



Education

Fibre Channel over Ethernet (FCoE)

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- The Fibre Channel (T1 I.3) standards committee developed a Standard called Fibre Channel over Ethernet (FCoE)
- The FCoE standard specifies the encapsulation of Fibre Channel frames into Ethernet Frames and the amalgamation of these technologies into a network fabric that can support Fibre Channel protocols and other protocols such as TCP/IP, UDP/IP etc.
- A “Direct End-to-End” FCoE variant has been accepted for the next version of the Standard
- The tutorial will show the Fundamentals of these FCoE concepts and describe how they might be exploited in a Data Center environment

- **Introduction**
- **FCoE Fabrics & Convergence**
- **Architecture**
- **Discovery & Link Instantiation**
 - ◆ **With FCFs**
 - ◆ **Direct End-to-End (w/o FCFs)**
- **Topologies with FCFs**
- **Scenarios with FCFs**
- **Summary**

- This presentation provides an overview of Fibre Channel over Ethernet (FCoE)
- One should think about FCoE as placing the FC protocol on a new physical link
 - ◆ New Lossless Ethernet links instead of physical FC links
 - ◆ But it is still Fibre Channel
- The protocol has been defined in the INCITS Fibre Channel (T11.3) technical committee
- The needed Lossless Ethernet links has been defined in the IEEE 802
- A newly defined “Direct End-to-End” (VN2VN) protocol will also be explained

FCoE Fabrics & Convergence

FCoE Fabrics (part 1)

(This is NOT Traditional Ethernet)

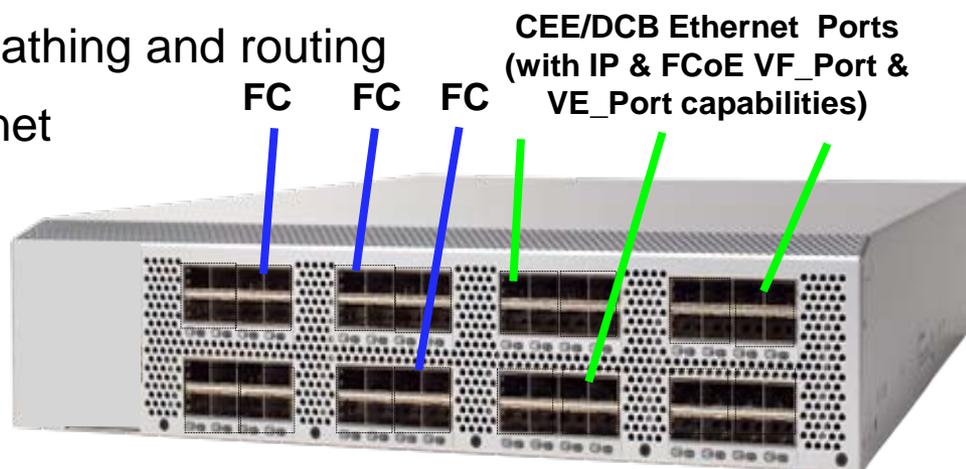
- ◆ **FCoE requires specific Ethernet extensions to be implemented**
 - ◆ Lossless switches and fabrics (e.g., supporting IEEE 802.3 PAUSE) configurations are required
 - ◆ Jumbo frame support is strongly recommended (not a standard, but widely available)
- ◆ **Deployments of FCoE should utilize the advances in Ethernet recently defined in IEEE 802.1, specifically:**
 - ◆ Priority-based Flow Control (PFC) → 802.1Qbb
 - ◆ Enhanced Transmission Selection (ETS) → 802.1Qaz
 - ◆ DCB (capability) eXchange (DCBX) Protocol → 802.1Qaz
 - ◆ CN -- Congestion Notification (802.1Qau) ← **New**
- ◆ **These 802.1 advances are important for Converged Flows (Messaging, Clustering and Storage)**

This set of functions is called CEE – Converged Enhanced Ethernet (intended for a Data Center Environment) or (in the IEEE) DCB -- Data Center Bridging
- ◆ **FCoE Fabrics must be built with FCoE – CEE/DCB Switches that:**
 - ◆ Are called **FC Forwarder** → **FCF**
 - ◆ Are **part of a lossless Ethernet Fabric** and have **CEE/DCB Lossless Ethernet ports**
 - ◆ Also provide **functions of traditional FC switches (capabilities and services)**

