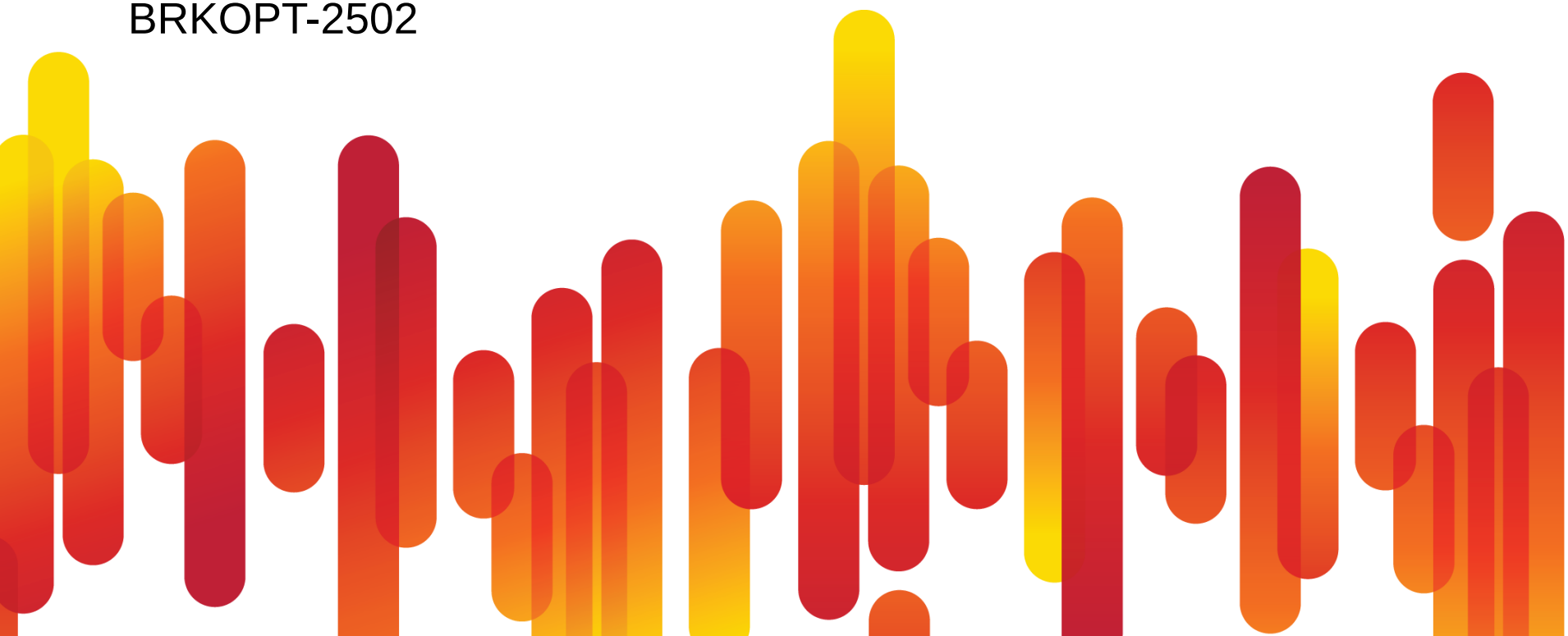
Deploying Carrier Ethernet L2VPN Over DOCSIS

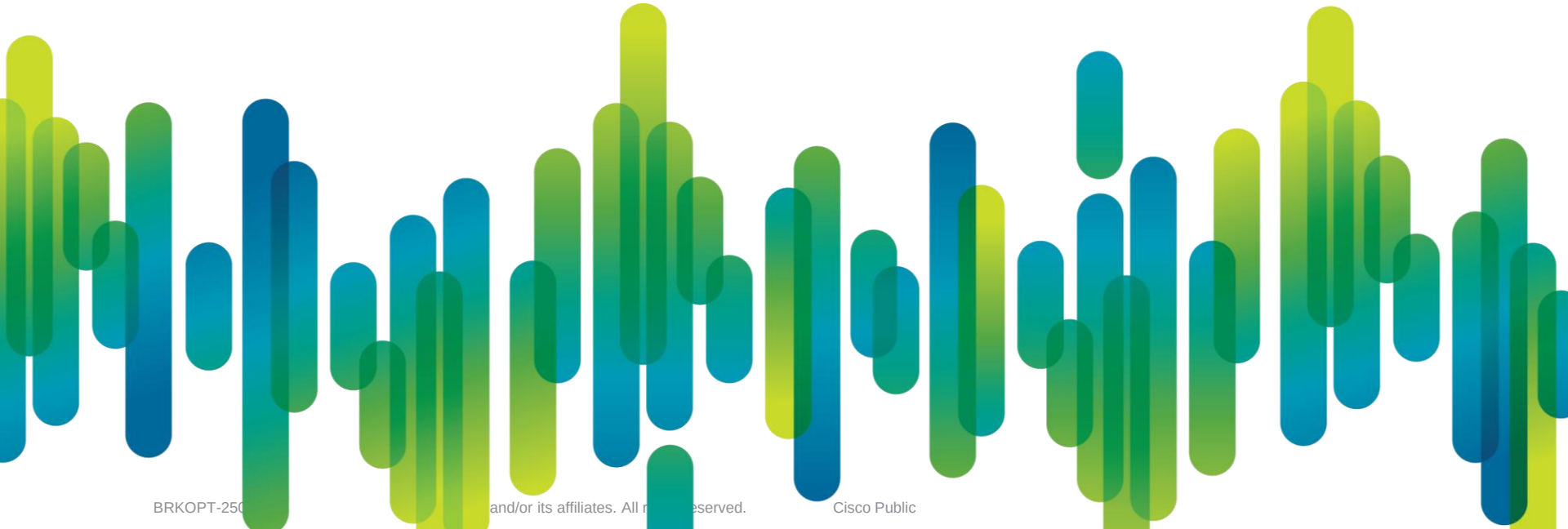
BRKOPT-2502



Agenda

- The Case for Business Services over DOCSIS
- Carrier Ethernet Business Services
- L2VPN over DOCSIS Deployment Models
  - CPE-Based L2VPN
  - Transparent LAN Services over DOCSIS
  - Dot1Q-Based Business Services over DOCSIS
  - MPLS-Based Business Services over DOCSIS
- Choosing a BSoD Deployment Model
- Summary

The Case for Business Services Over DOCSIS



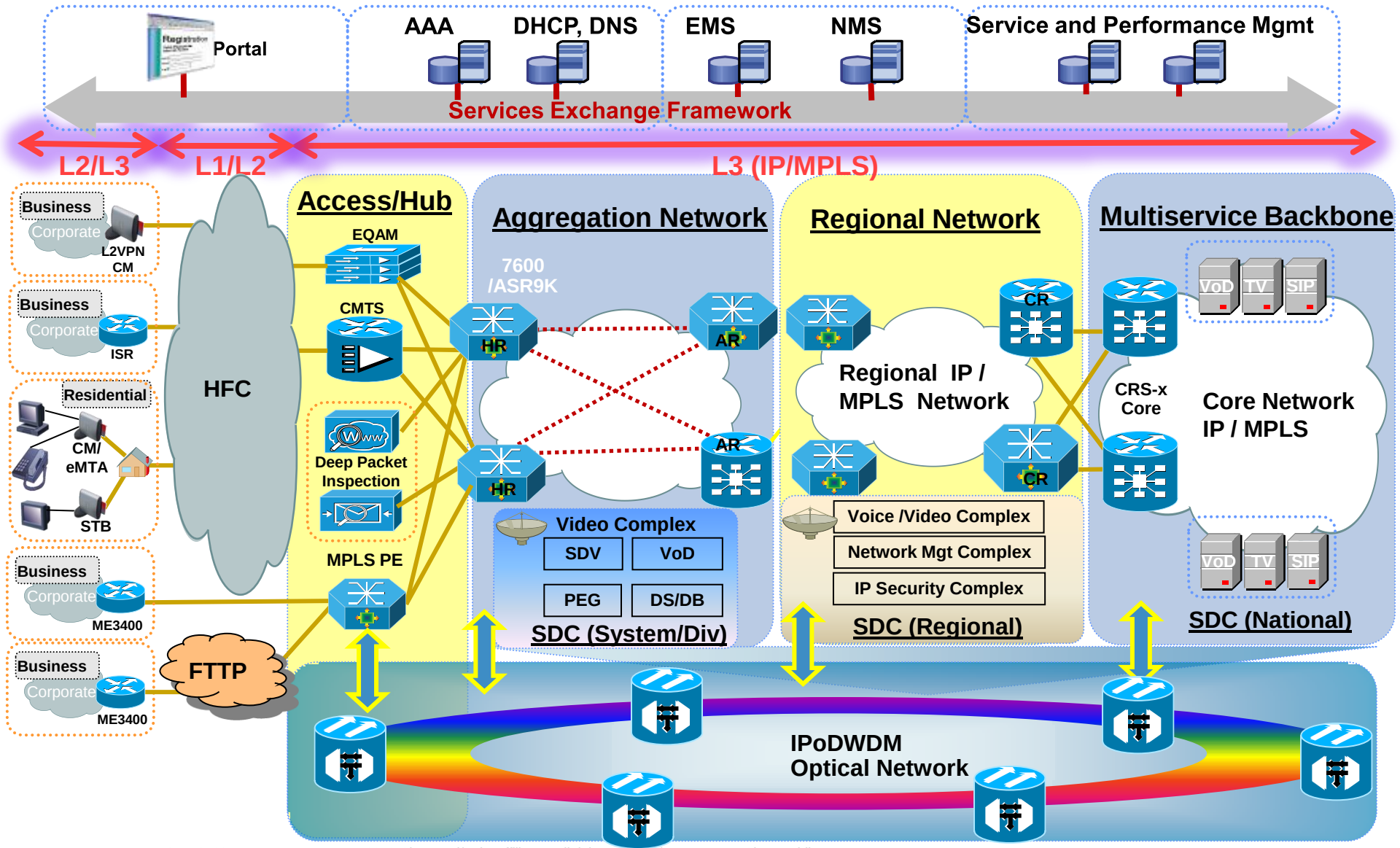
CMTS-Based Services Landscape

- Massive investment in HFC Infrastructure
- HFC and DOCSIS footprint and coverage
- Predominantly High Speed Data, Internet Access
- Voice over IP Revolution
  - New revenue stream for Cable Service providers
  - Competitive pricing for consumers
- Is this the end of line for CMTS and HFC-based services?
- Next revenue generating service over HFC/CMTS?

The Next Wave of Evolution—BSoD

- Long history of VPN services over Fiber
- HFC plant under-utilized in Business hours
  - Dual purpose HFC networks
- Business Services over DOCSIS – BSoD
- No additional cost in most cases
- Same HFC network, additional services
- Zero touch CMTS provisioning
- Standardized service offerings

Cable Multi-Service Networks



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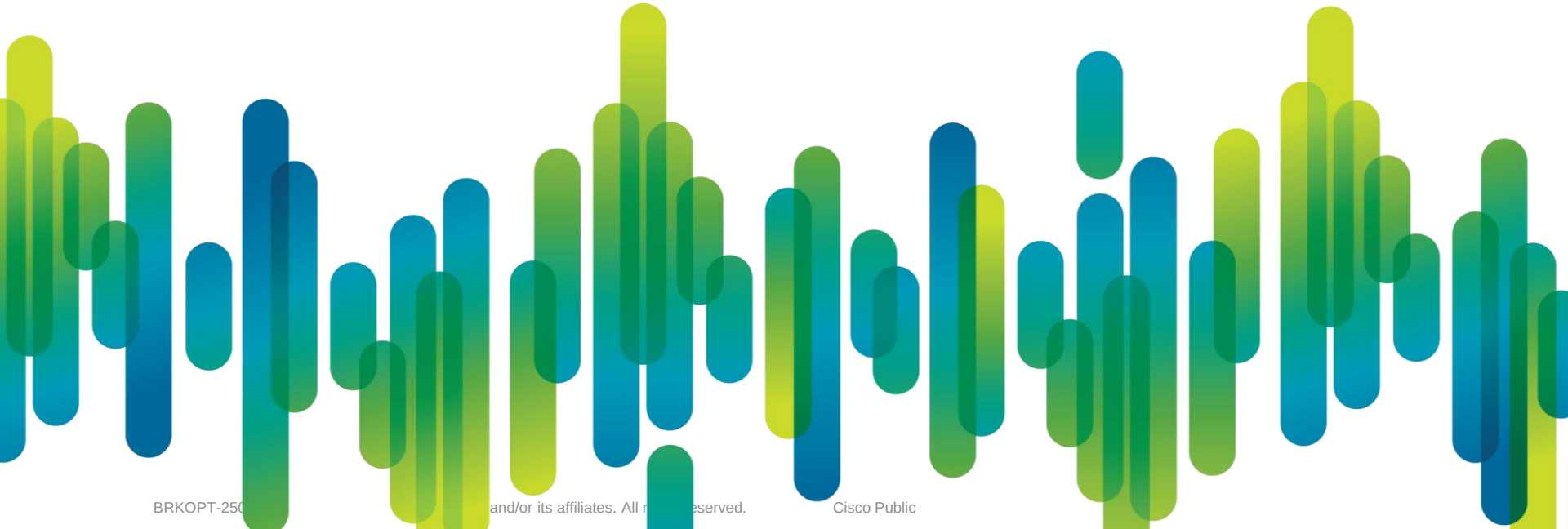
Carrier Ethernet Business Services



Why Ethernet Services?

