# Foresight is 2020
## NDOT building an ITS Network for the next Decade and Beyond

# Nevada Department of Transportation (NDoT)

Responsible for the planning, construction, operation and maintenance of 5400 miles of highway and > 1000 bridges that make up Nevada's state highway system.

NDOT's primary goal is "safety first."

# Vision for a Connected Future

Lay the foundations for NDoT's next-generation Intelligent Transportation System (ITS), making it easier to connect and manage the growing mesh of Internet of Things (IoT) devices on the state's highways

# Connected Vehicles: SciFi…or at our doorstep?

"I have no doubt that the automotive industry will change more in the next five to 10 years than it has in the last 50. The convergence of connectivity, vehicle electrification, and evolving customer needs demand new solutions."

Mary Barra
CEO General Motors
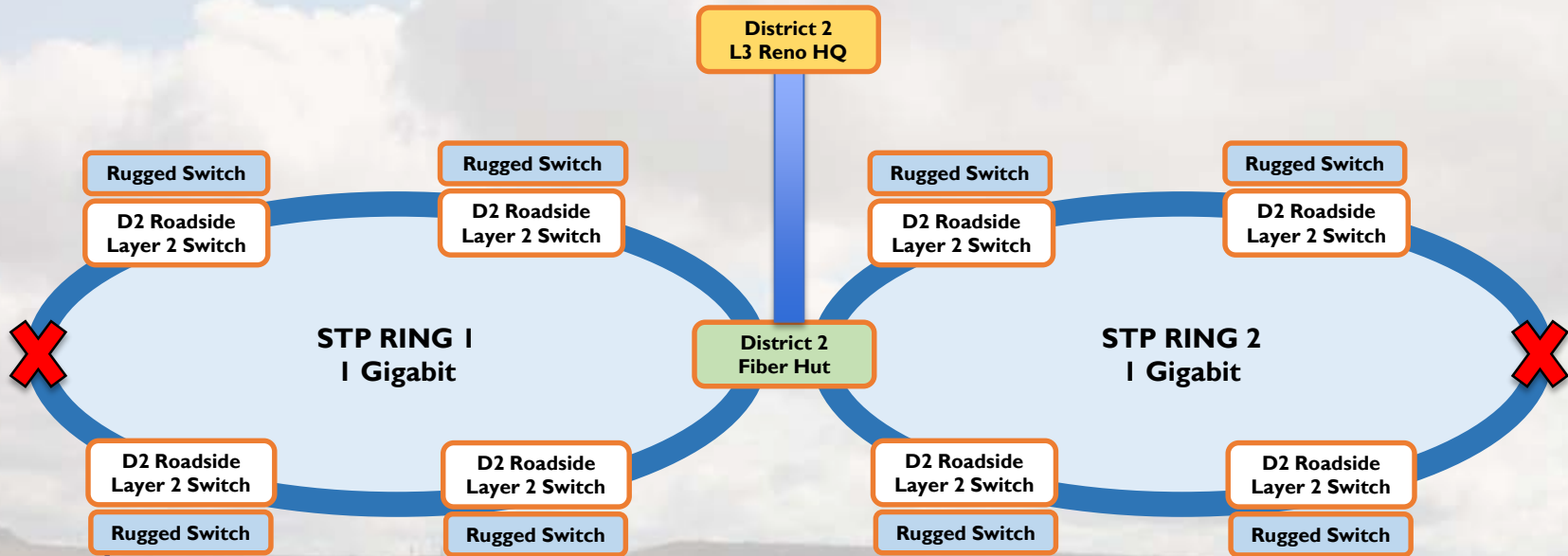2016 CES Show

# *Background*

# Background

❖ Shortest Path Bridging (SPB IEE 802.1aq) was introduced to NDOT IT & Traffic Operations (TO) in 2012.
- o SPB features of interest to NDOT
  - ❑ Native multicast
  - ❑ Elimination of Rapid Spanning Tree (RST)
  - ❑ Manageability

# Dated Network Infrastructure

District 2
L3 Reno HQ

Rugged Switch

D2 Roadside
Layer 2 Switch

Rugged Switch

D2 Roadside
Layer 2 Switch

Rugged Switch

D2 Roadside
Layer 2 Switch

Rugged Switch

D2 Roadside
Layer 2 Switch

**STP RING 1
1 Gigabit**

District 2
Fiber Hut

**STP RING 2
1 Gigabit**

D2 Roadside
Layer 2 Switch

D2 Roadside
Layer 2 Switch

D2 Roadside
Layer 2 Switch

D2 Roadside
Layer 2 Switch

Rugged Switch

Rugged Switch

Rugged Switch

Rugged Switch

- Aging network switches
- Mis-match of STP settings in flat vs MSTP regions
- Lack of SPB services at the edge
- Hop-by-hop manual configurations are prone to error
- Power/Fiber Physical error events cause network flooding
- Inefficient IGMP snooping causing poor video quality
- High convergence time
- Limitation of 4096 VLAN IDs

# Background

❖ Conducted and completed comparison of vendors supporting SPB.
  o In 2013 Avaya & Alcatel Lucent (ALE)where the only two vendors which supported SPB. The review was conducted by both IT and TO personnel.
  o Review of Avaya found:
    ❑ Avaya had no hardened switch to push SPB to the edge. This means RST would not be eliminated and failover issues would continue.
    ❑ Avaya Implemented a proprietary mechanism which modifies the standard operations of IP multicast. Because of the proprietary mechanism Avaya is not compatible with our SPB switches, this is more impactful to users committed to an open architecture.
    ❑ Avaya uses several Operating System (OS) to manage switches.

# Background

- o Review of ALE:
  - ❑ Supports both hardened and non-hardened switches.
  - ❑ Fully supports 802.1aq which is less impactful to users committed to an open architecture.
  - ❑ One OS for all switches.
  - ❑ Compatible with other vendors who support 802.1aq with no modifications.

❖ Dealing with internal opposition
- o 2014, Review results were shared with IT and TO management.
- o IT network manager & Chief IT Manager approve purchase of ALE Equipment.
- o IT network manager & Chief IT Manager then disapprove purchase of ALE Equipment.
  - ❑ IT proposed a SPB solution and proposed to meet TO requirements.
- o 2014 Traffic Operation Management accepted IT's proposal and project kickoff started in fall of 2014.

# Background

- o 2017 TO & IT close SPB project
  - IT did not meet requirements
    - Spanning was not eliminated
    - SPB was not pushed to the edge
    - Proprietary system was installed
    - No hardened switches were identified which could interoperate with Avaya SPB

- ❖ Implementing the correct solution
  - o 2017 TO informed IT that ITS systems would move to its own network using ALE equipment
  - o June 2018 using ALE professional services TO kicked off SPB core installation project of ALE equipment
  - o February 2019, core installation project completed.
    - 221 switches installed including non-hardened and hardened switches
    - 802.1aq (no modifications) pushed to the cabinet level