Converged Enhanced Ethernet (CEE) & FCoE Switch (FCF) with FC connections

Implementations are combining the features and capabilities of a CEE/DCB Switch with the features and capabilities of a FC switch which will:

- Support Ethernet and IP standards for switching, pathing and routing
- Support FC standards for switching, pathing and routing
- Support current and CEE/DCB Ethernet Standards
- Adapt between FCoE and FC



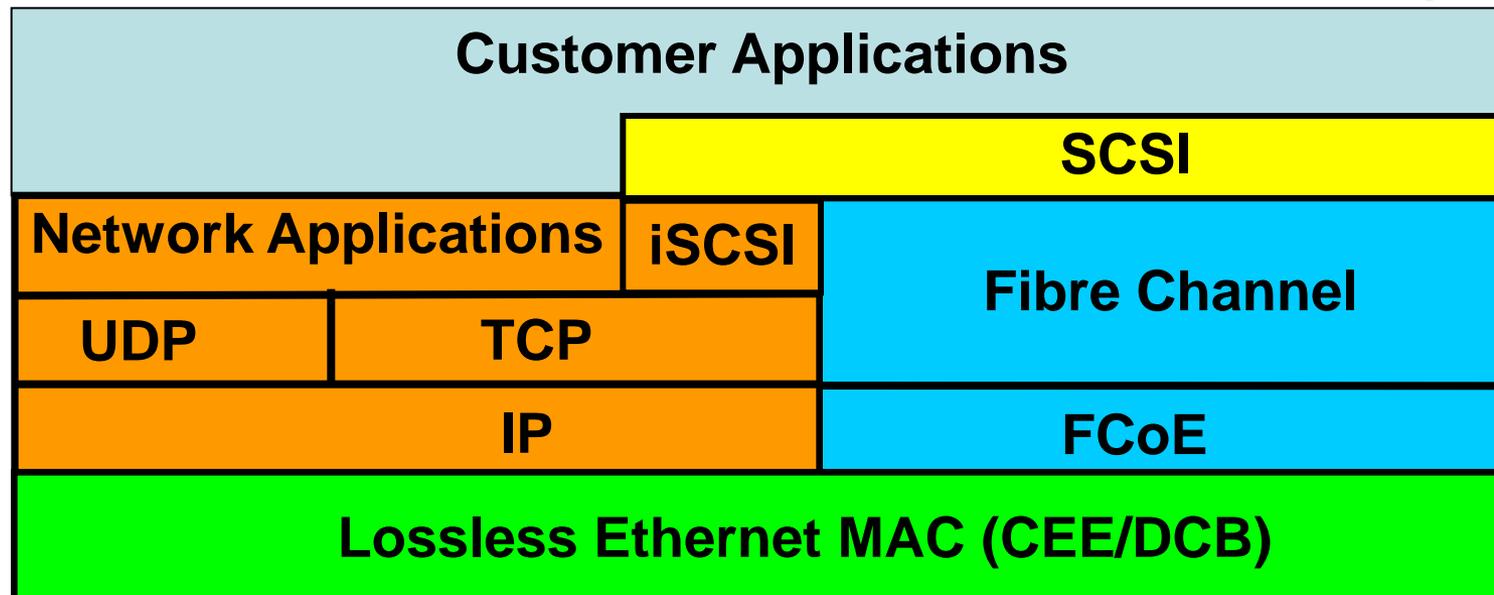
The FCoE Ports have F_Port or E_Port functions

Called VF_Ports and VE_Ports

(Because many logical (virtual) ports can share one physical port)

Connections to an Integrated CEE/DCB - FCoE Switch

- Fibre Channel is carried over lossless Ethernet as a L3 protocol



IP address 123.45.67.89

(FCoE VN_Port)

