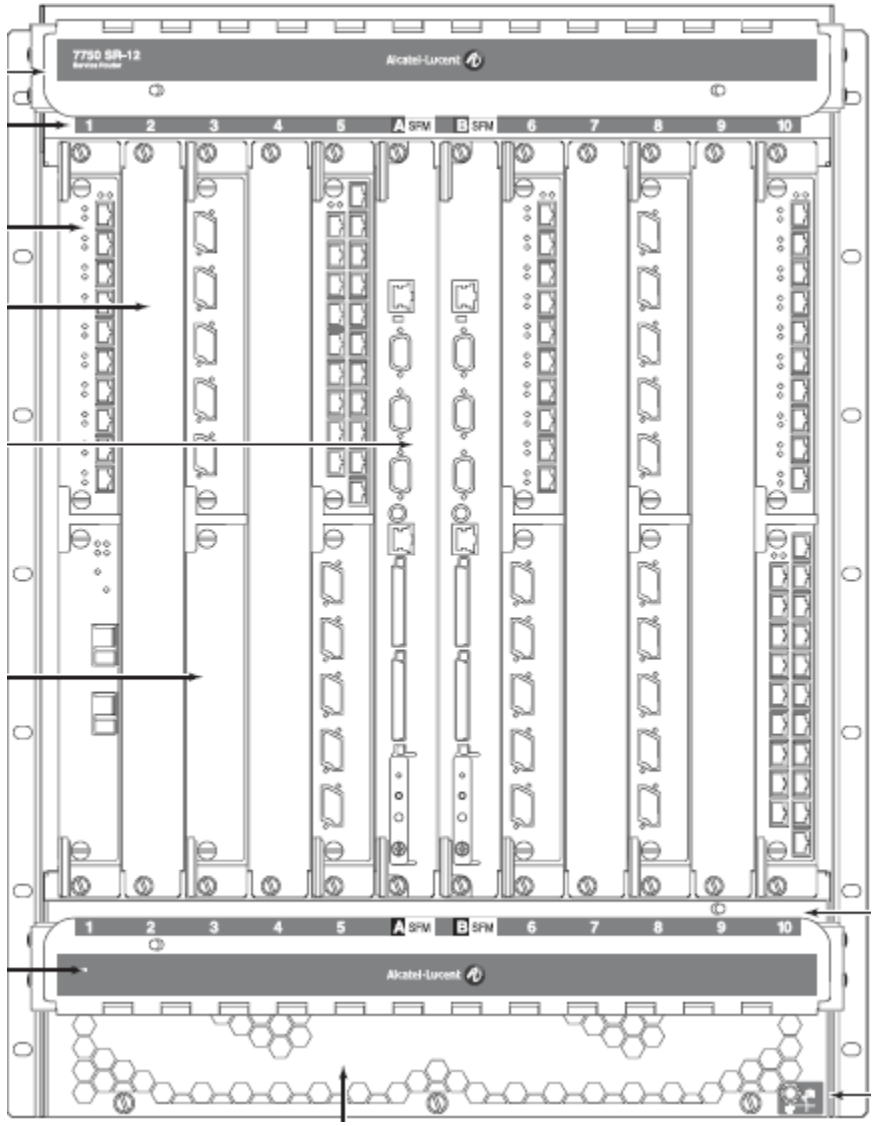
Access: 7705 SAR-x

	Province	P router	PE router	Aggregation Routers	Access Routers
	PSL		2		
	HUP		2		
	LNT		2		
	BOK		2		
	OUX		2		
	LPB		2		
	XYL		2		
	VTP		2		
	XSB		2		
	VTE	2	2		
	XKH		2	5	84
	BLX		2	7	85
	KHM		2	3	61
	SVK	2	2	8	123
	SRV		2	3	31
	XEK		2	2	26
	CPS		2	6	102
	ATP		2	2	25

P router

- Equipment Type: 7750 SR-12

7750SR-12											
P*4											
1	2	3	4	5	A	B	6	7	8	9	10
2 pt 100GE IMM	2 pt 100GE IMM				SF/CPM5	SF/CPM5		20 pt 10GE IMM	20 pt 10GE IMM	20 pt 10GE IMM	20 pt 10GE IMM
FAN											