# *Searching for a New Solution*

# ITS Network Requirements

**Eliminate STP**

- Using IEEE 802.1aq SPB-M end-to-end

- Provide end-to-end Layer 2 services throughout

- Bring district-specific VLANs directly to ITS help desk

**Provide backward compatible with the legacy network**

- IP Multicast Applications

- Legacy PIM routers

**Multi-tenancy**

- Enable edge-only provisioning

- Provide Layer 2 services for various departments / entities

- Provide Layer 3 VPN services to various departments / entities

**PoE everywhere**

- Provide 802.3af and 802.3at PoE and PoE+ in all locations

- Allow for High Power PoE on multiple ports in all locations

# The Search for Comprehensive ITS Network Deployment

| | ALE | Cisco | Extreme | RuggedCom |
|---|---|---|---|---|
| Enterprise Portfolio | Yes | Yes | Yes | No |
| Advanced Network Management System | Yes | Yes | Yes | No |
| Hardened switch offerings | Yes | Yes | Yes | Yes |
| Service-based Networking Option | SPB | MPLS | MPLS/SPB | None |
| Industry-standard Multicasting | Yes | Yes | Yes | Yes |
| Industry-standard mulicasting over SPB | Yes | No | No | No |
| PoE, PoE+, HPoE | Yes | No | ? | No |
| High density port count | Yes | Yes | Yes | Yes |
| Commitment to Transportation market (1-5) | 5 | 3.5 | 3 | 2 |
| Comprehensive support | Yes | Yes | Yes | No |
| Robust Professional Services | Yes | Yes | ? | ? |
| Total Cost of Ownership | $$ | $$$$ | $$$ | $$ |

# *ALE Compared to RuggedCom*

| Switch Model | ALE OS6865-P16X | ALE OS6465-P12 | RuggedCom RS900GP | RuggedCom RS940G |
|---|---|---|---|---|
| 10/100 Ports | 0 | 0 | 8 | 0 |
| 10/100/1000 Port Count | 12 | 8 | 0 | 6 |
| 1G SFP | 2 | 4 | 2 | 2 |
| 10G SFP+ | 2 | 0 | 0 | 0 |
| PoE 802.3af | 12 | 8 | 8 | 0 |
| PoE+ 802.3at | 12 | 8 | 4 | 0 |
| High Power PoE | 4 | 4 | 0 | 0 |
| PoE Power Budget | Up to 300W | Up to 150W | Up to 160W | N/A |
| Layer 2 | Yes | Yes | Yes | Yes |
| Layer 3 | Yes | No | No | No |
| Shortest Path Bridging | Yes | No | No | No |
| Stackable | Yes | Yes | No | No |
| NEMA TS2 Compliant | Yes | Yes | Yes | Yes |
| IEEE 1588 | Yes | Yes | No | No |
| AC PS Options | Yes, up to 2 | Yes, up to 2 | Yes, up to 1 | Yes, up to 1 |
| DC PS Options | Yes, up to 2 | Yes, up to 2 | Yes, up to 2 | Yes, up to 2 |
| Full GUI NMS Support | Yes | Yes | No | No |
| Part of Enterprise family | Yes | Yes | No | No |
| List Price | $7,205 | $2,992 | $3,410 | |

# *Why SPB?*

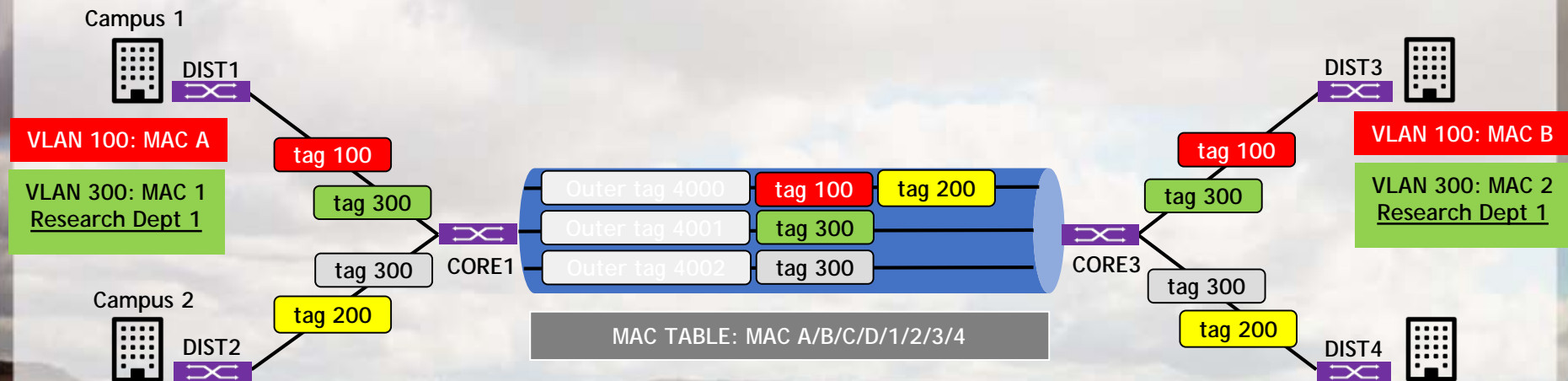# 802.1 Standard Evolution & Challenges
# 1998 802.1Q Bridging Data Plane

Campus 1

DIST1

VLAN 100: MAC A

VLAN 300: MAC 1
Research Dept 1

tag 100

tag 300

tag 300

Campus 2

DIST2

VLAN 200: MAC C

VLAN 300: MAC 3
Research Dept 2

tag 200

| Payload |
| 802.1Q |
| SA |
| DA |

**4 Bytes**

| TPID |
| PRIORITY |
| CFI |
| VID |

Tag Protocol Identifier 0x8100 – 16 bits
QoS 802.1P Priority Level – 3 bits
Canonical Format – 1 bit
VLAN Identifier – 12 bits = 4096 IDs