Ethernet port with IP & FCoE VF_Port capabilities



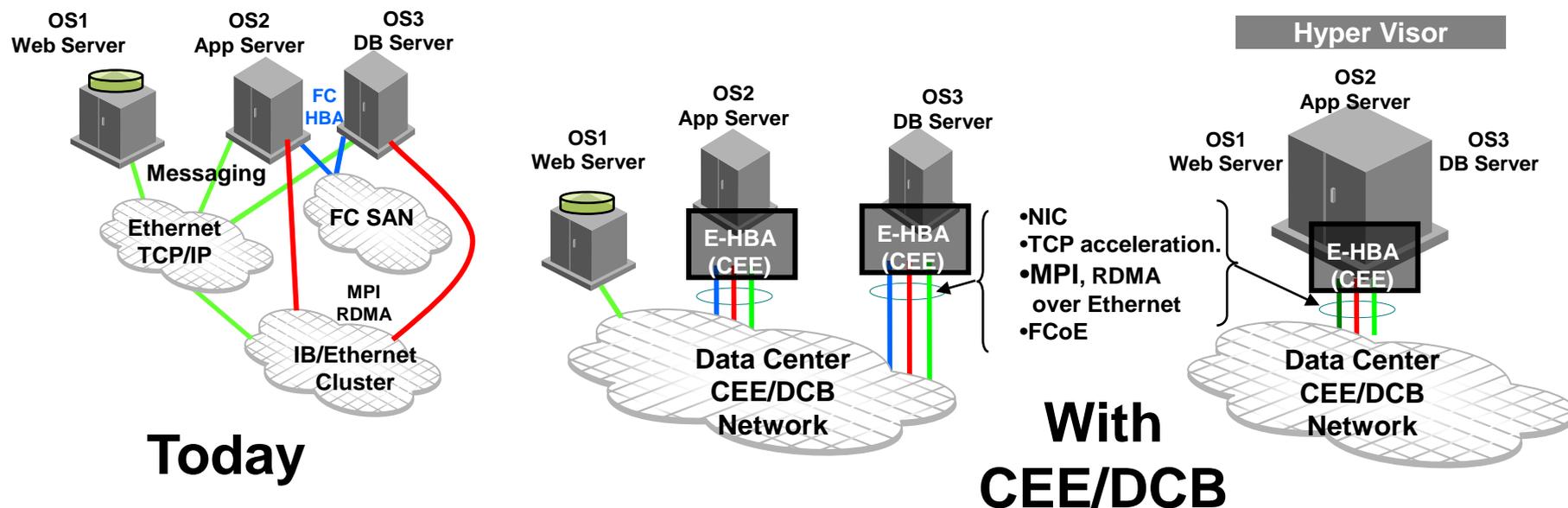
↑
**Integrated Lossless Ethernet (CEE/DCB) Switch
with FCoE Switch (FCF) capabilities**

FCoE Fabrics (part 2)

(This is NOT Traditional Ethernet)