The Basics

1. Mature and Widely Deployed

Long History of Deployment

De-facto LAN Technology

2. Resilient and Versatile

Can Terminate Fiber and Copper Effectively

Ethernet over DOCSIS adds a new paradigm

3. Cost Effective

Not as Expensive as Other WAN Technologies

IT Staff Already Trained in Ethernet

4. Constantly Evolving

Ethernet Has Came a Long Way Since Its Early Days

What VPN Services?

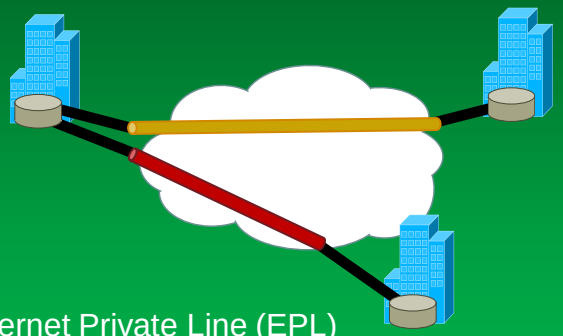
- Mass scale Carrier Ethernet Services adoption
- MPLS-based L3 VPN and L2 VPN services
- Advantages of L2 VPN services over L3 VPN:
  - Protocol Agnostic
  - No protocol sharing between SP and Customer
  - More customer control over their network
  - Simpler to deploy
- Standardized Carrier Ethernet L2VPN Services

Carrier Ethernet L2VPN Services

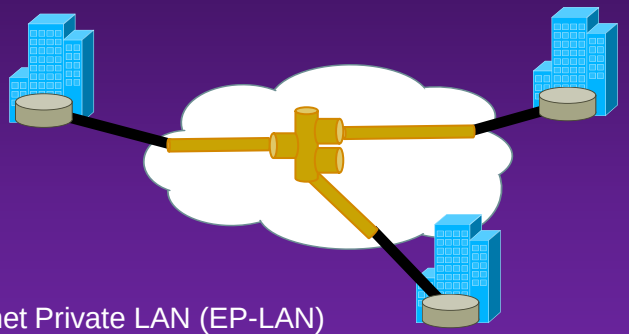
E-LINE Services

E-LAN Services

Port-based

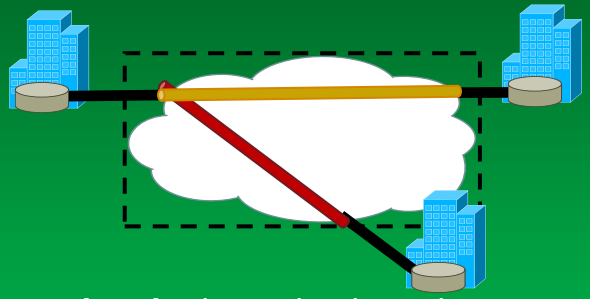


Ethernet Private Line (EPL)
Replaces a TDM private line
Dedicated UNIs for point-to-point connections
Single Ethernet Virtual Connection (EVC) per UNI
The most popular Ethernet service due to its simplicity

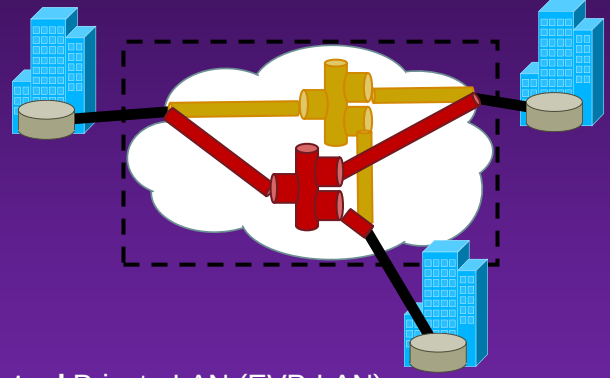


Ethernet Private LAN (EP-LAN)
Supports dedicated UNIs
Supports transparent LAN services
Supports multipoint Layer 2 VPNs

VLAN-based



Ethernet **Virtual** Private Line (EVPL)
Replaces Frame Relay or ATM services
Supports service multiplexed UNIs (i.e., multiple EVCs per UNI)
Allows single physical connection (UNI) to customer premise equipment for multiple virtual connections



Ethernet **Virtual** Private LAN (EVP-LAN)
Supports service-multiplexed UNIs
Supports multipoint Layer 2 VPNs

Business Services Over DOCSIS

- Builds on standards defined by MEF
- Competitive advantage for Cable SPs due to HFC reach
- Cable Labs specs available for L2VPNs
- DOCSIS 3.0 offer new opportunities for BSOD
  - Higher speed with Channel bonding
  - Effective Competition against T1, leased line and in some cases, fiber

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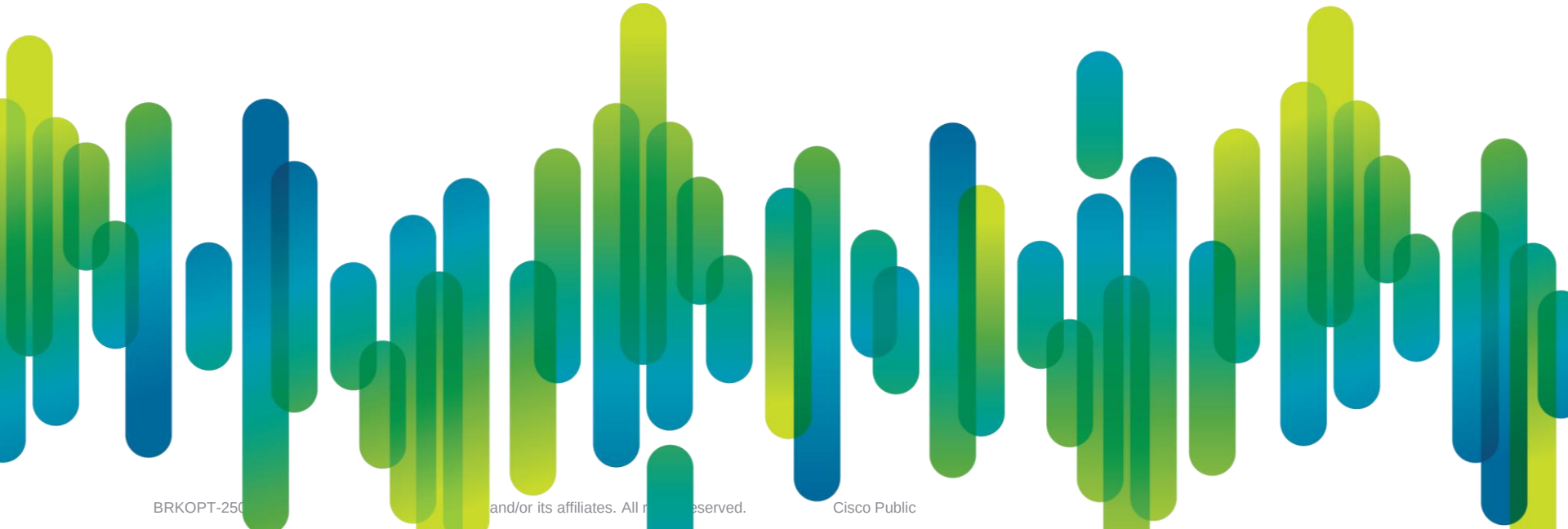
Business Services Over DOCSIS Deployment Models



BSoD L2VPN Deployment Models

- Two distinct deployment models
  - CPE-Based L2VPN
    - Minor adjustments over established HSIA services
    - Layer 2 Tunnel established between CM Routers
  - Network-Based L2VPN
    - True L2 service through CMTS
    - Layer2 tunnel established within Cable SP Network
    - Multiple variations available
      - Transparent LAN Services over DOSCIS
      - Dot1Q-based BSoD
      - MPLS-based BSoD

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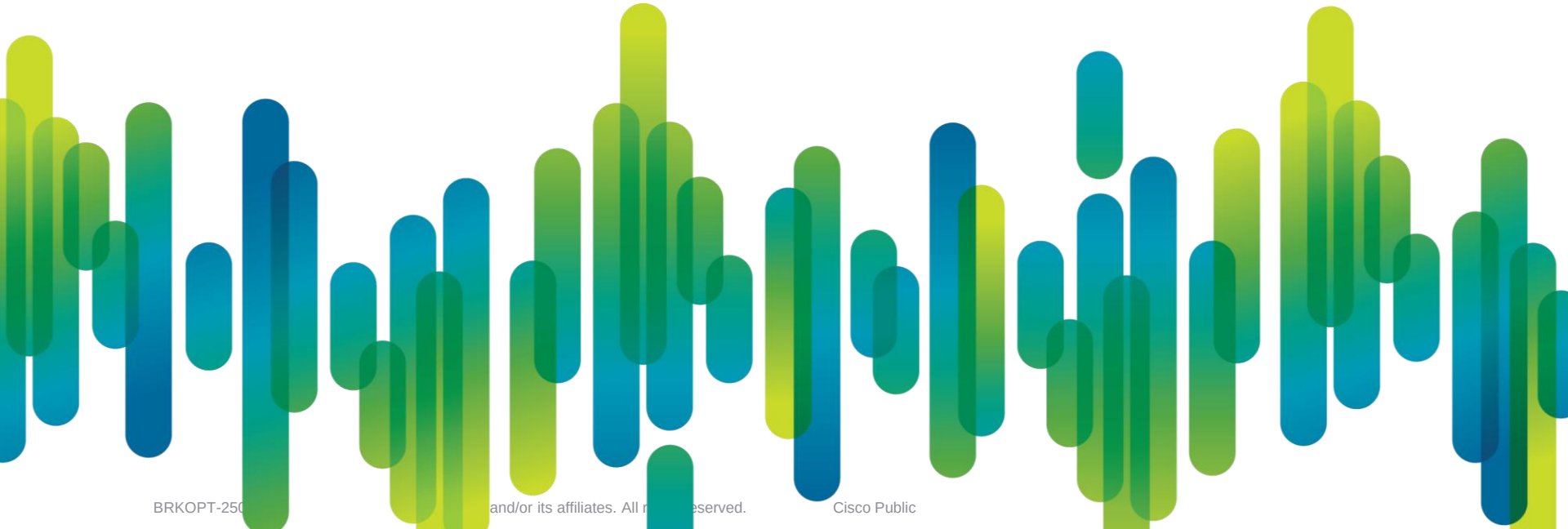
CPE-Based L2VPN Services