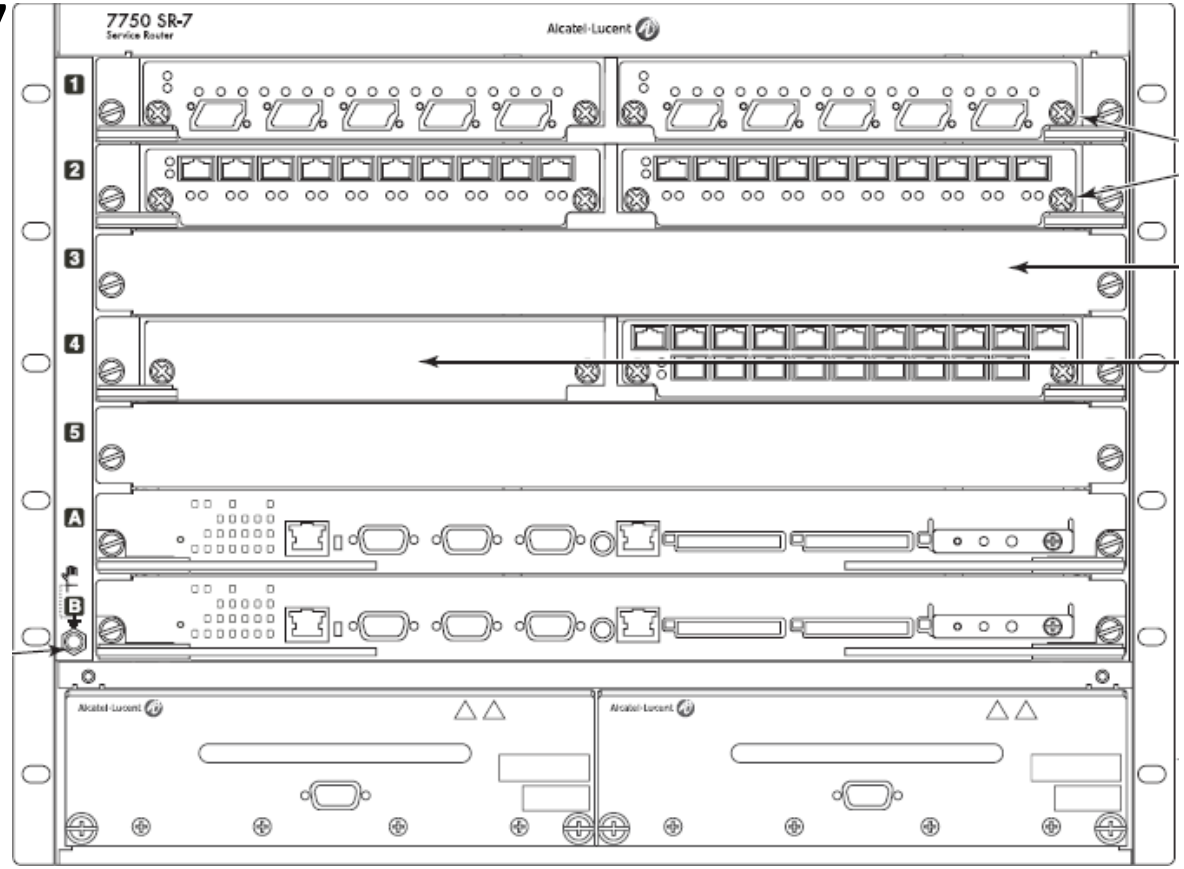


PE router

- Equipment Type: 7750 SR-7

	(7750SR-7) Core PE
1	2 pt 100GE IMM
2	2 pt 100GE IMM
3	
4	20 pt 10GE IMM
5	20 pt 10GE IMM
A	SF/CPM5
B	SF/CPM5