CORE1

tag 100

tag 200

tag 300

MAC TABLE: MAC A/B/C/D/1/2/3/4

CORE3

DIST3

VLAN 100: MAC B

VLAN 300: MAC 2
Research Dept 1

tag 100

tag 300

tag 300

tag 200

DIST4

VLAN 200: MAC D

VLAN 300: MAC 4
Research Dept 2

**1** Single tag label - Twelve-bit VLAN identifier (VID) - 2^12 gives 4096 VLANs with 0 and 4095 reserved.

**2** Overlapping VLAN - both customers want to use the same VLAN ID – will be in the same broadcast domain

**3** MAC Explosion - dynamic learning methods used to build forwarding databases

**4** Manual Configuration – hop by hop, prone to error

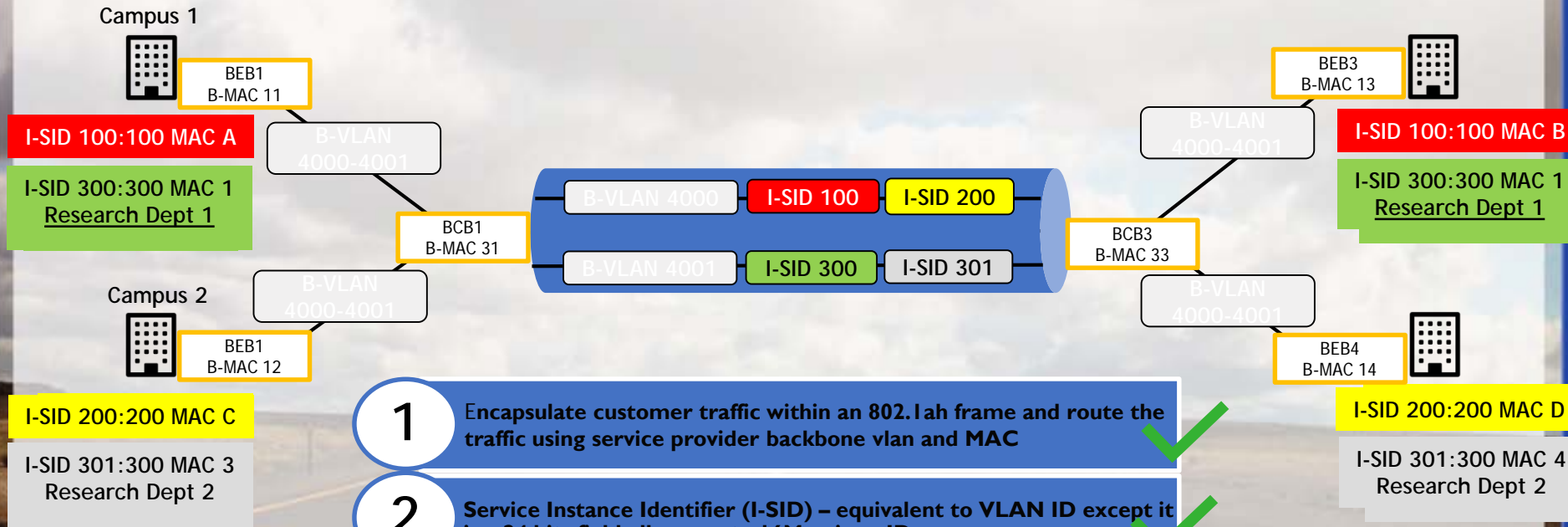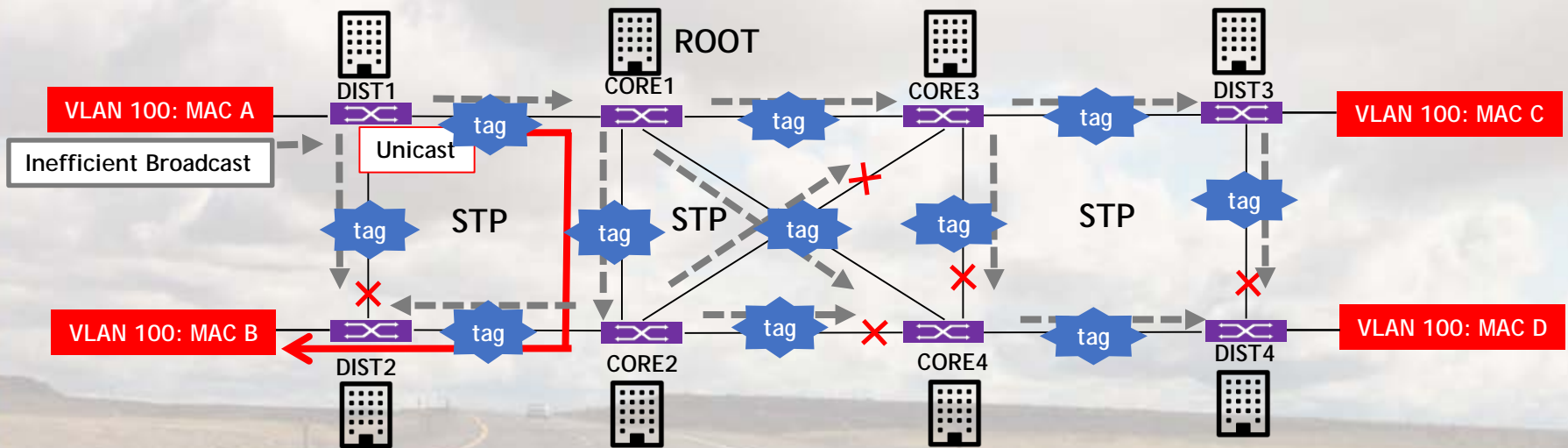# 802.1 Standard Evolution & Challenges 2005 802.1AD Bridging Data Plane

Campus 1

DIST1

**VLAN 100: MAC A**

**VLAN 300: MAC 1
Research Dept 1**

tag 100

tag 300

tag 300

CORE1

Campus 2

DIST2

tag 200

**VLAN 200: MAC C**

VLAN 300: MAC 3
Research Dept 2

Outer tag 4000 | tag 100 | tag 200
Outer tag 4001 | tag 300
Outer tag 4002 | tag 300

MAC TABLE: MAC A/B/C/D/1/2/3/4

DIST3

**VLAN 100: MAC B**

**VLAN 300: MAC 2
Research Dept 1**

tag 100

tag 300

CORE3

tag 300

tag 200

DIST4

**VLAN 200: MAC D**

VLAN 300: MAC 4
Research Dept 2

**1** Second tag label - Twelve-bit VLAN identifier (VID) - $2^{12}$ gives 4096 VLANs but using  tag Protocol Identifier 0x88a8, combination of inner/outer gives 16M services (4096x4096) ✓

**2** Overlapping VLAN – keeping the same customer inner vlan (C-VLAN) but use different service provider outer vlan (S-VLAN) ✓

**3** **MAC Explosion - dynamic learning methods used to build forwarding databases**

**4** **Manual Configuration – hop by hop, prone to error**

# 802.1 Standard Evolution & Challenges 2008 802.1AH Bridging Data Plane

Campus 1

BEB1
B-MAC 11

I-SID 100:100 MAC A

I-SID 300:300 MAC 1
Research Dept 1

B-VLAN
4000-4001

BCB1
B-MAC 31

B-VLAN 4000 | I-SID 100 | I-SID 200

B-VLAN 4001 | I-SID 300 | I-SID 301

Campus 2

B-VLAN
4000-4001

BEB1
B-MAC 12

I-SID 200:200 MAC C

I-SID 301:300 MAC 3
Research Dept 2

BEB3
B-MAC 13

B-VLAN
4000-4001

I-SID 100:100 MAC B

I-SID 300:300 MAC 1
Research Dept 1

BCB3
B-MAC 33

B-VLAN
4000-4001

BEB4
B-MAC 14

I-SID 200:200 MAC D

I-SID 301:300 MAC 4
Research Dept 2

**1** Encapsulate customer traffic within an 802.1ah frame and route the traffic using service provider backbone vlan and **MAC**

**2** Service Instance Identifier (I-SID) – equivalent to VLAN ID except it is a 24 bits field allows up to 16M unique ID

**3** Lots More Manual Configuration – hop by hop, prone to error

NEVADA DOT
SAFE AND CONNECTED

# 802.1 Standards Challenges: Control Plane STP



**VLAN 100: MAC A**
**VLAN 100: MAC B**
**VLAN 100: MAC C**
**VLAN 100: MAC D**

Inefficient Broadcast

Unicast

DIST1 — CORE1 (ROOT) — CORE3 — DIST3

DIST2 — CORE2 — CORE4 — DIST4

STP — STP — STP

tag

| STP/RSTP/MSTP |
| --- |
| ➢ **Inefficient links utilization** |
| ➢ **No Shortest Path** |
| ➢ **Inefficient Broadcast** |
| ➢ **Low scalability – Max of 40 Hops** |
| ➢ **High convergence times** |