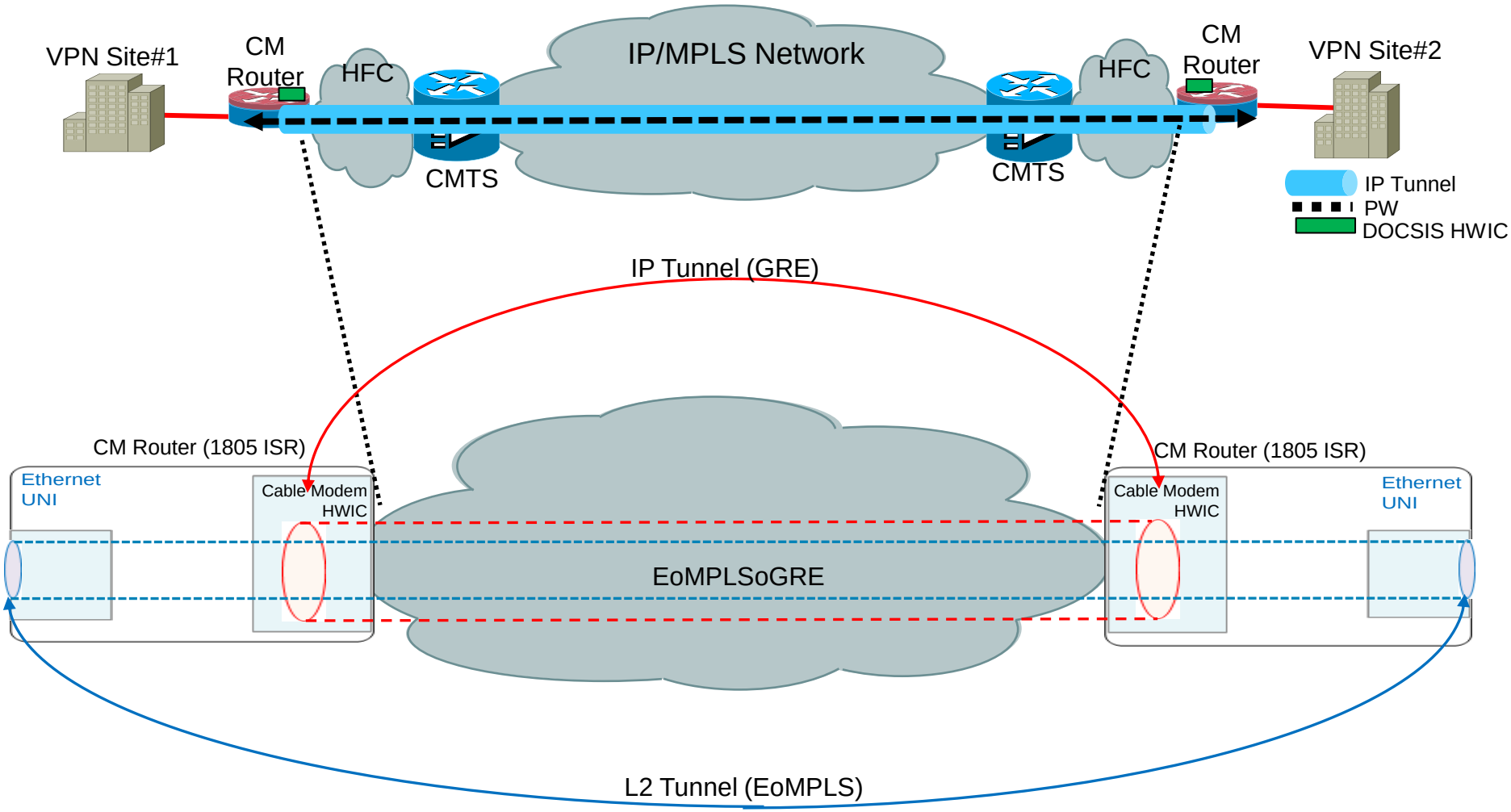


CPE-Based L2VPN

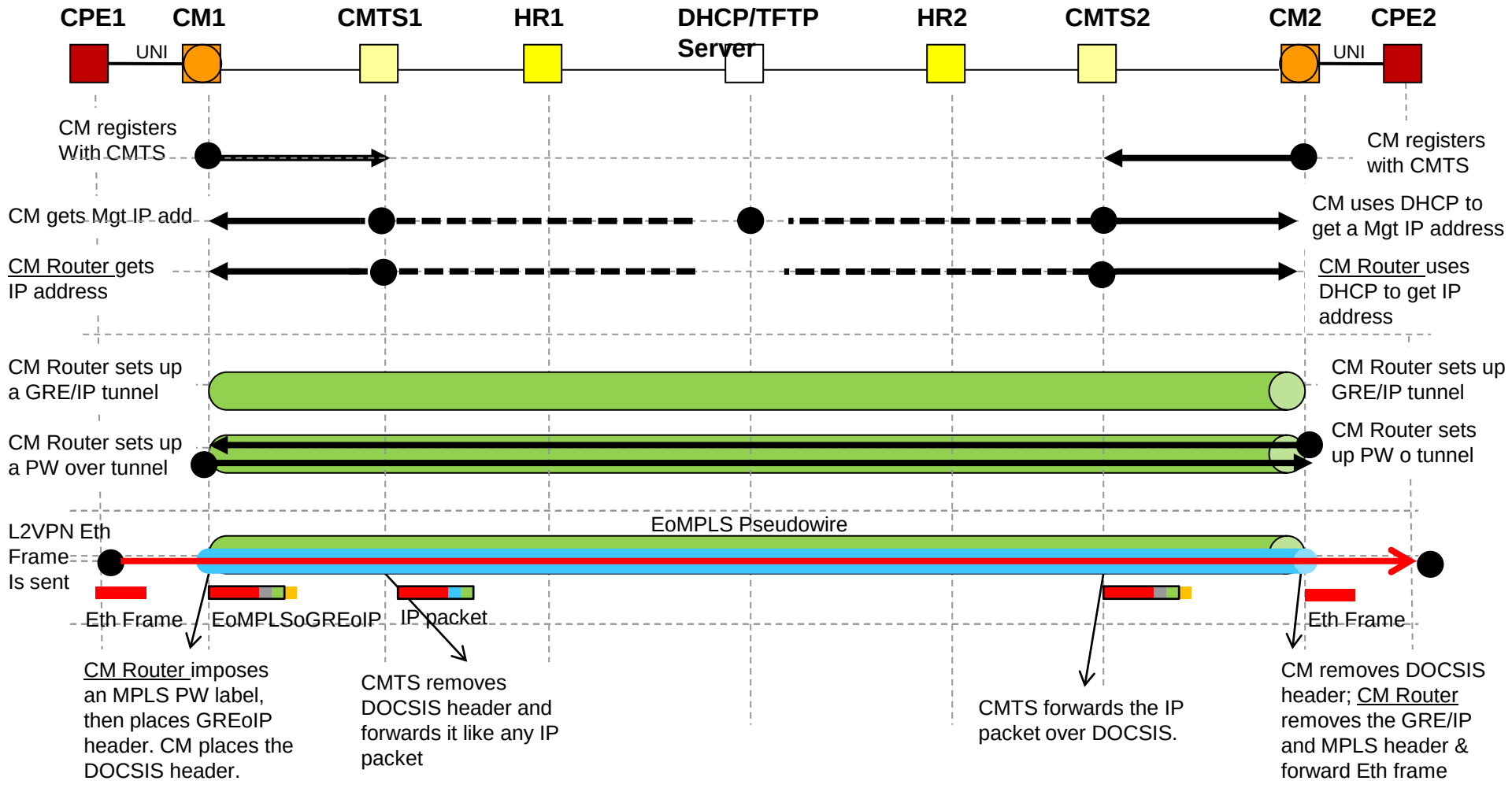
- “Over The Top” approach
- IP Tunnel created by CM router over HSIA Traffic
  - GRE or L2TPv3 Tunnel
- CM Router establishes EoMPLS over IP Tunnel
  - EoMPLSoGRE
  - EoMPLSoL2TPv3
- Cable SP see regular L3 traffic from customer
- Fragmentation may be a concern
- Simple, easy deployment, no changes to SP infrastructure

CPE-Based L2VPNs

How It Works?



CPE-Based L2VPN
Control Plane and Data Plane Flow



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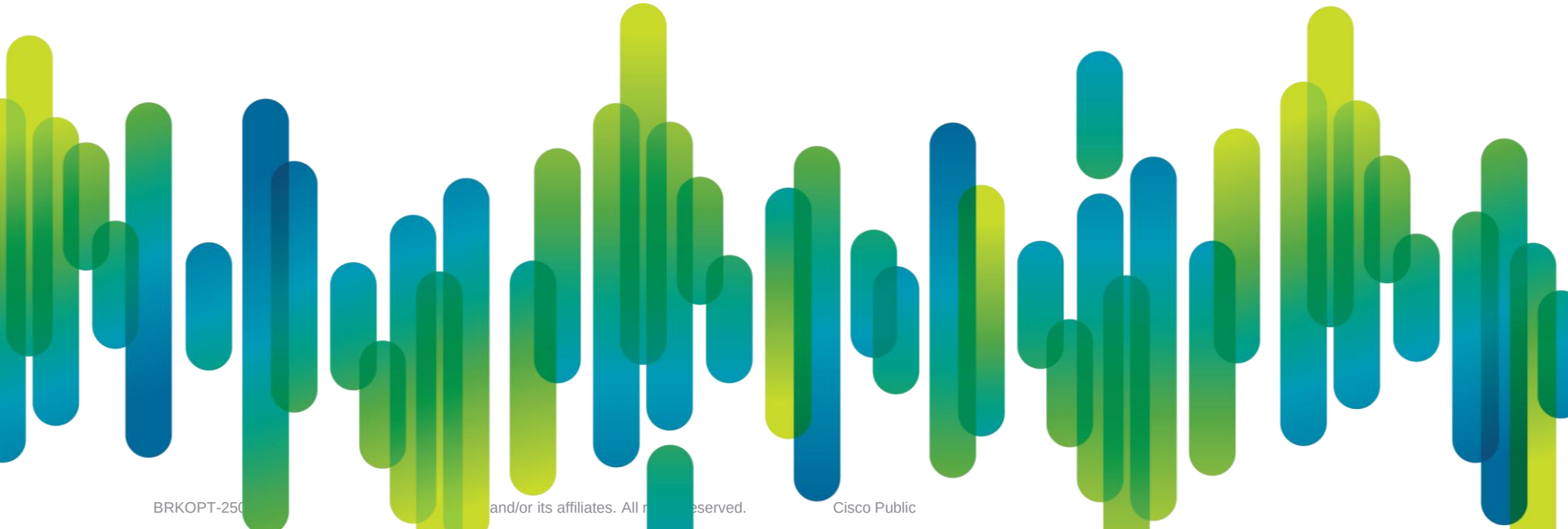
Network-Based L2VPN Services
TLS over DOCSIS



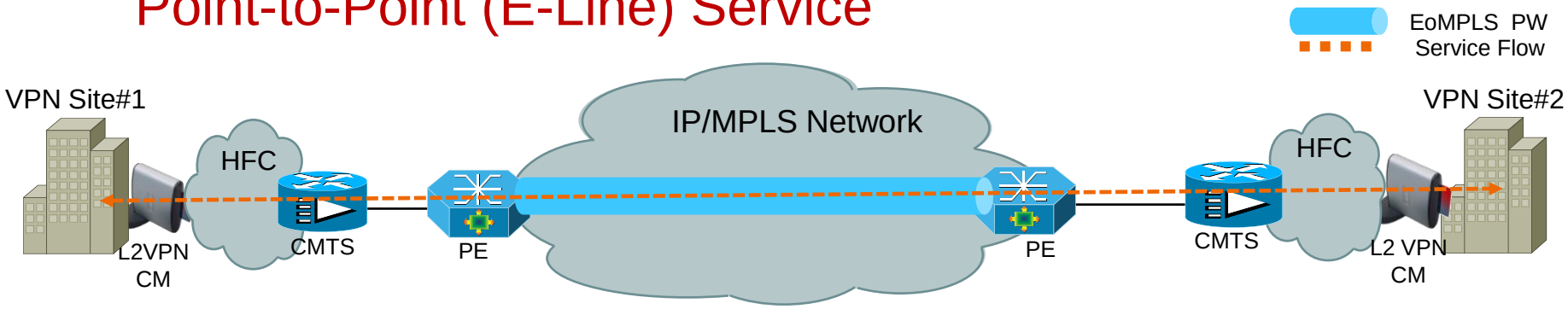
Transparent LAN Services (TLS) Over DOCSIS

How It Works?

- Cisco Proprietary Layer2 Tunneling mechanism
- Precursor to Cable Labs spec on L2VPN BSoD
- All CM traffic encapsulated in a unique VLAN on CMTS
- Upstream router implement EoMPLS or H-VPLS
- Each L2VPN site (CM) statically configured on CMTS
- No Multiplexed (EVPL, EVPLAN) Services

TLS Over DOCSIS

Point-to-Point (E-Line) Service



CMTS

```
Cable l2-vpn-service xconnect nsi dot1q

cable dot1q-vc-map 0022.3a61.7bcf Gig3/1/0 25 TLSoDOCSIS
```

- CM MAC Address
- Forwarding Interface (NSI)
- VLAN
- Customer Name (Optional)