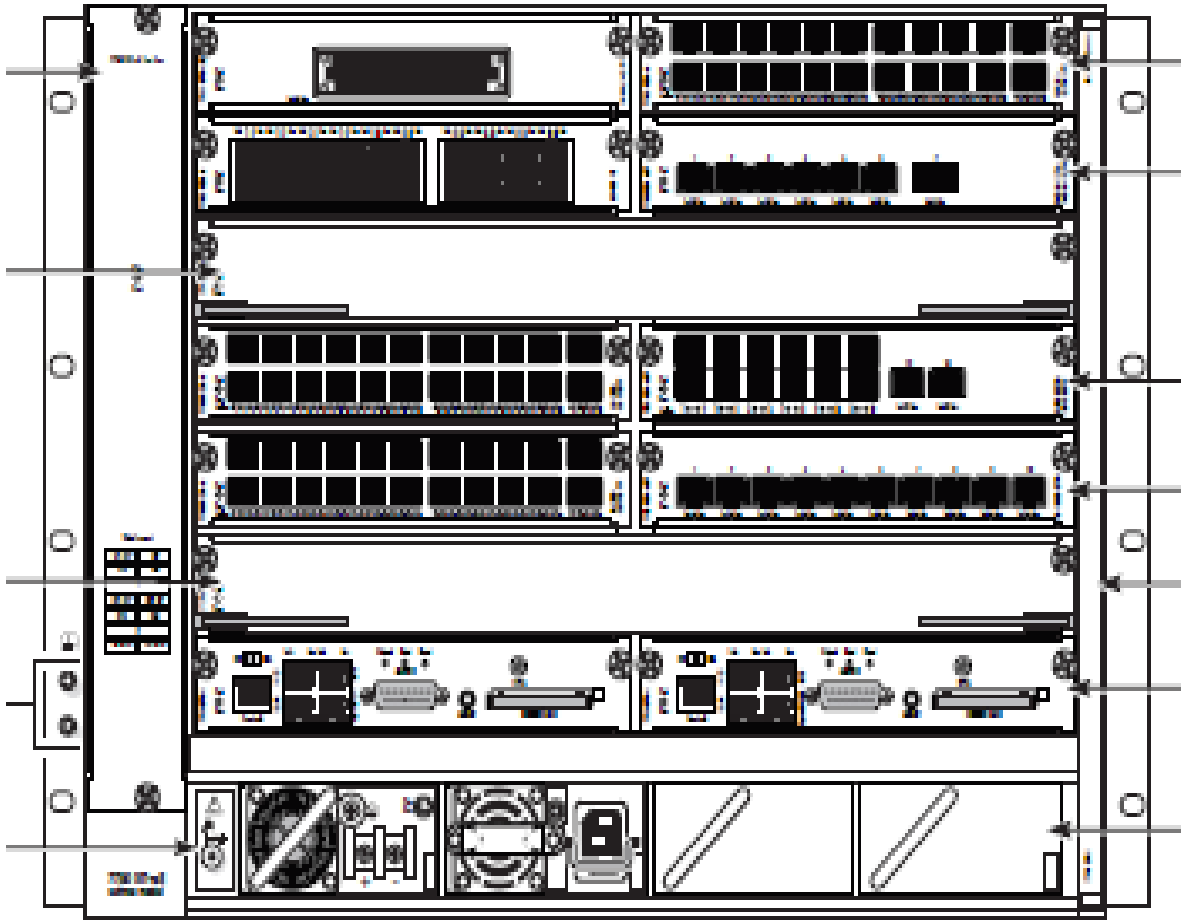
	(7750SR-7) PE
1	
2	
3	
4	20 pt 10GE IMM
5	20 pt 10GE IMM
A	SF/CPM5
B	SF/CPM5