# 802.1aq New Control Plane



| SERVICE 100: MAC A | SERVICE 100: MAC C |
| SERVICE 100: MAC B | SERVICE 100: MAC D |

Inefficient Broadcast

Unicast

ROOT

DIST1, CORE1, CORE3, DIST3
DIST2, CORE2, CORE4, DIST4

STP   STP   STP
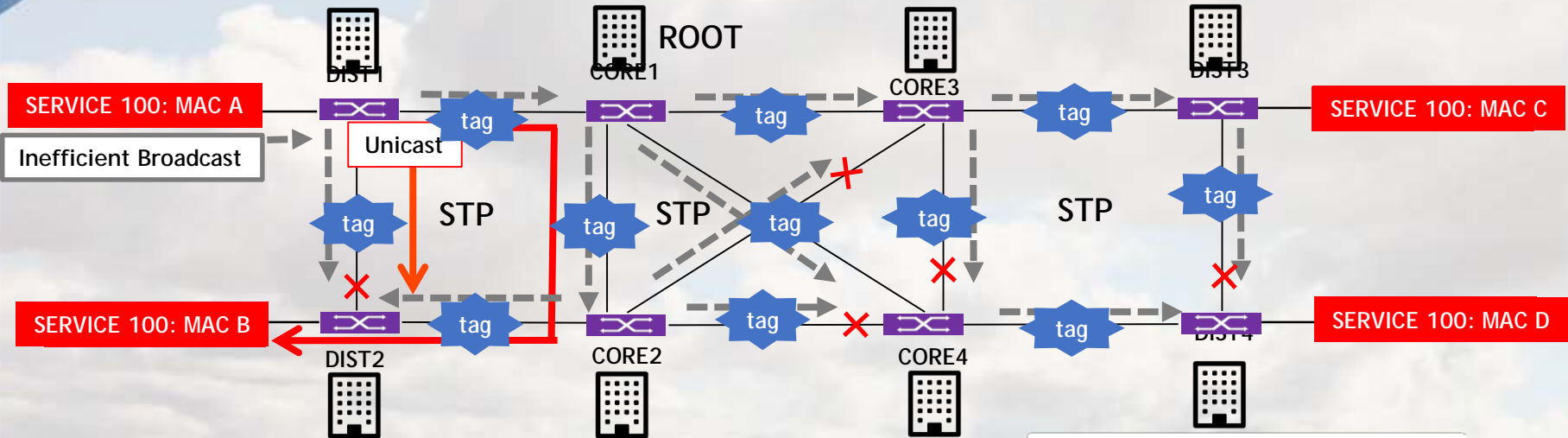
## STP/RSTP/MSTP

> **Hop by hop configuration**
> **Inefficient links utilization**
> **No Shortest Path**
> **Inefficient Broadcast**
> **Low scalability – Max of 40 Hops**
> **High convergence times**

RFC 6329
IS-IS &
New TVLs

## SPB Control Plane

> **No blocking ports / no loop**
> **Shortest Path when available**
> **Edge Provisioning**
> **Efficient broadcast**
> **Scale up to 1000 nodes**
> **Mesh topologies**
> **Fast Recovery sub second**