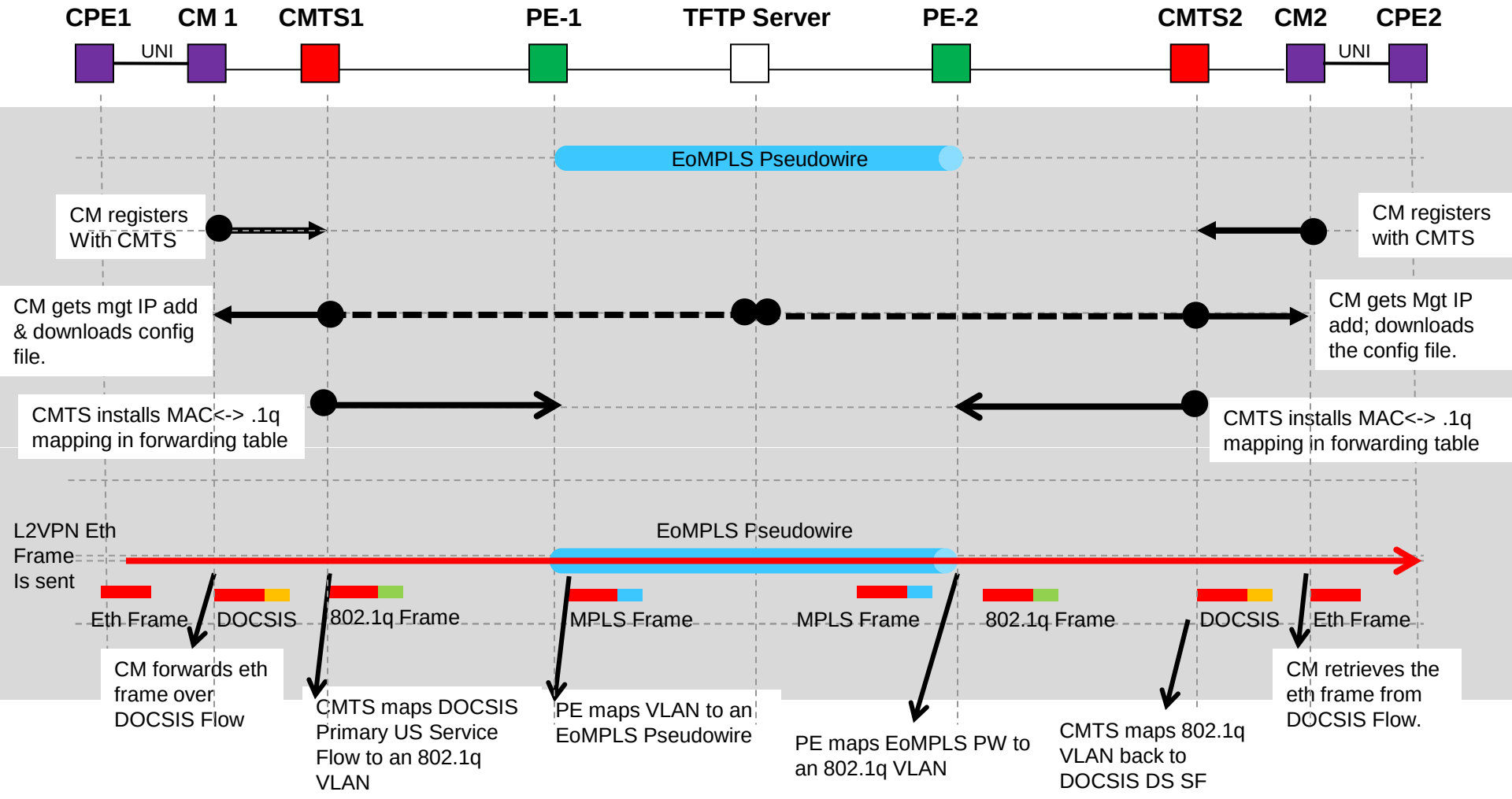
MPLS PE

```
interface GigabitEthernet1/23.25
 encapsulation dot1Q 25
 xconnect 99.1.1.21 50 encapsulation mpls
```

- VLAN encapsulated from CMTS
- EoMPLS VC ID

TLS Over DOCSIS

Control Plane and Data Plane Flow



TLS Over DOCSIS Service Verification

- Verify Cable Modem online

```
CMTS# show cable modem 0022.3a61.7bcf
Load for five secs: 0%/0%; one minute: 1%; five minutes: 0%
Time source is NTP, 17:18:54.122 EDT Mon Mar 22 2010
                                                                          D
MAC Address    IP Address     I/F          MAC             Prim RxPwr   Timing Num I
                                           State           Sid  (dBmv)  Offset CPE P
0022.3a61.7bcf 17.101.75.100  C5/1/0/U0    online(pt)      187  17.00   1186   0   N
```

- Verify Cable Modem is L2VPN enabled

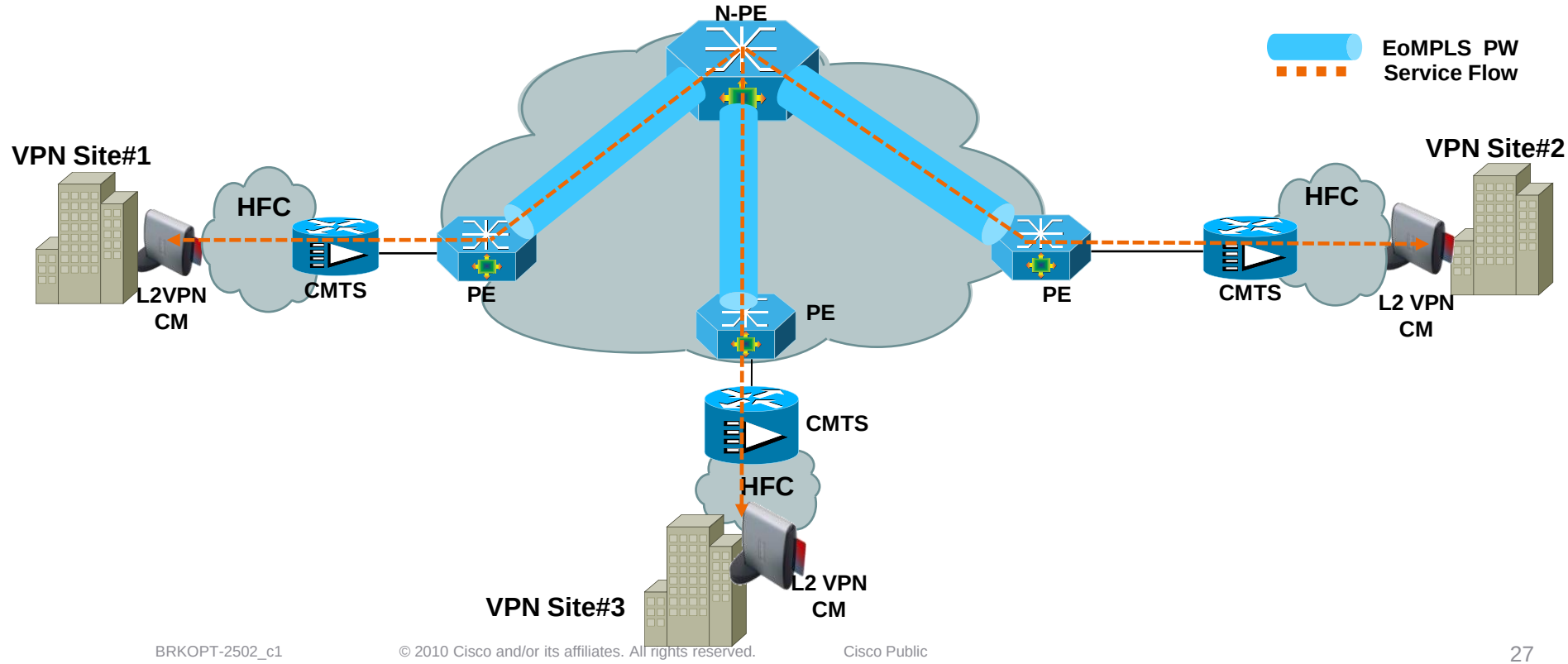
```
CMTS# sh cable l2-vpn xconnect dot1q-vc-map 0022.3a61.7bcf verbose
Load for five secs: 1%/0%; one minute: 0%; five minutes: 0%
Time source is NTP, 17:23:02.633 EDT Mon Mar 22 2010

MAC Address                    : 0022.3a61.7bcf
Customer Name                  : TLSoDOCSIS
Prim Sid                       : 187
Cable Interface                : Cable5/1/0
Ethernet Interface             : GigabitEthernet3/1/0
DOT1Q VLAN ID                  : 25
Total US pkts                  : 0
Total US bytes                 : 0
Total DS pkts                  : 0
Total DS bytes                 : 0
```

TLS Over DOCSIS

Multipoint (E-LAN) Service

- Upstream routers implements the multipoint aspect
- Full mesh VPLS may be used
- H-VPLS recommended for better scaling in N-PE



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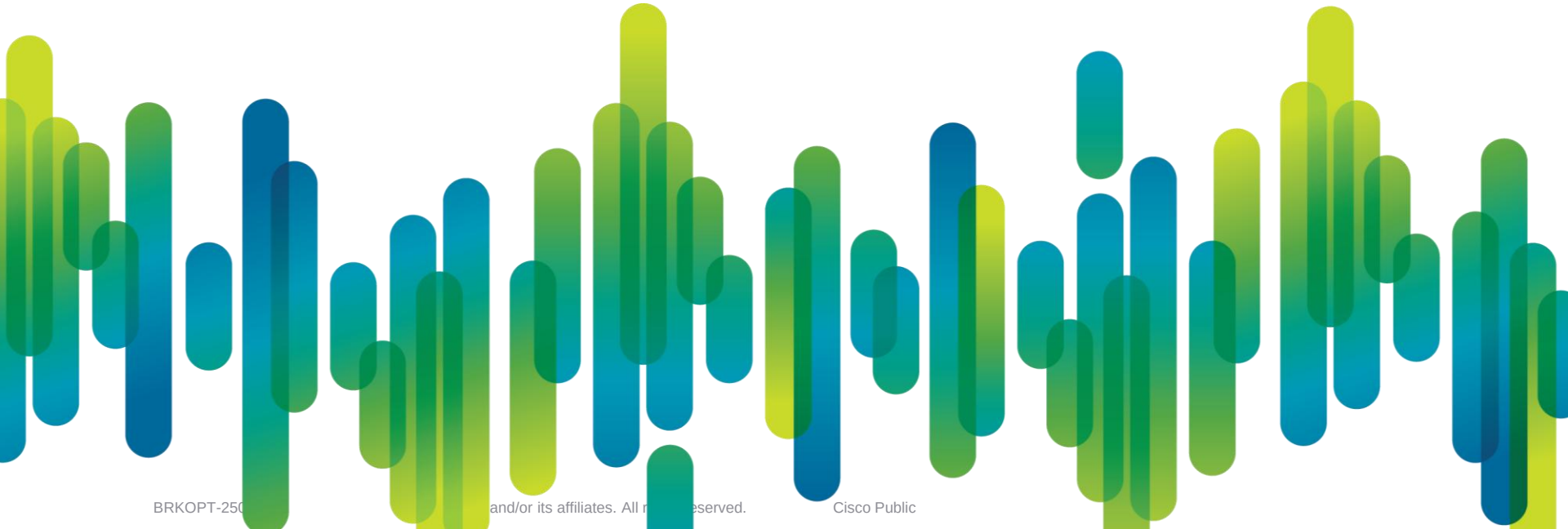
Dot1Q-Based BSoD



Dot1Q-Based BSoD Overview

How It Works?

- Standardized by CableLabs
- Requires DOCSIS 2.0+
- Zero touch CMTS provisioning
  - No per site CMTS configuration required
  - Unique CM config file per L2VPN CM
- Up to 4 L2VPN's per CM based on service flow classification
  - Multiplexed (EVPL/EVPLAN) and non-multiplexed (EPL/EPLAN) services

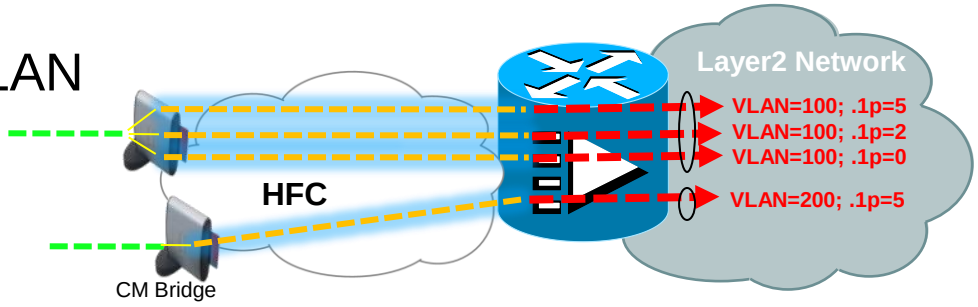
Dot1Q-Based BSoD

- CMTS implements L2 “Network Service Interface”—NSI
  - Statically defined NSI Interface
- NSI encapsulation is set to Dot1Q
- Individual DOCSIS service flow map to a VLAN
  - Mapping is defined by CM via CM config file
  - VLAN tagged frames forwarded on NSI
  - CMTS send/receive IP/MPLS and L2 traffic on same NSI
- Upstream PE router implements EoMPLS or H-VPLS

Dot1Q-Based BSoD Services

Service Multiplexing

- Service multiplexing on CM allowed by CableLabs
  - Allows for more services than TLS over DOCSIS
- Many US/DS SFs to One VLAN
  - EPL type services
  - One VLAN for all traffic from CM
  - May use per SF 802.1p marking
  - Up to 8 US SFs per L2VPN