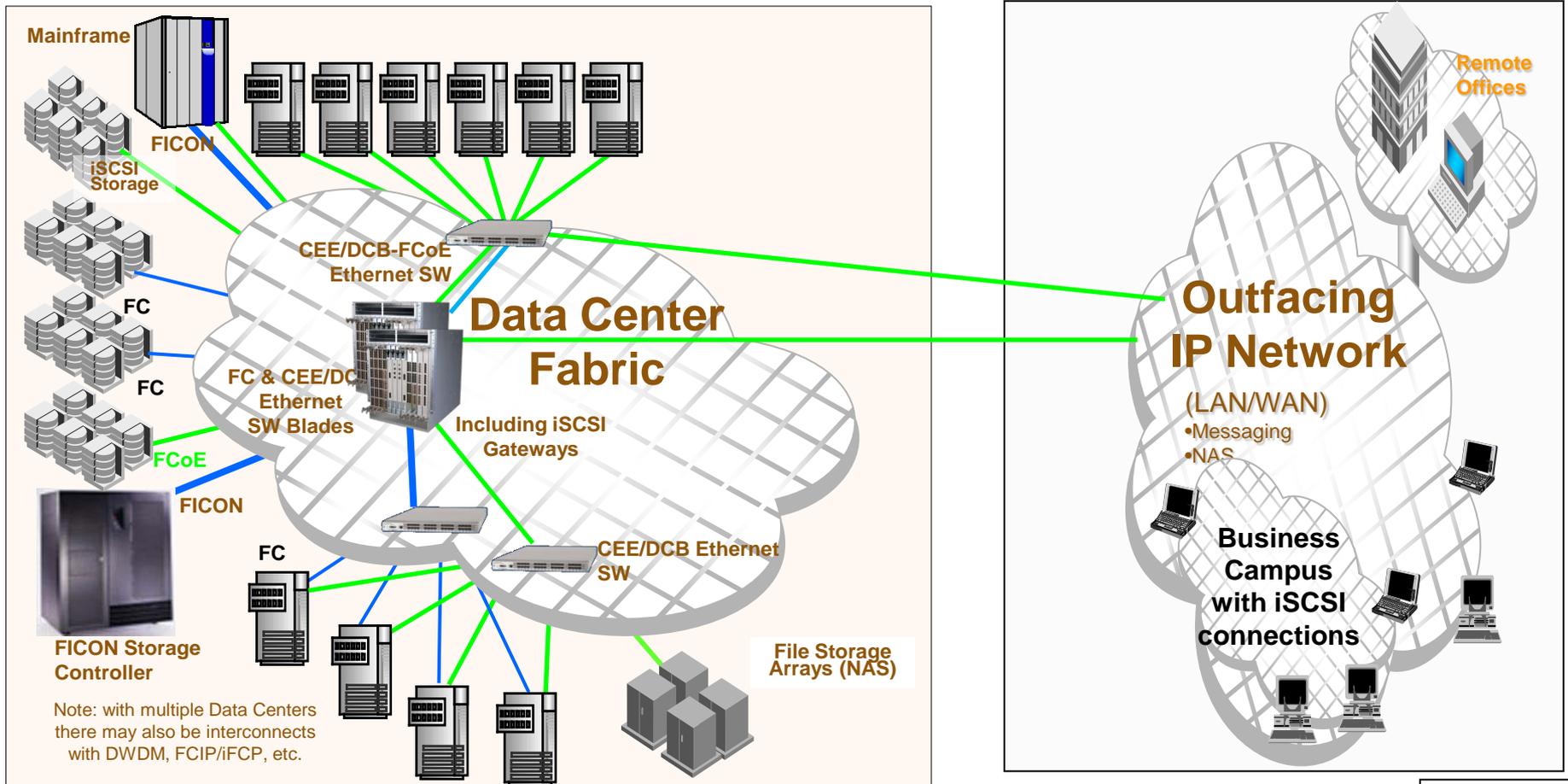
- ◆ CEE/DCB only Ethernet switches may also exist in an FCoE capable Fabric but one or more switches with FCoE capabilities must also exist
- ◆ FCoE fabrics must **inter-operate seamlessly** with real FC Fabrics
- ◆ FC services must operate identically on FCoE fabrics and Fibre Channel fabrics
- ◆ FCoE must support **all Fibre Channel advanced features** (e.g. virtual fabrics, IFR, security, etc.) transparently
- ◆ **FCoE will not require changes to FC software (Apps, Drivers, etc.)**
 - ◆ However, vendors have enhanced Drivers & Mgmt to exploit new capabilities
- ◆ **FCoE is NOT a replacement for FCIP**
 - ◆ FCIP is for tunneling inter-switch links (**beyond the Data Center**)
 - ◆ FCIP uses TCP/IP

The Compelling Value of Convergence is at the (Server Edge) Interface

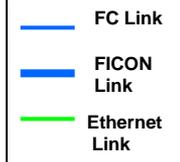


- ◆ **Dramatic Interface reduction in adapters, switch ports, cabling, power, & cooling**
 - ◆ 4-6 cables can be reduced to 2 Interfaces/cables per server
- ◆ **Seamless connection to the installed base of existing SANs and LANs**
- ◆ **Effective sharing of high bandwidth links**

But Even a Total Data Center (CEE/DCB) Fabric Requires Phase in (starting at the Server Edge Interface)