# Service deployment: Logical View

Voice · Video — Bldg C

Voice · Oracle · Video — Bldg B

Voice · Oracle — Bldg D

Voice · Oracle — Bldg A, Floor 2

Voice · Oracle · Video — Bldg A, Floor 1a

Voice · Oracle — Bldg A, Floor 1b

Legend

Location

VLAN

1. When an enterprise deploys a service, it generally limits that service exclusively to locations that need it

2. The usual mechanism for doing this is to create a virtual LAN

3. Add a new service, add a new VLAN

4. Add a location, extend the VLANs

# Service deployment: Physical View
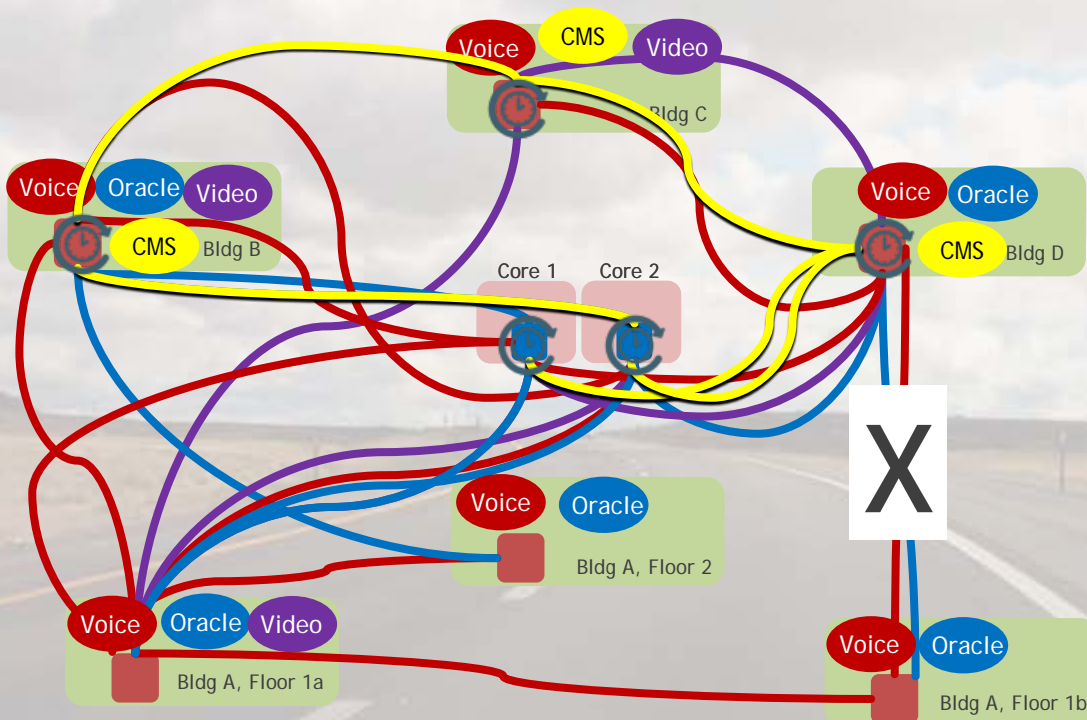


1. The use of VLANs requires the use of Spanning Tree

2. Adding a new service means configuring every switch involved in the service, edge and core

# With an SPB Architecture:
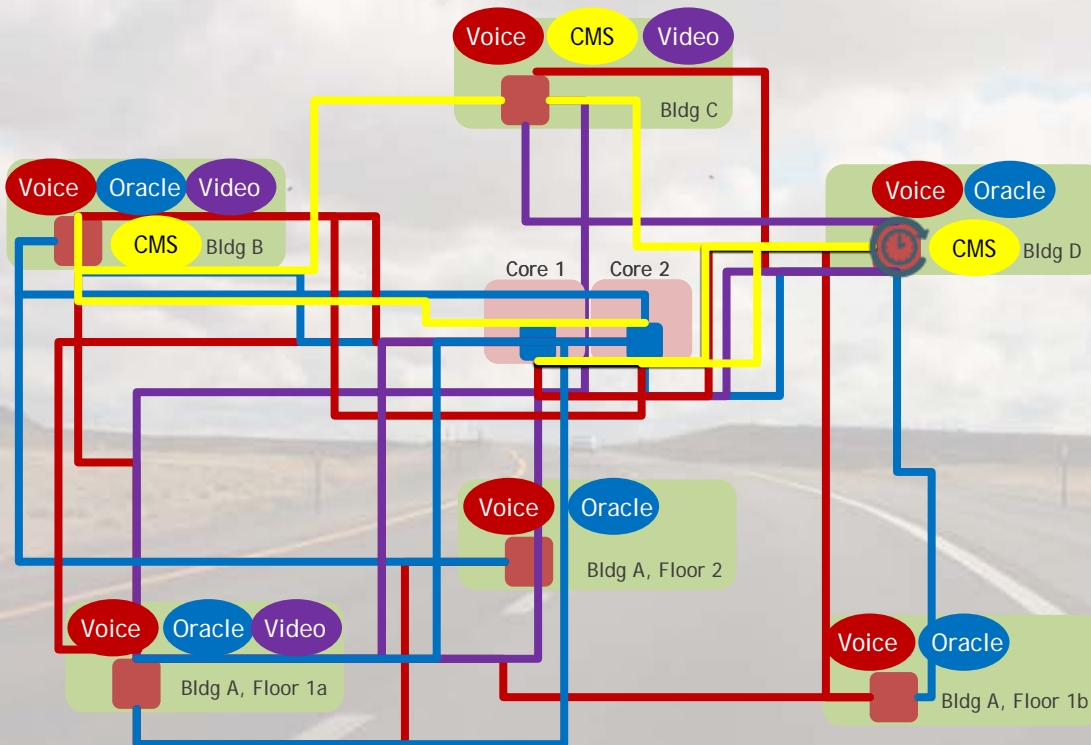


1. No more spanning tree: each service determines the SHORTEST path

2. Adding a new location means making a simple configuration change at the edge of the network - touch **one** switch

   …and with OmniSwitch uNP,

3. **zero-touch** provisioning is possible

# Advantages of SPB

**District 2**
**L3 Reno HQ**

**Rugged Switch** | **Rugged Switch**
**D2 Roadside Layer 2 Switch** | **D2 Roadside Layer 2 Switch**

Shortest Path Bridging
Mac-in-Mac
IEEE 802.1aq

**District 2**
**Fiber Hut**

**Rugged Switch** | **Rugged Switch**
**D2 Roadside Layer 2 Switch** | **D2 Roadside Layer 2 Switch**

Shortest Path Bridging
Mac-in-Mac
IEEE 802.1aq

**D2 Roadside Layer 2 Switch** | **D2 Roadside Layer 2 Switch**
**Rugged Switch** | **Rugged Switch**

**D2 Roadside Layer 2 Switch** | **D2 Roadside Layer 2 Switch**
**Rugged Switch** | **Rugged Switch**

- No more blocked ports, can use shortest path to communicate
- Ensures loop prevention by using IS-IS routing
- Sub-second convergence time in the event of node or link failure
- Ethernet as a service provisioning only at edge – no more hop-by-hop – 16M ISIDs
- Enables building of services from anywhere to anywhere, including to the ITS Helpdesk
- Scales to 1000 nodes
- Utilizes any type of topology: ring, partial or full meshed

NEVADA DOT
SAFE AND CONNECTED

# Virtual Private Network Ethernet Service
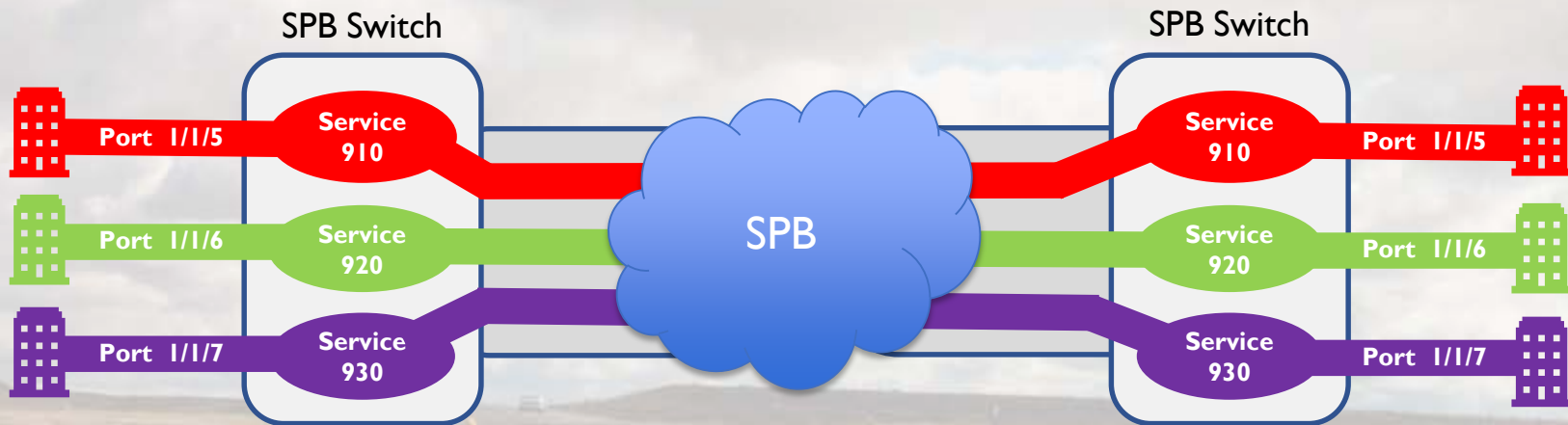


- Virtual Private Network (VPN) is a secure Ethernet service used to provide multi-tenant network connectivity and transport across locations
- Point-to-point or point-to-multiple point VPN
- Option to provision Quality of Service and Rate-limiting

# Physical Topology Core/Data Center Design



Local Subnets
DISTRICT 2

ITS HSP BEB
L3 Router Core

ITS CC BCB
WAN Core

ITS LV BCB
WAN Core

ITS LV BEB
L3 Router Core

Local Subnets
DISTRICT 3

Local Subnets
Data Center

ITS HSP BEB
L3 Router Core

ITS CC BCB
WAN Core

ITS LV BCB
WAN Core

ITS LV BEB
L3 Router Core

Local Subnets
DISTRICT 1
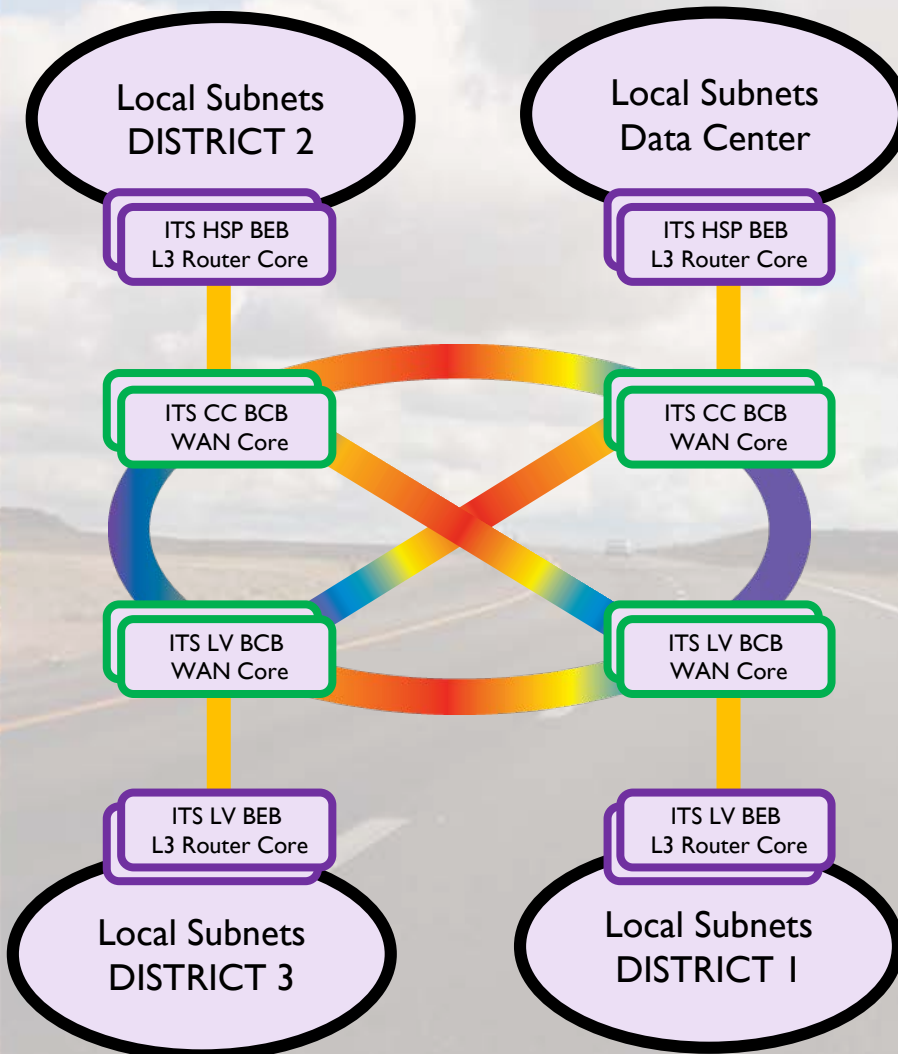
- Take advantage of ONS DWDM to simplify WAN Core layer