- One US/DS SFs to One VLAN
  - EVPL type services
  - Up to 4 VLAN for a single CM
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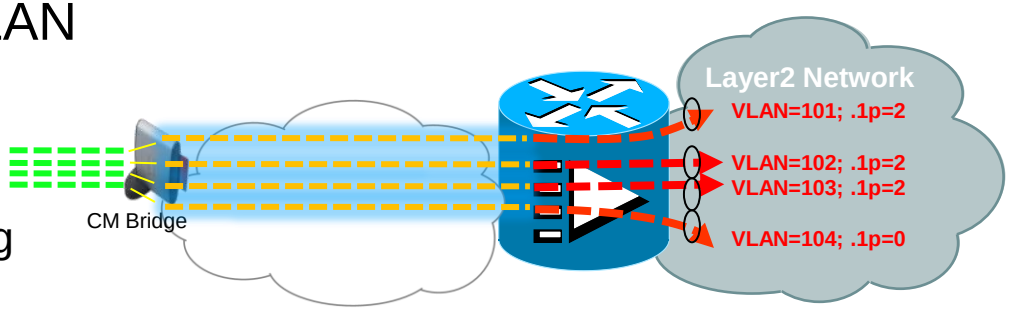
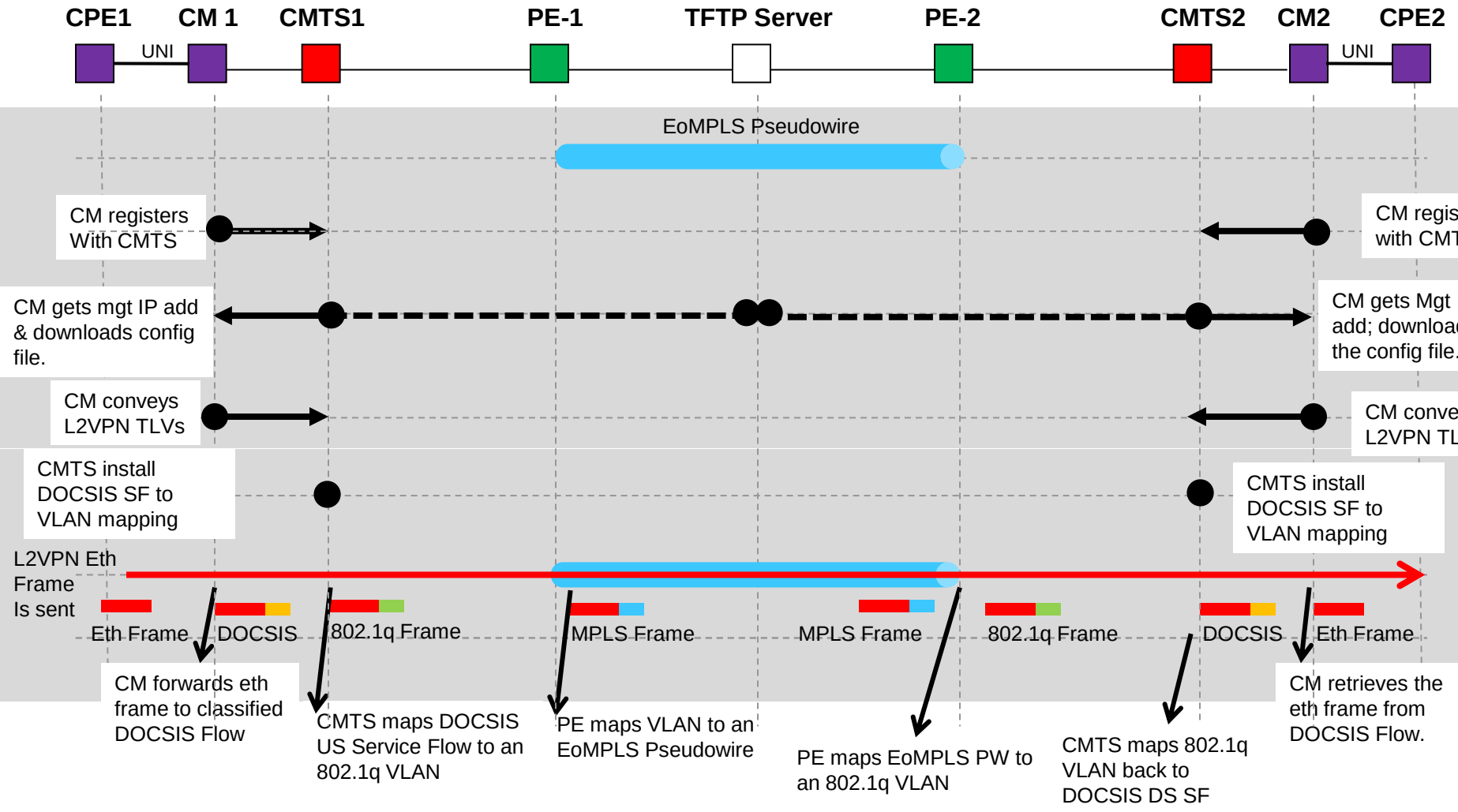


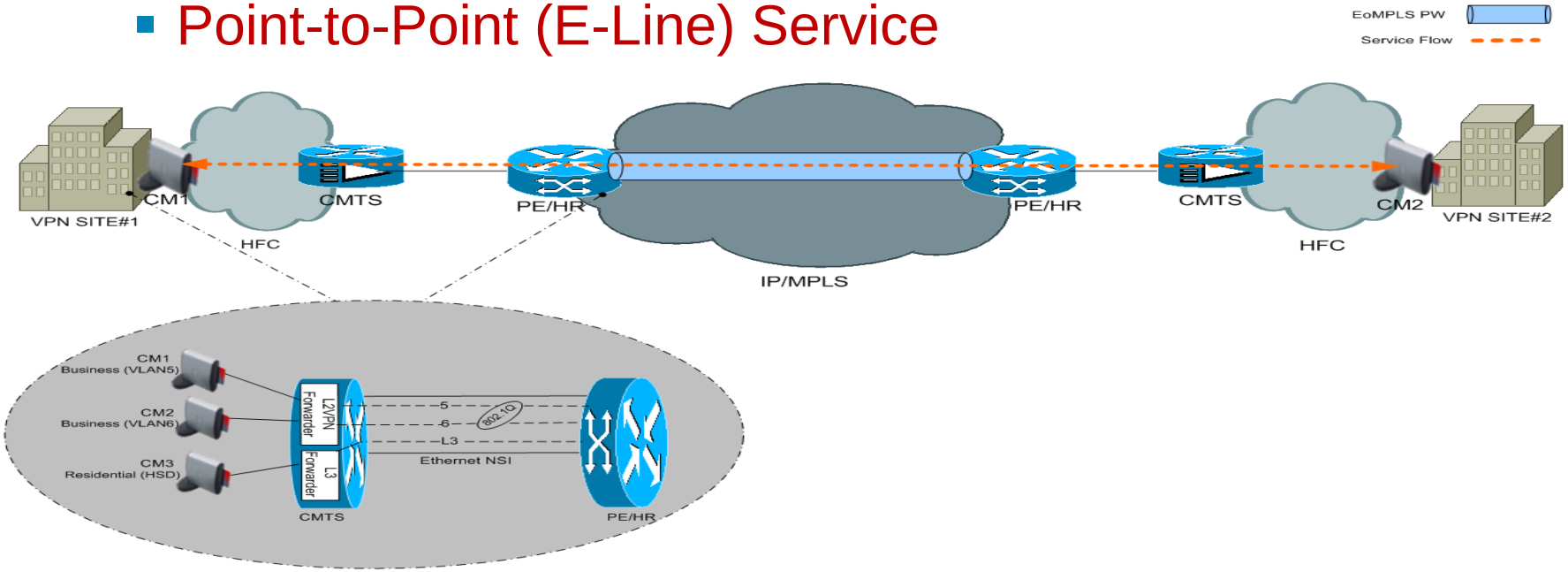
Dot1Q Based BSoD

Control Plane and Data Plane Flow



End-to-End Dot1Q-Based BSoD Service

- Point-to-Point (E-Line) Service



CMTS

```
cable l2-vpn-service xconnect nsi dot1q interface
Gig1/1/0
```

Designated NSI Interface

NSI Encapsulation

MPLS PE

```
interface GigabitEthernet1/23.100
 encapsulation dot1Q 100
 xconnect 99.1.1.21 50 encapsulation mpls
```

Dot1Q-Based BSoD Configuration

CM Config File Requirements

```
3,NetworkAccess,1,1
18,MaxCPE,1,0
24,UsServiceFlow
              1,ServiceFlowRef,2,1
              6,QosParamSetType,1,07
              43,VendorSpecificSubtype
                8,VendorIdentifier,3,FF FF FF
                5,L2VPNEncoding
                1,L2VPNIdentifier,9, DOT1Q BSoD
                8,IngressUserPriority,1,04
25,DsServiceFlow
              1,ServiceFlowRef,2,3
              6,QosParamSetType,1,07
29,GlobalPrivacyEnable,1,1
45,DUTFiltering
              1,DUTControl,1,01
43,GeneralExtensionInformation
              8,VendorIdentifier,3,FF FF FF
              5,L2VPNEncoding
                1,L2VPNIdentifier,9, DOT1Q BSoD
                2,NSIEncapsulation
                           2,IEEE802.1Q,2,100
```

Vendor specific subtype for L2VPN.

Vendor ID for GEI

L2VPN Id=DOT1Q BSoD must be the same as specified in L2VPN Encoding.

.1p bits = 4 to be imposed by CMTS

L2VPN Id=DOT1Q BSoD must be the same as specified in L2VPN Encoding.

100 is 802.1q VLAN id to be imposed by CMTS

```
CMTS#

cable l2-vpn-service xconnect nsi dot1q interface Gig1/1/0
!
```

One-time config needed on CMTS.

Dot1Q-Based BSoD Service Verification

- Verify Cable Modem is L2VPN enabled

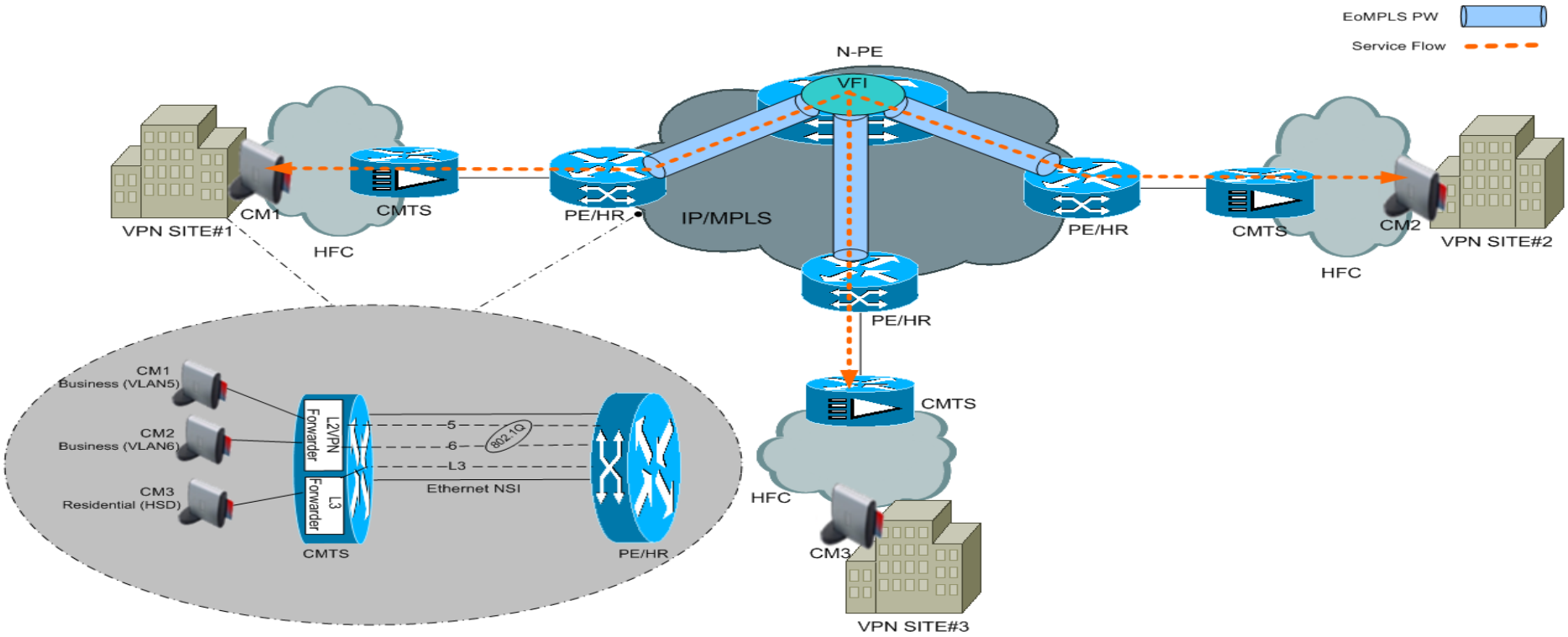
```
CMTS#sh cable l2-vpn xconnect dot1q-vc-map 0022.3a61.7bcf verbose

MAC Address             : 0022.3a61.7bcf
Prim Sid                : 17
Cable Interface         : Cable5/1/0
L2VPNs provisioned      : 1
DUT Control/CMIM        : Enable/0x8000FFFF
VPN ID                  : DOT1Q BSoD
L2VPN SAID              : 12302
Upstream SFID Summary   : 29
Upstream SFID [29   ]   : SID 17   UserPrio 4
Downstream CFRID[SFID]: Primary SF
CMIM                    : 0x60
Ethernet Interface      : GigabitEthernet3/1/0
DOT1Q VLAN ID           : 100
Total US pkts           : 0
Total US bytes          : 0
Total US pkt Discards   : 0
Total US byte Discards: 0
Total DS pkts           : 0
Total DS bytes          : 0
Total DS pkt Discards   : 0
Total DS byte Discards: 0
```