Aggregation router

- Equipment Type: 7750 SR-a8

			(7750SR-a8)
1	10pt10GE	2	
3		4	
IOM			
1	10pt10GE	2	
7		8	
IOM			
CPM		CPM	
FAN			

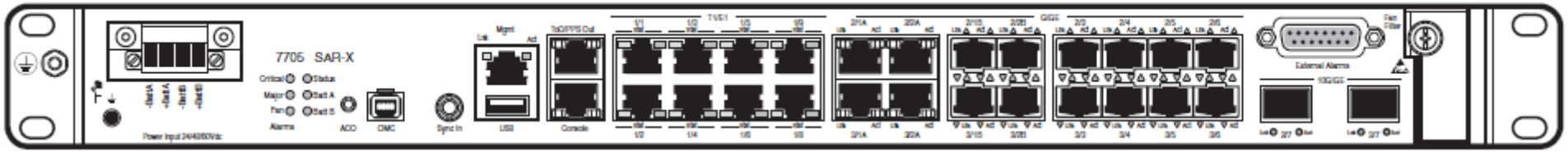


7750 SR-a8

Access router

- Equipment Type: 7705 SAR-x

7705 SAR-x

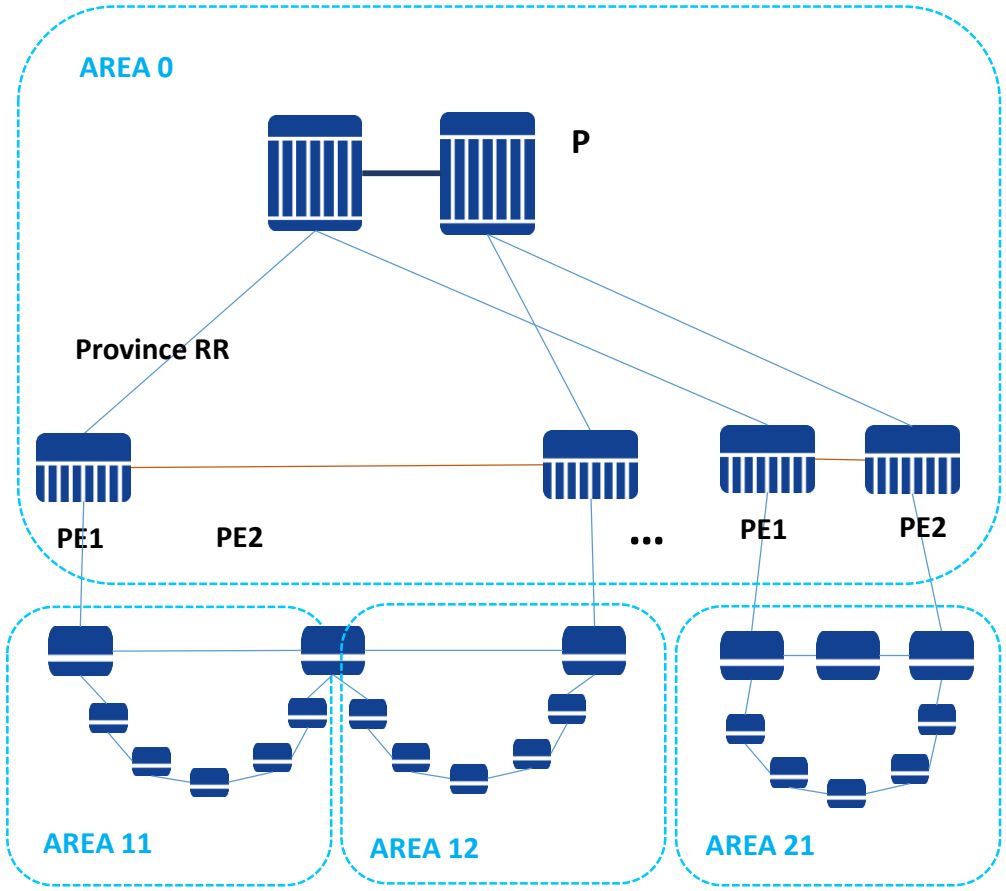


OSPF fast convergence

- Upon detection of a link failure the local node must generate a new OSPF LSA to reflect the current state of its local interfaces
- The time for a network to fully converge following a link-state change is essentially derived from the following inputs
  - Time taken for the source system to generate and flood the LSP/LSA to adjacent neighbors
  - Time taken for the LSP/LSA to propagate to adjacent neighbors
  - Time taken for the adjacent neighbors to re-flood the LSP/LSA and subsequently execute an SPF to re-compute the SPT topology. It is worthy of note that the LSP/LSA must be re-flooded BEFORE an SPF is executed; an implementation that exhibited the inverse behavior would ultimately impose a negative impact on convergence times
- OSPF Timers

  Following minimum value are recommended:
  - SPF-wait: Inital 10ms wait 10ms max 10ms
  - LSA-generate: Inital 10ms wait 10ms max 10ms
  - LSA-arrive: 2ms