- Full-mesh at the core for shortest path/redundancy to Data Center(s)

- Physical redundancy using Virtual Chassis at the Core/Distribution Layers to simplify configuration, improve convergence, offer In-Service Software Upgrade

- CORE Layer will be configured as Backbone Core Bridge (BCB) elements, focusing only on backbone bridging

- Regional Core Layers will providing Layer 3 services (OSPF/PIM)

# Virtual Routing Forwarding Separation For Management/Data
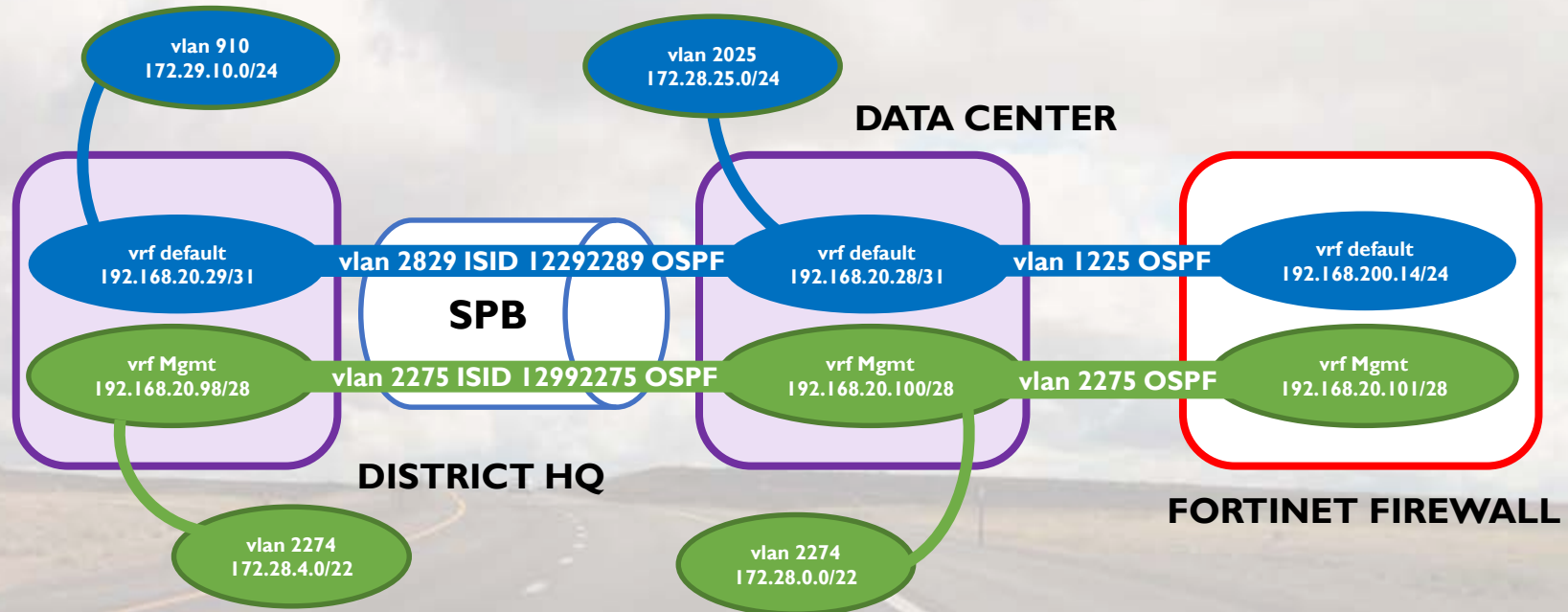


- Virtual Routing Forwarding (VRF) is a technology which effectively allows multiple independent routers to be hosted in the same physical router

- Routers maintain their own routing tables entirely independent of each other VRF creating security zones

- The firewall sits between all the security zones for policy enforcement

# *The Building Blocks*

# The Switch Platforms

- OmniSwitch 6865 Hardened LAN Switch

- OmniSwitch 6860E Stackable LAN Switch

- OmniSwitch 6900 Stackable LAN Switch

# The Network Building Blocks

- Alcatel-Lucent Enterprise family of non-hardened and hardened Ethernet switches

- All switches share the same operating system, CLI, and network management

- PoE is provided in all locations, including Core, Distribution, and Access (Edge) Layers

- Edge to Distribution Layer connectivity is provisioned at 1G today with built-in migration option for 10G without requiring an equipment forklift

- Distribution to Core Layer connectivity is provisioned at 1G and in some cases 10G - built-in migration option for 10G everywhere or 40G without requiring an equipment forklift

- ALE models of choice include:
  o Core/Distribution: OS6900-X72
  o Access in environmentally-controlled locations: OS6860E-P48
  o Access in roadside locations: OS6865-P16X

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# Core/Distribution 10G Switch
# ALE Omniswitch OS6900-X72 Features



Member of the OS6900 family

OS6900-X72 fixed form factor
- 6x40G QSFP+ fixed ports
- 48x10G SFP+ ports

VXLAN gateway support

Low latency ~500 ns

Can operate in a virtual chassis up to 6 units
- Any combination of OS6900 models is supported
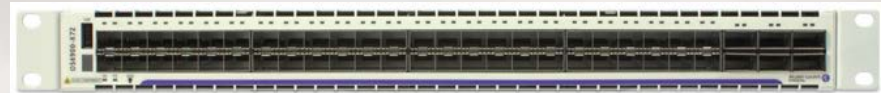
Data center positioned as a spine layer or ToR

Positioned as a multipurpose fundamental platform to serve as:
- Core interconnect switch between core sites
- Core Router
- High-density aggregation switch
- Distribution layer switch
- High-speed (10G) server access layer switch