Dot1Q-Based BSoD

Multipoint (E-LAN) Service

- Upstream routers implements the multipoint aspect
- Dedicated N-PE with H-VPLS



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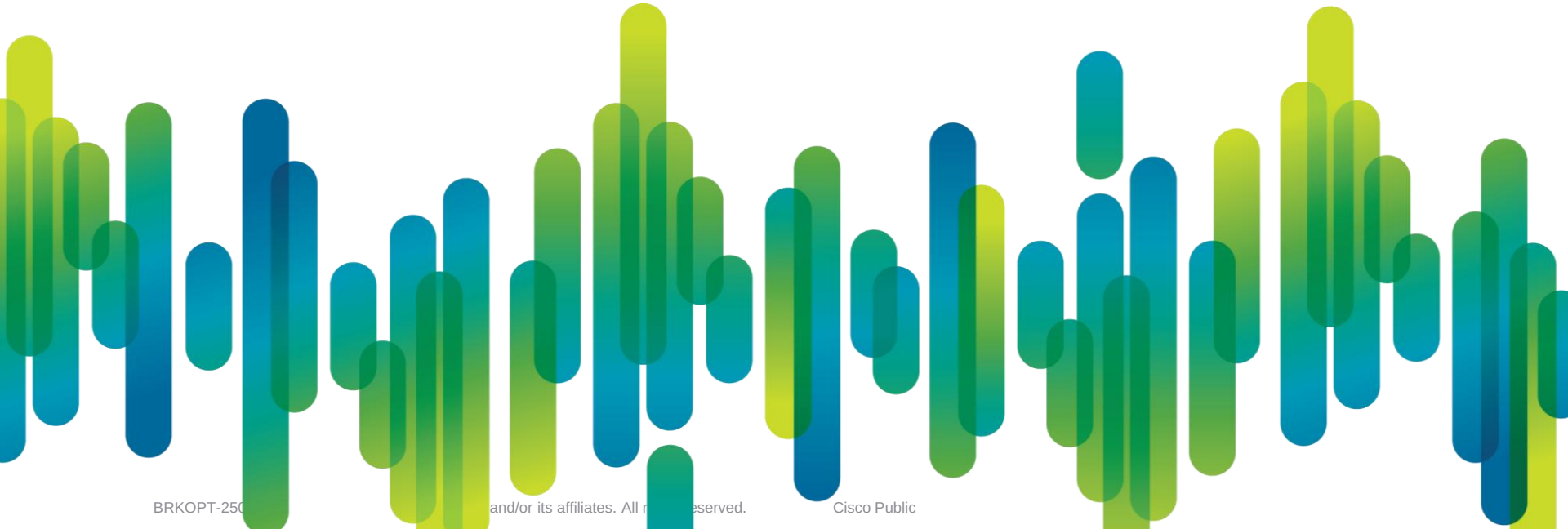
MPLS-Based BSoD Services



MPLS-Based BSoD Services

How It Works?

- Why settle for VLAN encapsulation on CMTS for BSoD?
- Evolution of Dot1Q-Based BSoD Services
- EoMPLS on CMTS !!!

  Supported on CMTS 12.2(33)SCC and later
- No need for upstream PE device
- Better scaling (no more 4000 VLAN limit)
- Upstream redundancy and load-balancing

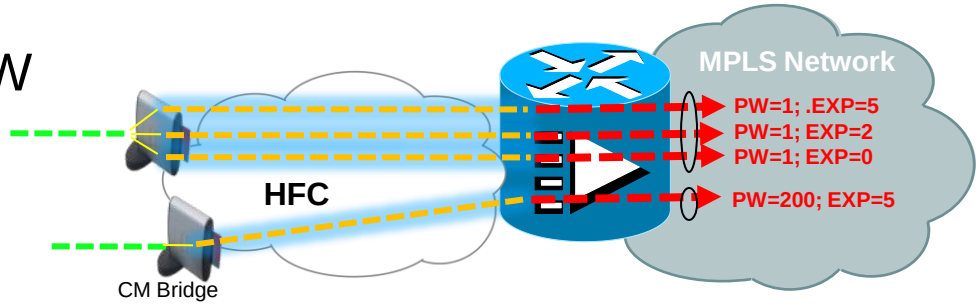
MPLS-Based BSoD Architecture

- NSI encapsulation is set to MPLS on CMTS
- CM maps Ethernet UNI to a DOCIS service flow
- DOCSIS service flow map to an EoMPLS PW
  - Mapping is defined by CM via CM config file
  - EoMPLS frames forwarded on any available MPLS uplink
- Zero Touch CMTS provisioning possible
  - Cable modem config file define PW parameters
- QoS provided through MPLS EXP bits

MPLS-Based BSoD Services

Service Multiplexing

- Service multiplexing on CM allowed by CableLabs
  - Allows for more services than TLS over DOCSIS
- Many US/DS SFs to One PW
  - EPL type services
  - One PW for all traffic from CM
  - May use per SF EXP marking
  - Up to 8 US SFs per L2VPN



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  - EVPL type services
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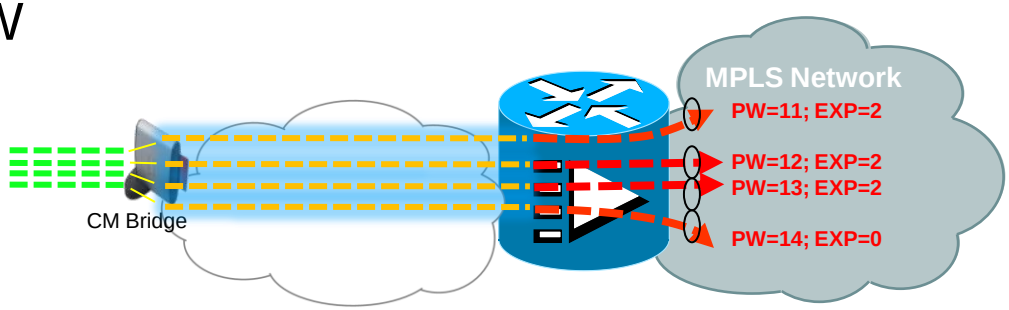
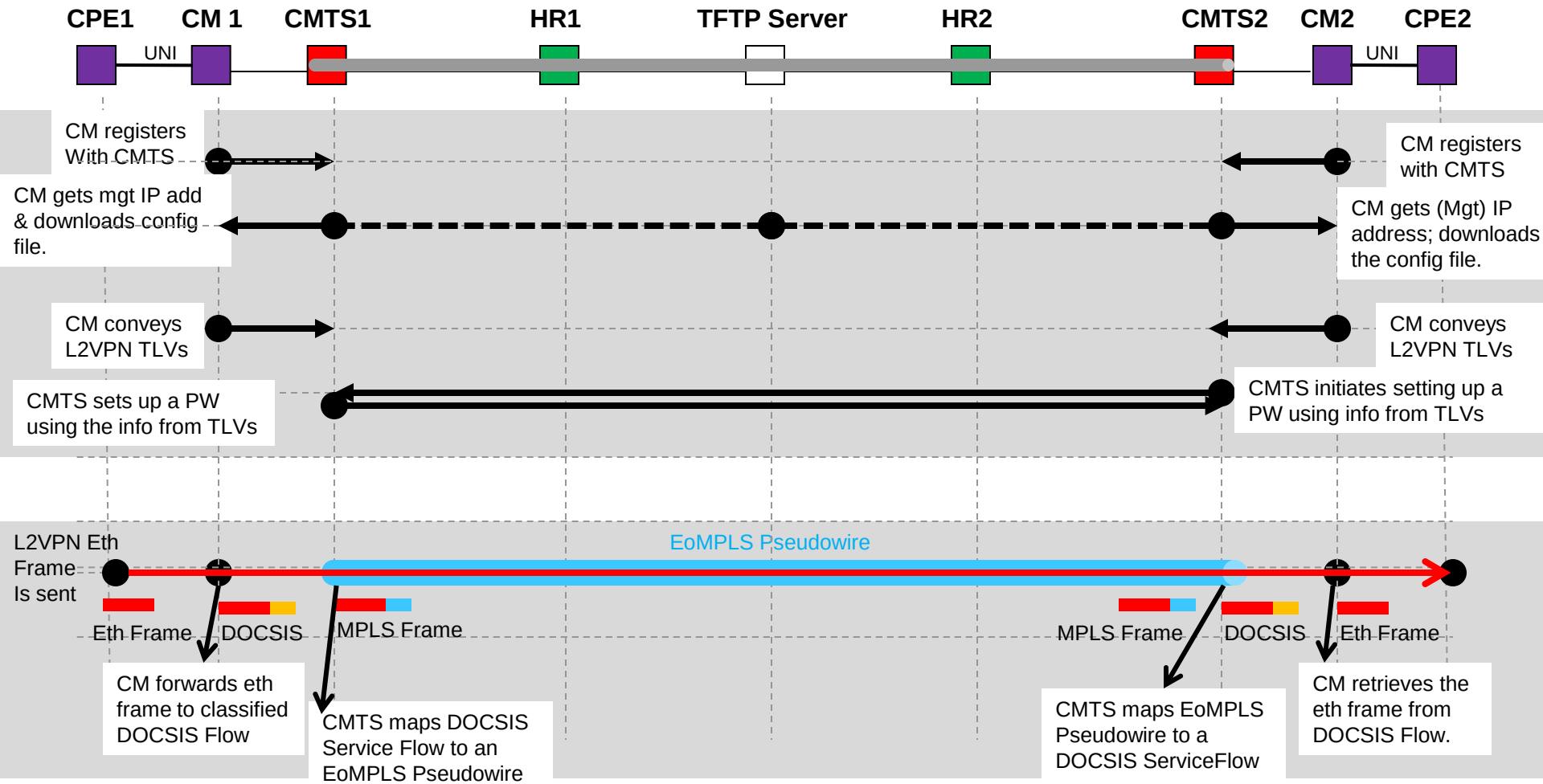
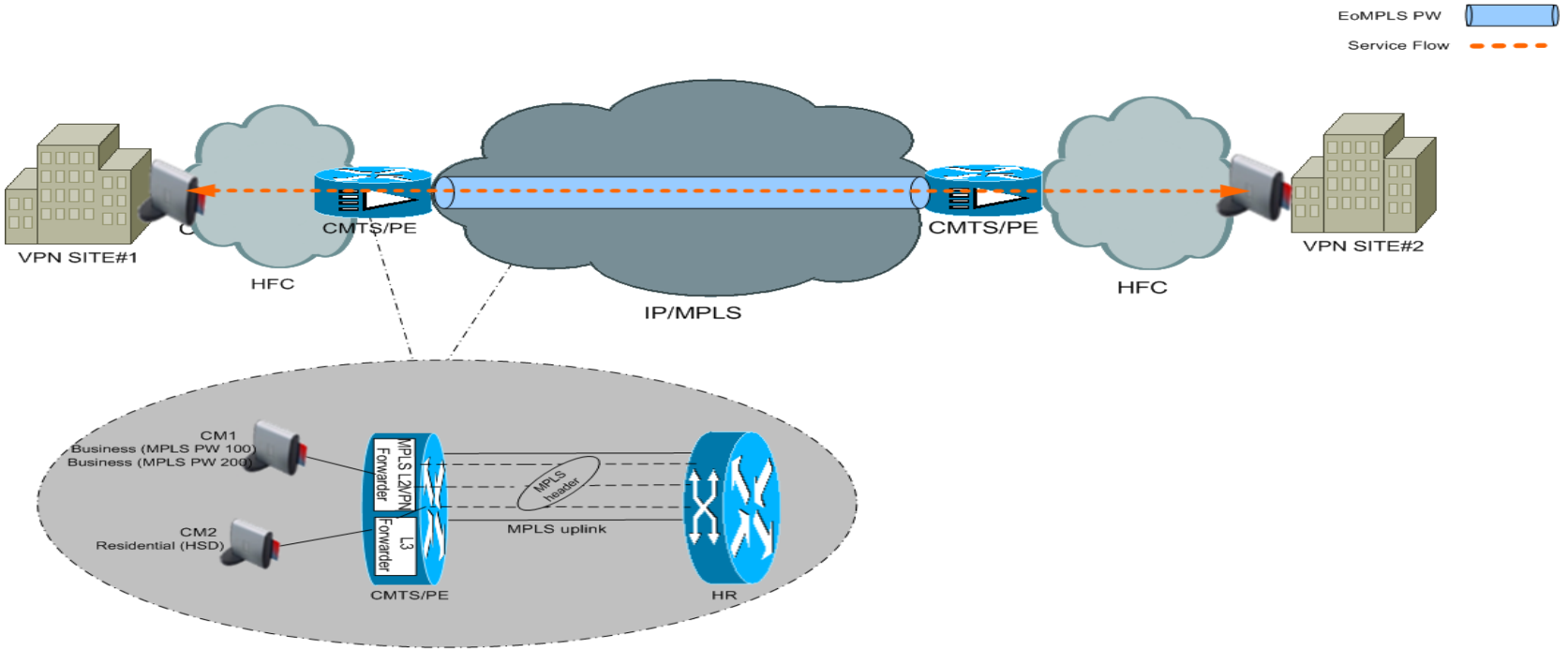