OSPF area



P Router

PE Router

Aggragation Router

Access Router

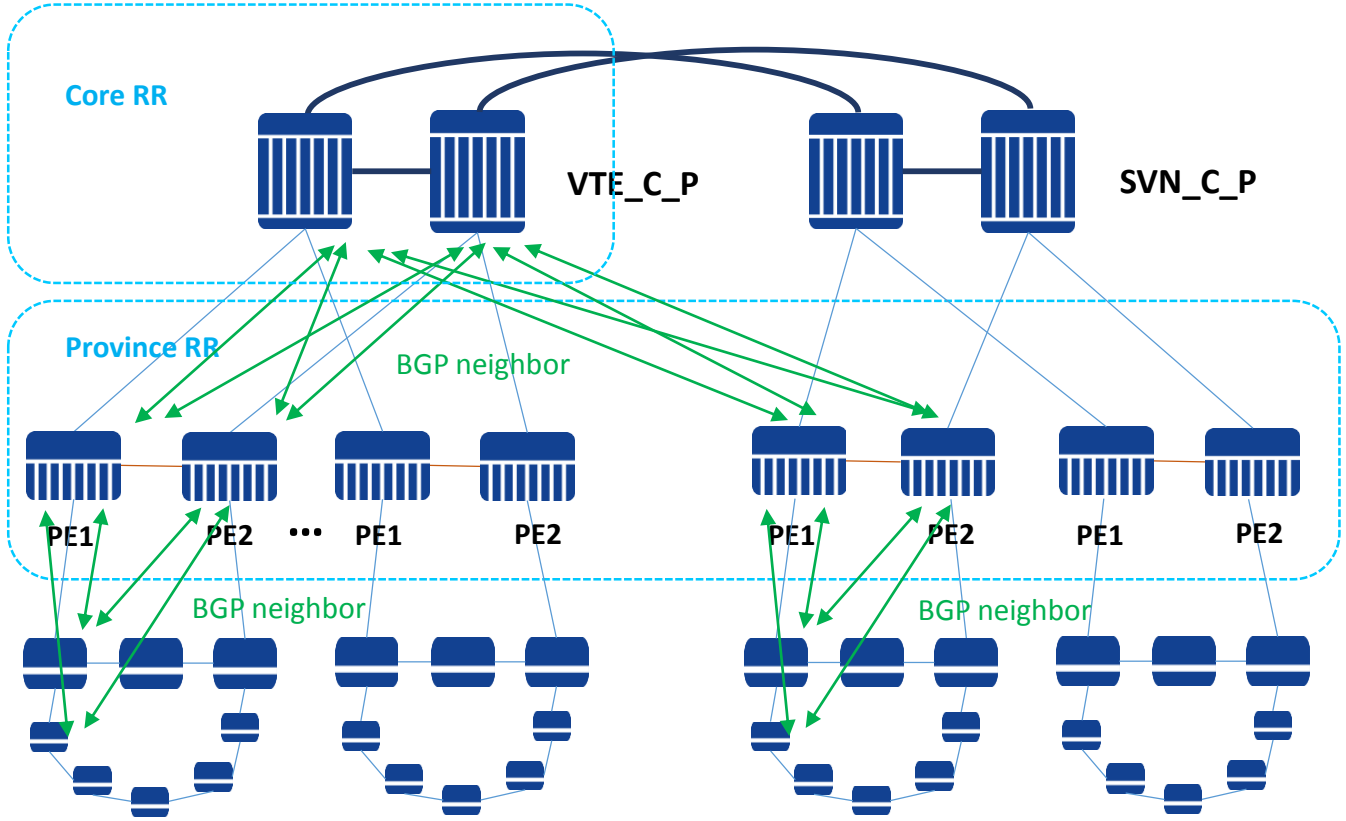
N*10G LINK

10G LINK

BGP design

- Route reflectors to minimize I-BGP peering sessions
- BGP version = 4
- BGP extended community strings
- BGP peer groups should be used
- MP-BGP to provide MPLS/BGP Layer3 VPN services
- All current PE establish MP-iBGP neighbor with current RRs (Huawei in VTE).
- VTE P pair take act of core RR router.
- PE pair take act of province RR router.
- All Aggregation and Access routers will establish MP-iBGP neighbor with province RR.