# ALE OS6900-X72
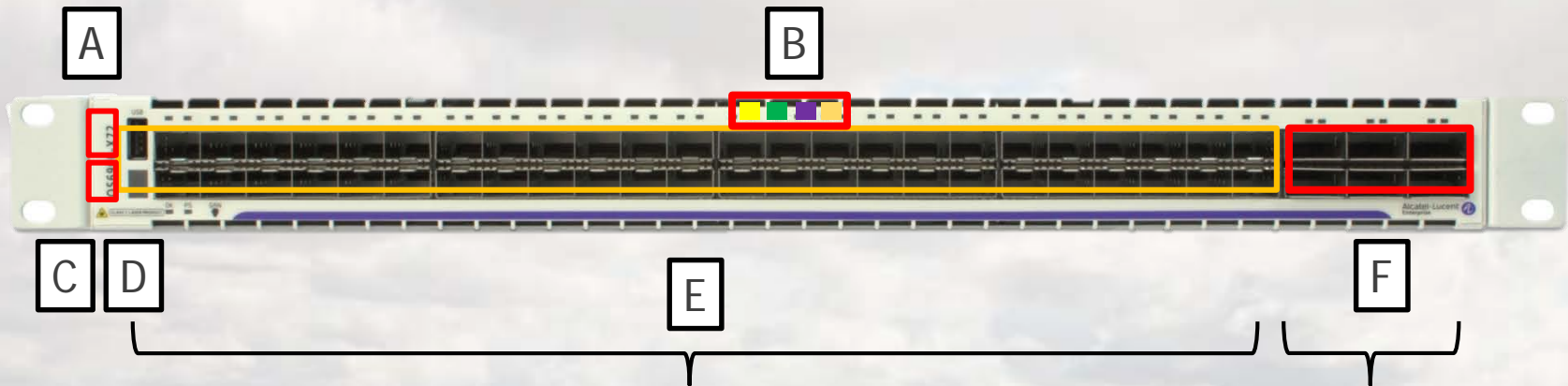


**A** Type A USB 2.0 Port
**B** Port Status LEDs
**C** Stacking Position Indicator LED
**D** Chassis/System Status LEDs
**E** 1/10G SFP+ ports 1 through 48
**F** QSFP+ ports 49 through 54: providing 40G or optional 4X10G splitter cable support

48x 10G SFP+ ports

6x 40G QSFP+ ports – can be used with splitter cables if desired

# ALE OS6900-X72 (Rear View)
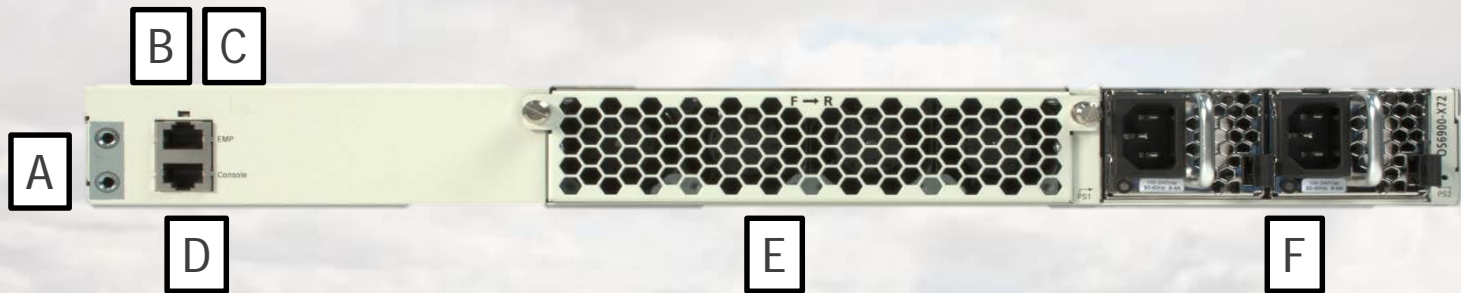


**A** Chassis Grounding Lug
**B** Ethernet Management Port (EMP) Status LED
**C** RJ-45 Ethernet Management Port (EMP)
**D** RJ-45 Console Management Port
**E** Fan Tray
**F** Power Supply Bays

# Access Switch (Core and fiber huts) ALE OmniSwitch OS6860E-P48 Features

OS6860E-P48
- 48 RJ-45 10/100/1000 BaseT POE ports,
- 4 fixed SFP+ (1G/10G); 2 VFL QSFP+ ports (20G each)
- 920W AC power supply
- All models have four built-in 10Gig SFP+ ports
- All models have two VFL ports ( 20G each )
- Support for PoE+ ( up to 30W per port) on all ports
- Support for PoE++ (up to 60W per port) four ports per unit
- Common power supplies ( hot-swappable)
- Connection to the Backup Power Shelf (BPS)
- Can be mixed in Virtual Chassis (VC) configuration

- Seven segment LED for VC numbering
- USB for file management and Bluetooth connection
- Micro-USB to USB console; Micro-USB – RS232
- Energy Efficient Ethernet supported on all copper models
- Deep Packet Inspection (DPI) in hardware
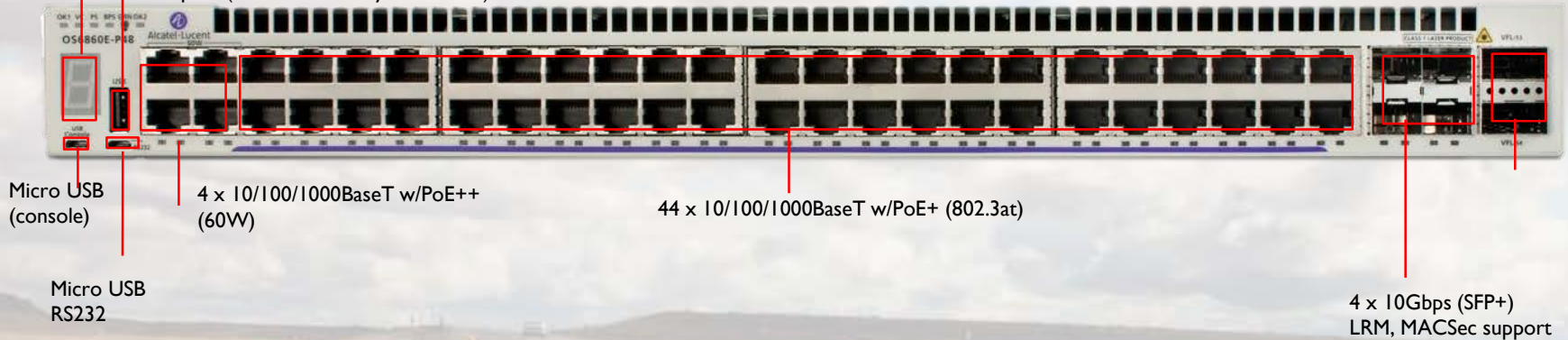- Run the same AOS version and optional software packages

# OmniSwitch 6860E-P48 – HW Overview

**OS6860E-P48**

7 segment LED

USB port (disaster recovery, Bluetooth)

Micro USB
(console)

4 x 10/100/1000BaseT w/PoE++
(60W)

44 x 10/100/1000BaseT w/PoE+ (802.3at)

Micro USB
RS232

4 x 10Gbps (SFP+)
LRM, MACSec support

EMP

BPS connector
N+N redundancy
PoE load sharing

Backup Load Sharing PSU

Load Sharing PSU.