MPLS-Based BSoD

Control Plane and Data Plane Flow



End-to-End MPLS-Based BSoD Service



CMTS

```
cable l2-vpn-service xconnect nsi mpls
```

NSI Encapsulation

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18,MaxCPE,1,16
24,UsServiceFlow
              1,ServiceFlowRef,2,1
              6,QosParamSetType,1,07
              43,VendorSpecificSubtype
                8,VendorIdentifier,3,FF FF FF
                5,L2VPNEncoding
                1,L2VPNIdentifier,9, MPLS BSoD
                8,IngressUserPriority,1,04
25,DsServiceFlow
              1,ServiceFlowRef,2,3
              6,QosParamSetType,1,07
29,GlobalPrivacyEnable,1,1
45,DUTFiltering
              1,DUTControl,1,01
43,GeneralExtensionInformation
              8,VendorIdentifier,3,FF FF FF
              5,L2VPNEncoding
                1,L2VPNIdentifier,9, MPLS BSoD
                2,NSIEncapsulation
                          4,MPLSIPv4Peer,5,1.99.1.1.22
                          5,AttachmentGroupID,4,55 55 55 55
                          6,SourceAttachmentIndividualID,4,2001
                          7,TargetAttachmentIndividualID,4,2001
```

```
CMTS#
!
cable l2-vpn-service xconnect nsi mpls
!
```

Optional: Vendor specific subtype for L2VPN.

Vendor ID for GEI

L2VPN Id=MPLS BSoD must be the same as specified in L2VPN Encoding.

MPLS EXP=4 to be imposed by CMTS

L2VPN Id=MPLS BSoD must be the same as specified in L2VPN Encoding.

99.1.1.22 is peer PE's IP address.*

2001 is used as the PW-id.

Source AII and Target AII must be the same.

One-time config needed on CMTS.

* Peer PE address may not be needed in the future.

MPLS-Based BSoD Service Verification

- Verify Cable Modem is MPLS L2VPN enabled

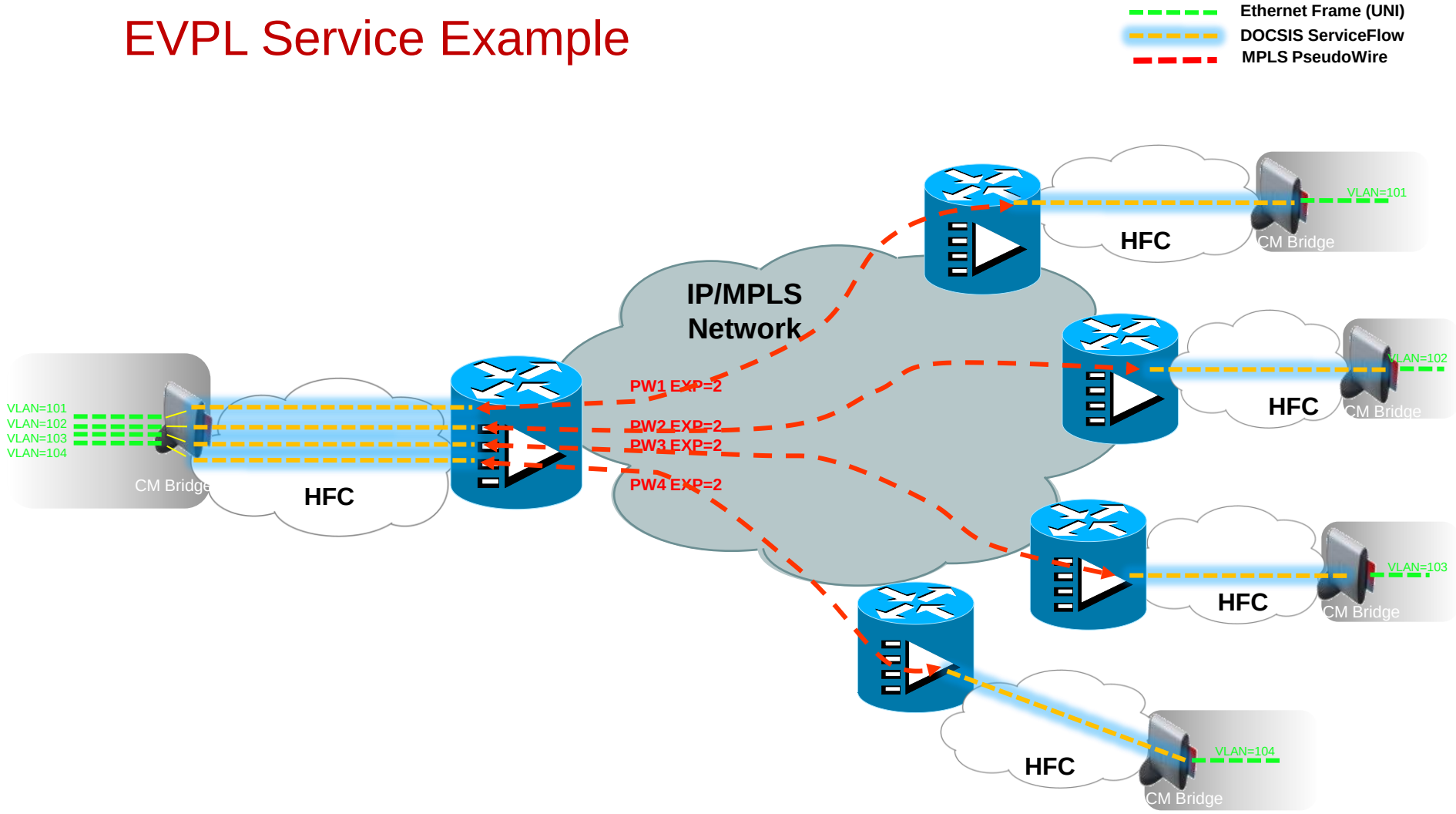
```
CMTS-uBR10k# sh cable l2-vpn xconnect mpls-vc-map 0022.3a61.7bcf verbose
MAC Address                          : 0022.3a61.7bcf
Prim Sid                             : 16
Cable Interface                      : Cable5/1/0
L2VPNs provisioned                   : 1
DUT Control/CMIM                     : Enable/0x8000FFFF
VPN ID                               : MPLS BSoD
L2VPN SAID                           : 12296
SAII                                 : 000007D1
TAII                                 : 000007D1
Upstream SFID Summary                : 27
Upstream SFID [27   ]                : SID 16   MPLS-EXP 4
Downstream CFRID[SFID] Summary       : Primary SF
CMIM                                 : 0x60
MPLS PEER IpAddress                  : 99.1.1.22
MPLS PW VCID                         : 2001
MPLS PW TYPE                         : Ethernet
MPLS PW Circuit ID                   : Bu254:2001
MPLS PW Remote State                 : UP
MPLS PW Local  State                 : UP
Total US pkts                        : 0
Total US bytes                       : 0
Total US pkt Discards                : 0
Total US byte Discards               : 0
Total DS pkts                        : 0
Total DS bytes                       : 0
Total DS pkt Discards                : 0
Total DS byte Discards               : 0
```

- Verify the pseudowire(PW) is up

```
CMTS-uBR10k#sh mpls l2transport vc 2001
Local intf     Local circuit              Dest address    VC ID      Status
-------------  -------------------------- --------------- ---------- ----------
Bu254          DOCSIS 2001                99.1.1.22       2001       Up
```

MPLS-Based BSoD Service

EVPL Service Example



MPL-Based BSoD

Cable Modem Config File for EVPL

```
24,UsServiceFlow
            1,ServiceFlowRef,2,1
            6,QosParamSetType,1,07
            43,VendorSpecificSubtype
              8,VendorIdentifier,3,FF FF FF
              5,L2VPNEncoding
              1,L2VPNIdentifer,9,MPLS EVPL1
              8,IngressUserPriority,1,04
24,UsServiceFlow
            1,ServiceFlowRef,2,2
            6,QosParamSetType,1,07
            43,VendorSpecificSubtype
              8,VendorIdentifier,3,FF FF FF
              5,L2VPNEncoding
              1,L2VPNIdentifer,9,MPLS EVPL2
              8,IngressUserPriority,1,05
22,UsPacketClassifer
            1,ClassifierRef,1,1
            3,ServiceFlowRef,2,1
            11,IEEE802Classifier
              2, VlanID 100
22,UsPacketClassifer
            1,ClassifierRef,1,2
            3,ServiceFlowRef,2,2
            11,IEEE802Classifier
              2, VlanID 200
25,DsServiceFlow
            1,ServiceFlowRef,2,5
            6,QosParamSetType,1,07
25,DsServiceFlow
            1,ServiceFlowRef,2,6
            6,QosParamSetType,1,07
```

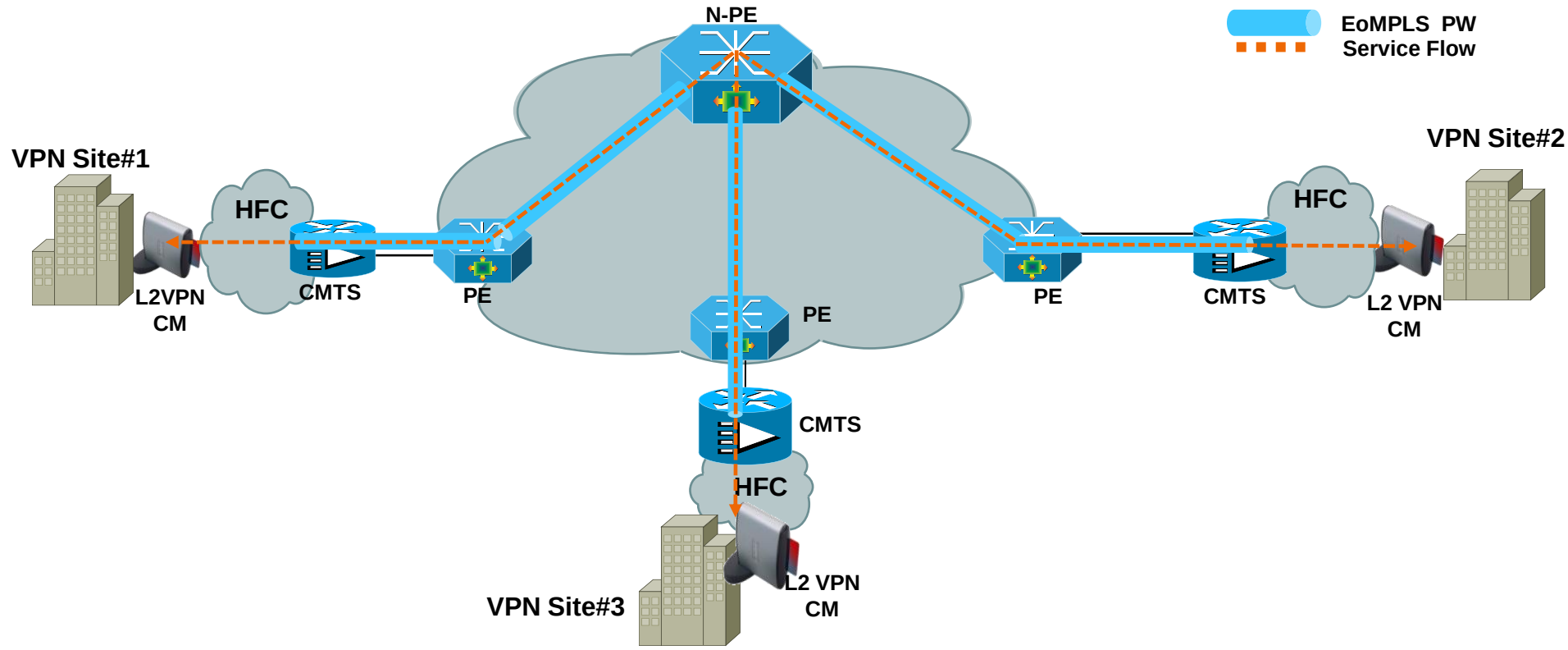
```
43,GeneralExtensionInformation
            8,VendorIdentifier,3,FF FF FF
            5,L2VPNEncoding
            1,L2VPNIdentifier,9, MPLS EVPL1
              2,NSIEncapsulation
                 4,MPLSIPv4Peer,5,1.99.1.1.22
                 5,AttachmentGroupID,4,55 55 55 55
                 6,SourceAttachmentIndividualID,4,2001
                 7,TargetAttachmentIndividualID,4,2001
43,GeneralExtensionInformation
            8,VendorIdentifier,3,FF FF FF
            5,L2VPNEncoding
            1,L2VPNIdentifier,9, MPLS EVPL2
              2,NSIEncapsulation
                 4,MPLSIPv4Peer,5,1.99.1.1.23
                 5,AttachmentGroupID,4,45 45 45 45
                 6,SourceAttachmentIndividualID,4,2002
                 7,TargetAttachmentIndividualID,4,2002
45,DUTFiltering
            1,DUTControl,1,01
```