BGP Design



P Router

PE Router

Aggregation Router

Access Router

N*10G LINK

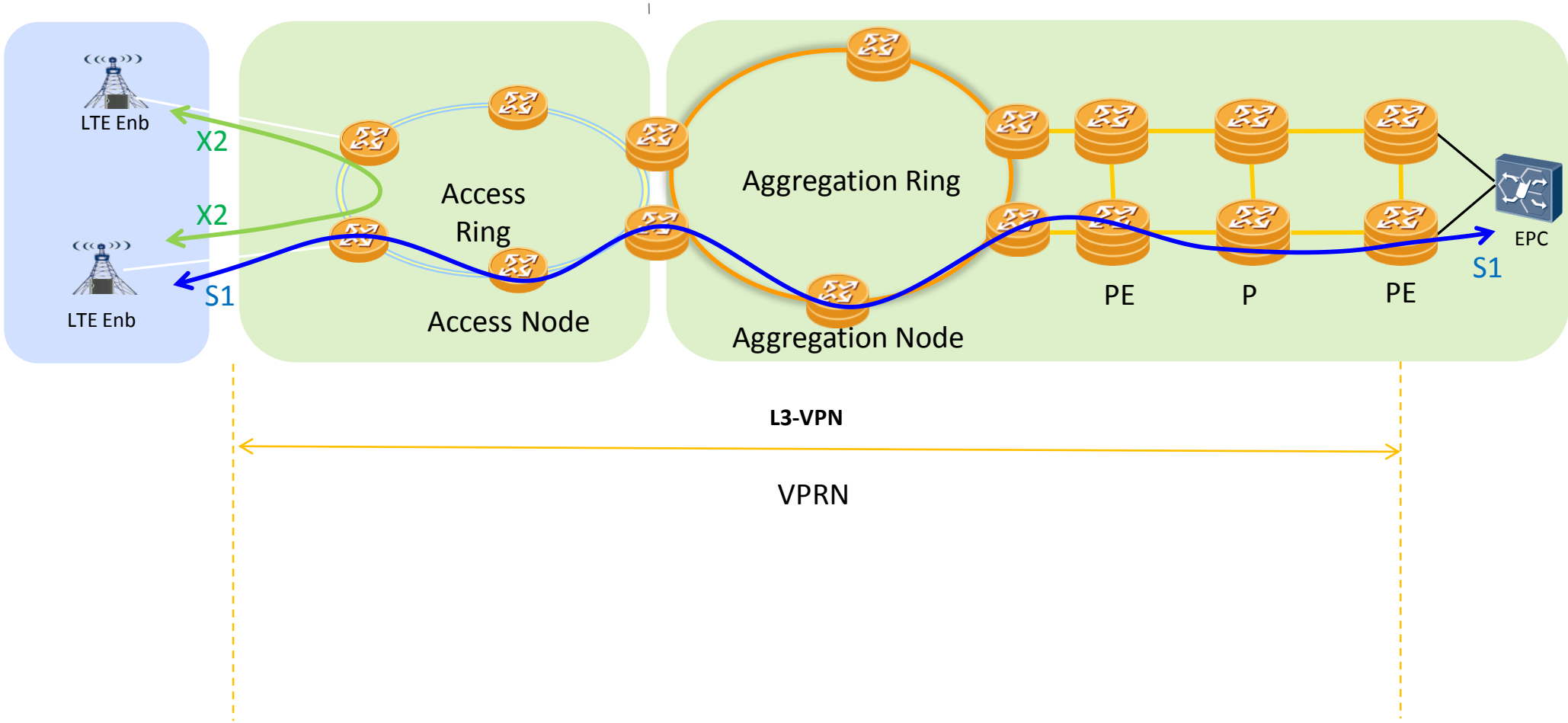
10G LINK

MPLS design

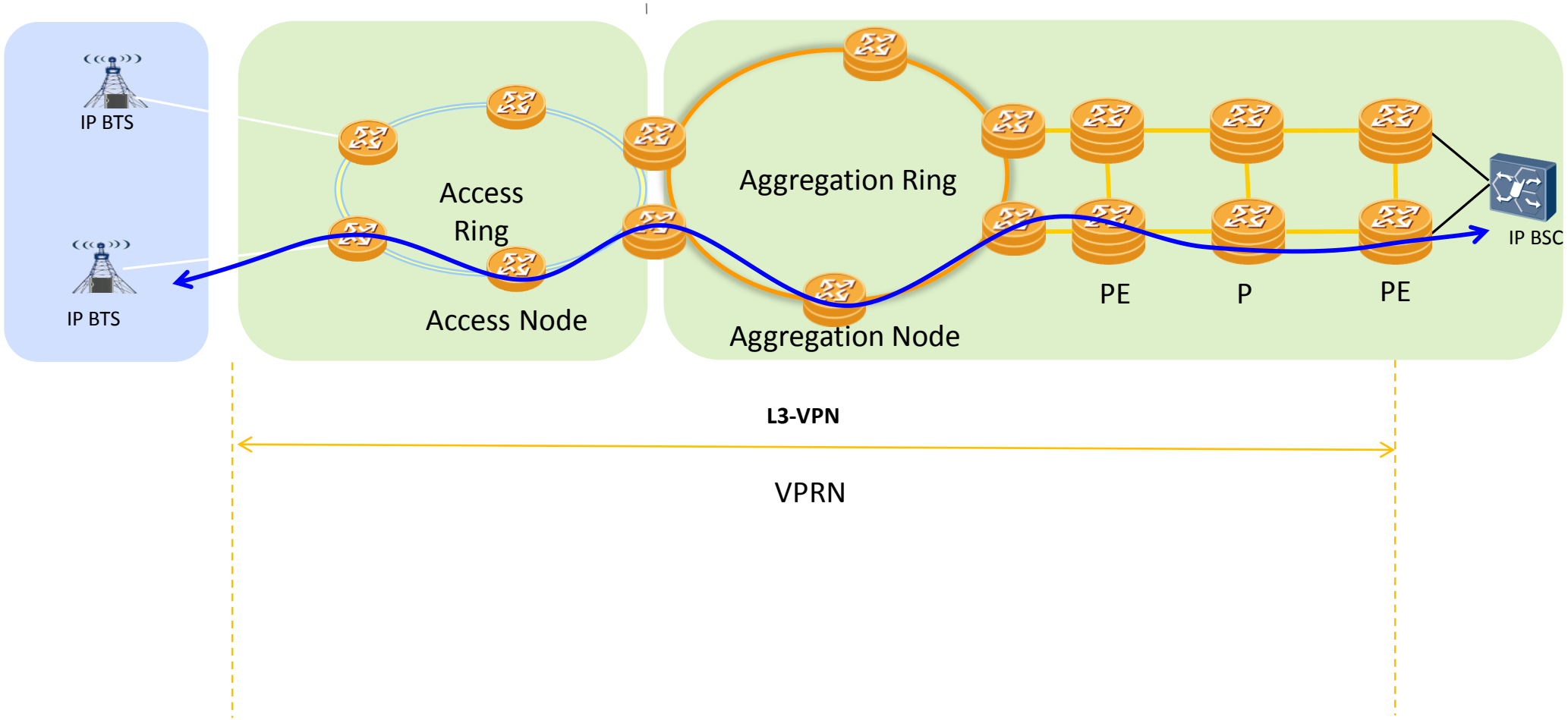
LDP

- IGP dependant convergence times
- Automatic tunnel creation
- Traffic completely dependent on the IGP

IPRAN Network for LTE Service



IPRAN Network for 2G Service



OAM mechanisms on service level

- Service Ping
- Service Mirroring
- VPRN Aware Ping and Traceroute
- Link Loss forwarding

Management protocols

- SNMP
- Syslog
- NTP
- Cflowd

Security

- CPM Filters and Queues
- CPU Protection (on 7x50)
- Access control
- Virtual Terminal Access
- Username/Password
- OAM Rate-Limiting
- Secure Copy
- Warning Banner

Thanks for your time and listening !