# Edge Switch (Roadside Cabinets) ALE Omniswitch OS6865-P16X Features



OS6865-P16X

- 12 RJ-45 10/100/1000 BaseT POE ports,
- 2 fixed SFP (1G) and 2 fixed SFP+ (1G/10G);
- 280W AC and/or DC power supply
- All ports support PoE and PoE+
- Four ports support High Power PoE (up to 75W)
- Two 1G and two 10G uplinks for future uplink speed migration
- Supports dual, redundant PSUs of either two AC, two DC, or 1 AC/1 DC unit
- Power supplies are hot swappable
- Supports full Layer 3 functionality
- Supports industry-standard IEEE 802.1aq Shortest Path Bridging

- Intelligent Fabric for automated deployment
- USB for file management and Bluetooth connection
- Micro-USB to USB console; Micro-USB –RS232
- Energy Efficient Ethernet supported on all copper models
- Run the same AOS version and optional software packages

# OmniSwitch™ 6865 model lineup

## OS6865-P16X

- Half-rack width
- 8 x 10/100/1000 POE+
- 4 x 10/100/1000 HPOE 75W*
- 2 x 1000BaseX SFP
- 2 x 1G/10G SFP+ Uplink/Stacking
- Up to 300W PoE Budget

## OS6865-U12X

- Half-rack width
- 4 x 100FX/1000BaseX SFP
- 2 x 1000BaseX SFP
- 4 x 10/100/1000 HPOE 75W
- 2 x 1G/10G SFP+ Uplink/Stacking
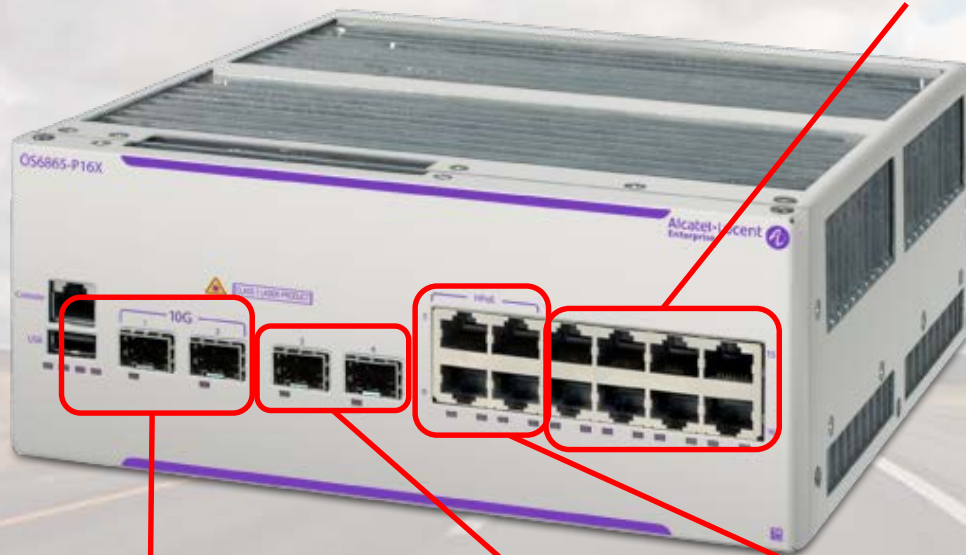- Up to 300W PoE Budget

## OS6865-U28X

- Full-rack width
- 20 x 100FX/1000BaseX SFP
- 4 x 10/100/1000 HPOE 75W
- 4 x 1G/10G SFP+ Uplink/Stacking
- 2 x 20G QSFP+ Stacking
- Up to 280W PoE Budget

# OmniSwitch™ 6865-P16X

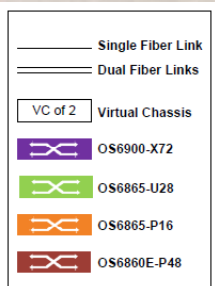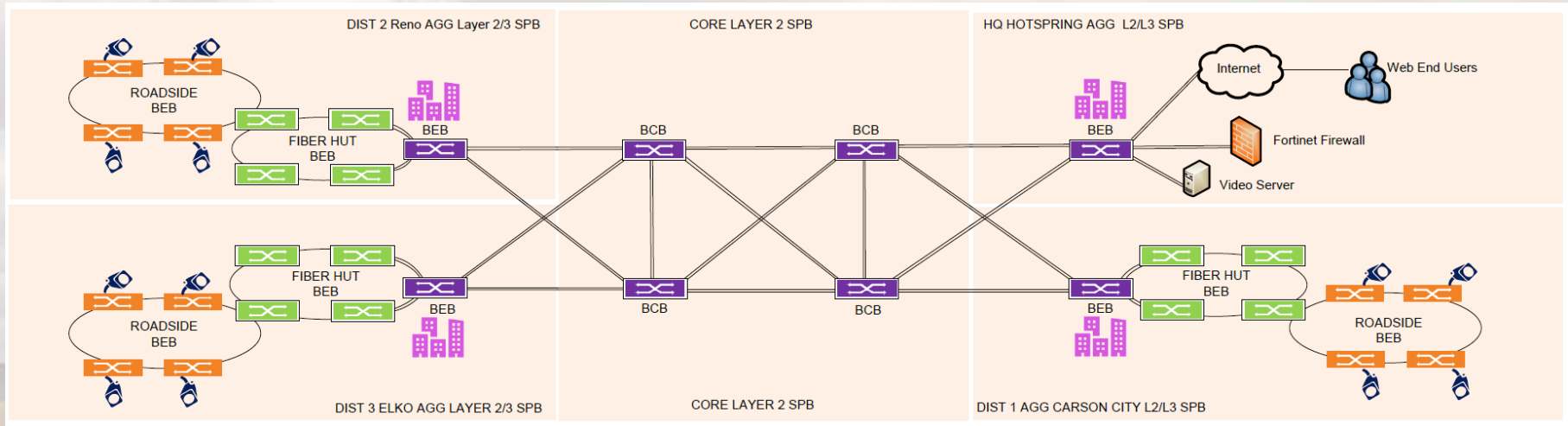10/100/1000 ports
(POE+, 1588v2)

- Half rack (19") wide
- 10.2" deep (excluding Power Supplies
- DIN, 19" Rack, Wall Mount
- Dual power supply connectors in the back
- External power supplies
  - 180W AC – 140W POE budget
  - 180W DC – POE budget – 140W @48V, 100W @24V

SFP+ ports (1G/10G, 1588v2, uplink or stacking)

1G SFP ports (1588v2, uplink)

10/100/1000 ports (POE+, 75W POE support, 1588v2)

# NDoT Network Overview



- ONS DWDM
- Full-mesh at the core
- Physical redundancy using Virtual Chassis at the core/dist/fiber hut CORE layer will be backbone core bridge (BCB)
- Distribution / Fiber hut aggregation layer will be the backbone edge bridge (BEB) providing layer 2/3 services

# *Benefits*
# *and*
# *Lessons Learned*

# Benefits

### Technical

- Support for future technology
- Reduced new device, service, and application roll out time

### Financial

- Increased staff availability to work on mission-critical projects

### User Experience

- Real-time travel information provided to drivers
- Increased safety and improved traffic flow

# Lessons Learned

## Identify specific goals of the project

- What is the main problem to be eliminated through this?
- What additional capabilities will we achieve?
- What is the timetable for execution and completion?

## Exercise due diligence in evaluating options

- Technology alternatives
- Vendor alternatives

## Enroll stakeholders in the vision

- Secure buy in from our whole team
- Secure buy in from our customers
- Secure buy in from management

## Prepare for the unexpected

- It's always more complicated than all the planning reveals
- Contingency plans and being nimble are essential
- Communicate, communicate and communicate!

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# *Questions?*

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