```
CMTS-10K#
!
cable l2-vpn-service xconnect nsi mpls
!
```

MPLS-Based BSoD

Multipoint (E-LAN) Service

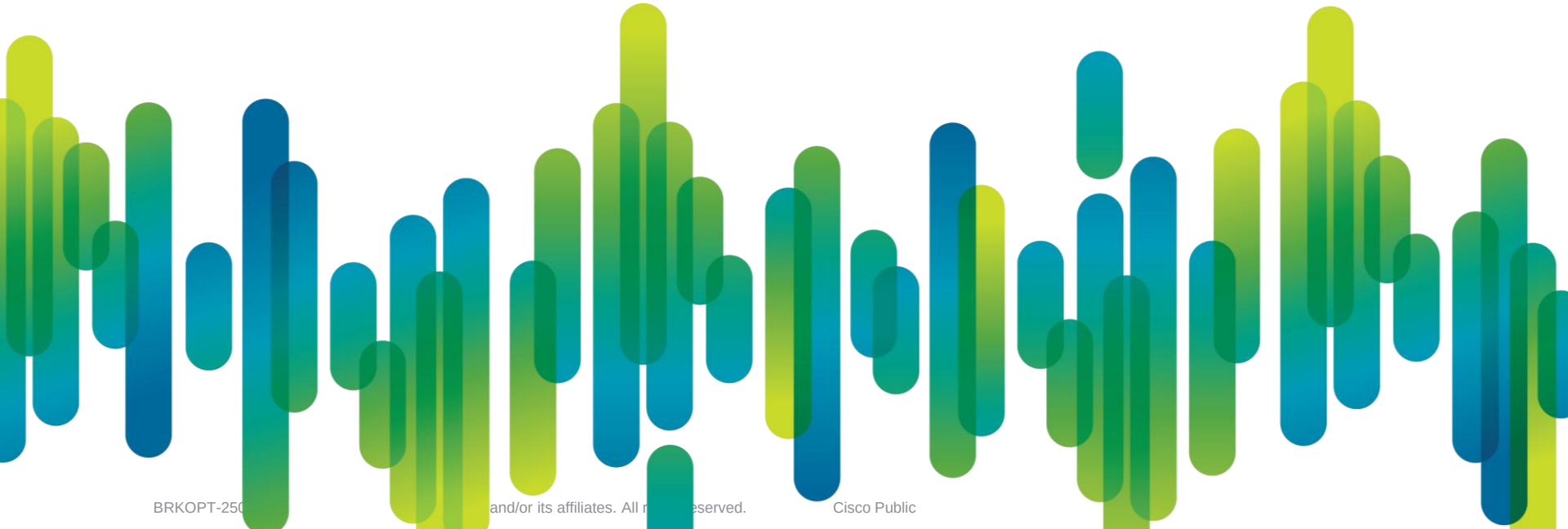
- Upstream routers implements the multipoint aspect
- Dedicated N-PE with H-VPLS



Agenda

- The Case for Business Services over DOCSIS
- Carrier Ethernet Business Services
- L2VPN over DOCSIS Deployment Models
  - CPE-Based L2VPN Services
  - Transparent LAN Services over DOCSIS
  - Dot1Q-Based Business Services over DOCSIS
  - MPLS-Based Business Services over DOCSIS
- Selecting a BSoD Deployment Model
- Summary

Selecting a BSoD Deployment Model



Which BSoD Model to Use?

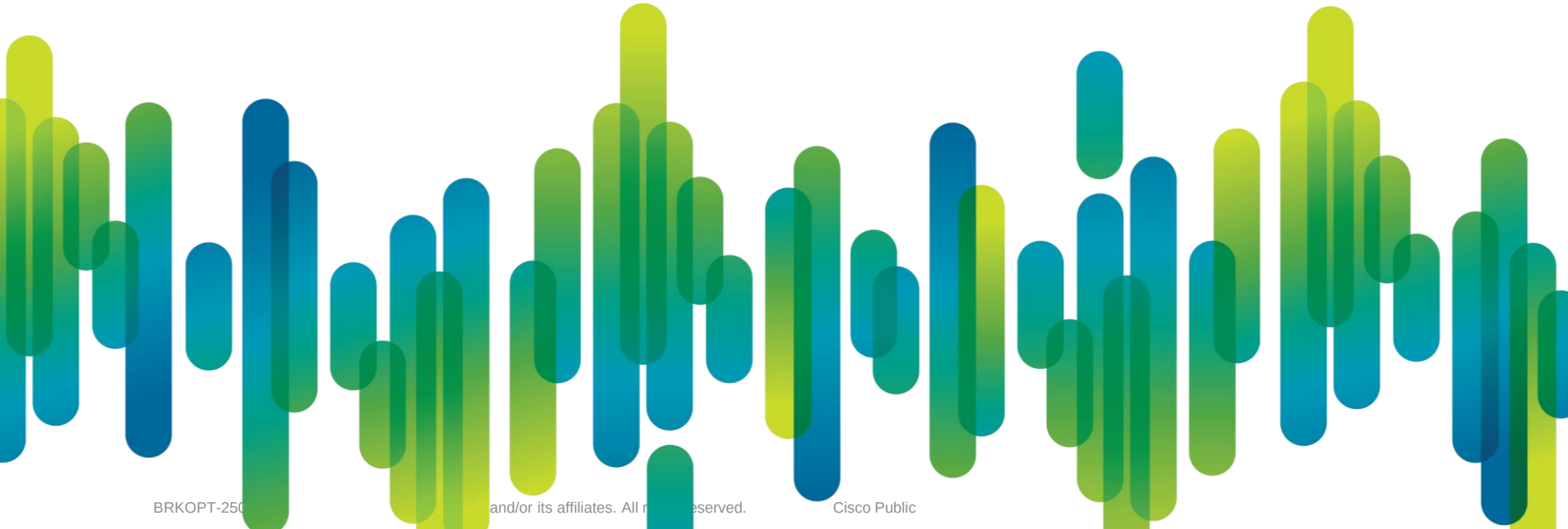
- No “One Size Fits All” answer
- Decision a function of various factors
- Technical Factors:
  - Scale and Performance
  - Fragmentation and Overhead
  - High Availability
  - Interworking with Fiber Access
- Operational Factors
  - CPE Cost
  - Ease of Deployment
  - CMTS Software and Configuration Changes

BSoD Comparison Matrix

Deployment Consideration	CPE-Based L2VPN	TLS over DOCSIS	Dot1Q-Based BSOD	MPLS-Based BSoD
Scale	CPE Capability	4000	4000	16000 (uBR10K)
Fragmentation & Overhead	👎	👍	👍	👍
CMTS Uplink High Availability	👍	👎	👎	👍
Separate PE Required?	👍	👎	👎	👍
Fiber Interworking	Limited	👍	👍	👍
CPE Cost	👎	👍	👍	👍
DOCSIS Backend Changes	👍	👍	👎	👎 👍 *
CMTS Config Changes	No	Per L2VP Site	One Time	One Time *

* For time to market, Per Site L2VPN configuration on CMTS can be done via CLI, thus bypassing the DOCSIS backend changes requirement

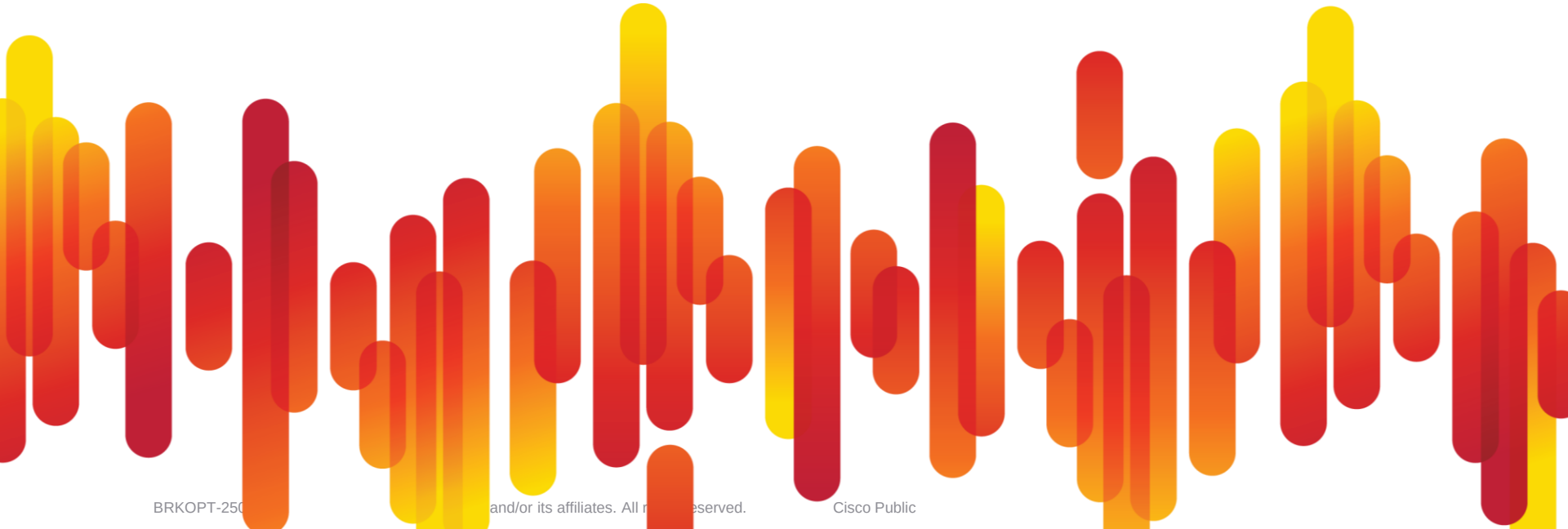
Summary



Summary

- Business Services over DOCSIS picking up steam
- Leverage existing HFC infrastructure
- Standardized MEF Carrier Ethernet Services
- Wide range of Deployment option
- CPE-based L2VPN model provides ease of deployment
- Network-based BSOD provides flexibility and enhanced functionality
- Multiple decision factors for correct BSoD model

Q & A



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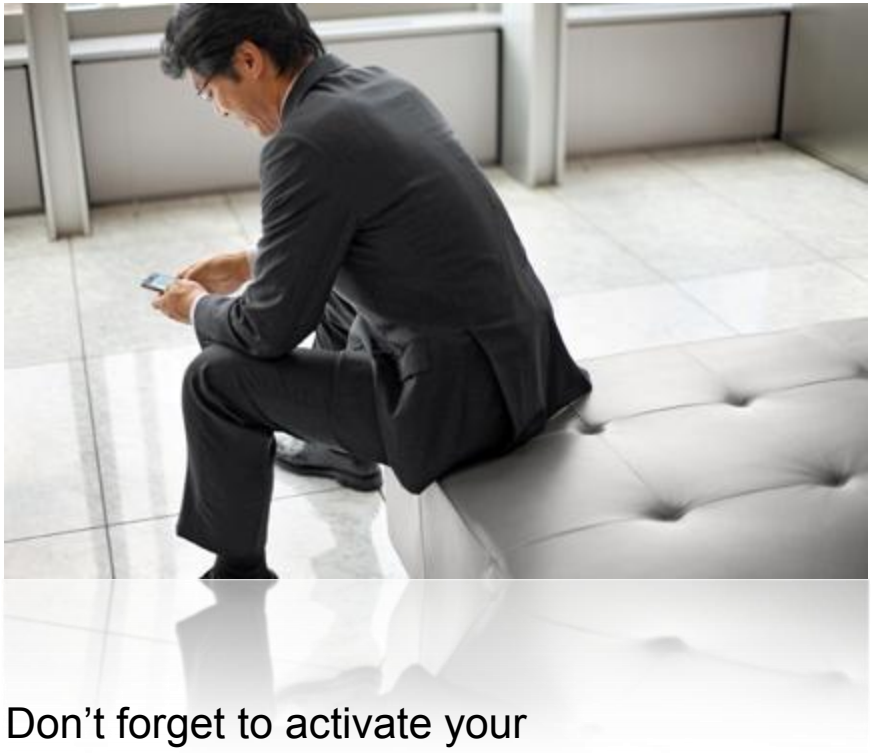

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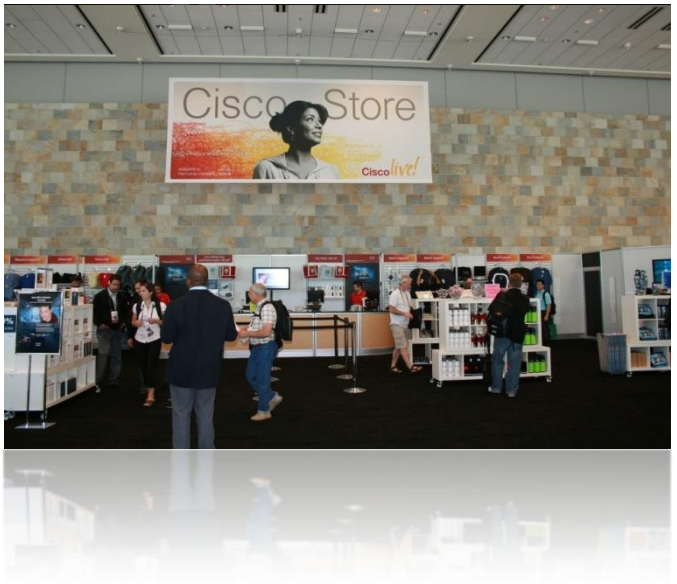

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