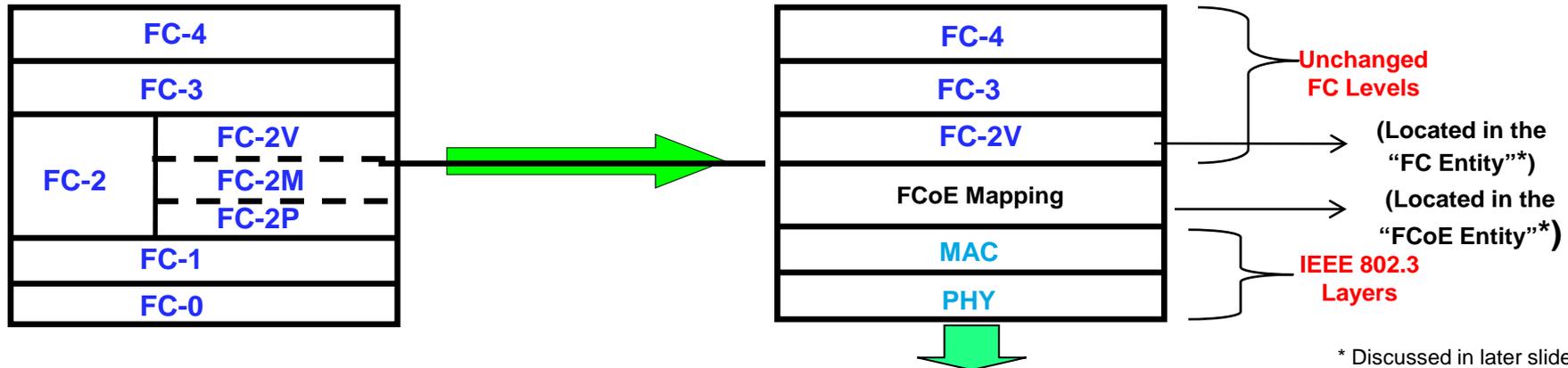


- **FCoE permits intermixing of multiple Connection types/protocols**
 - Clustering messaging, General Messaging, and Storage
- **The Data Center Fabric will “Trunk” to the “Outfacing” Network**
- **But many Customers may want keep a mixed environment on-going**

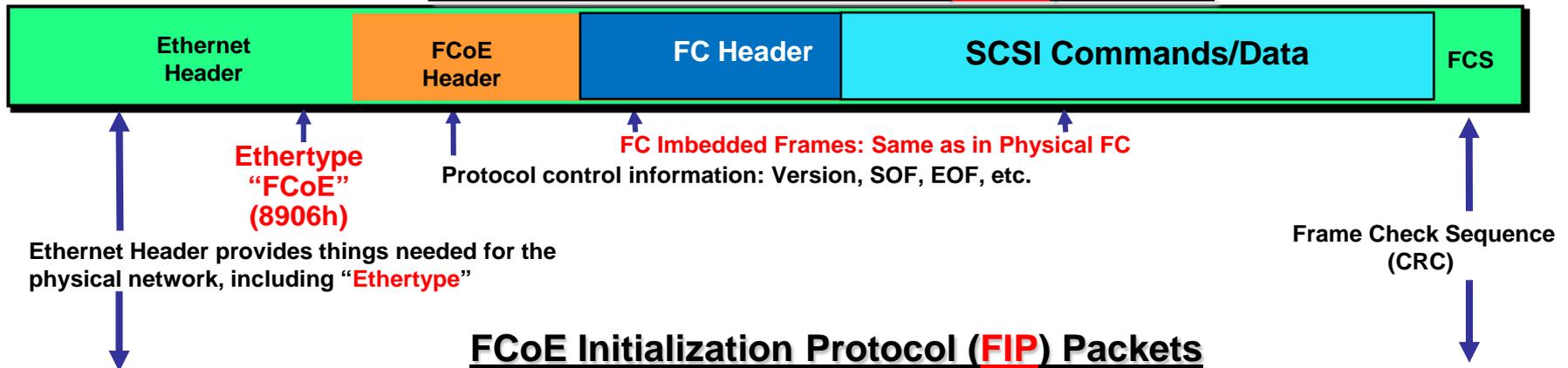


Architecture

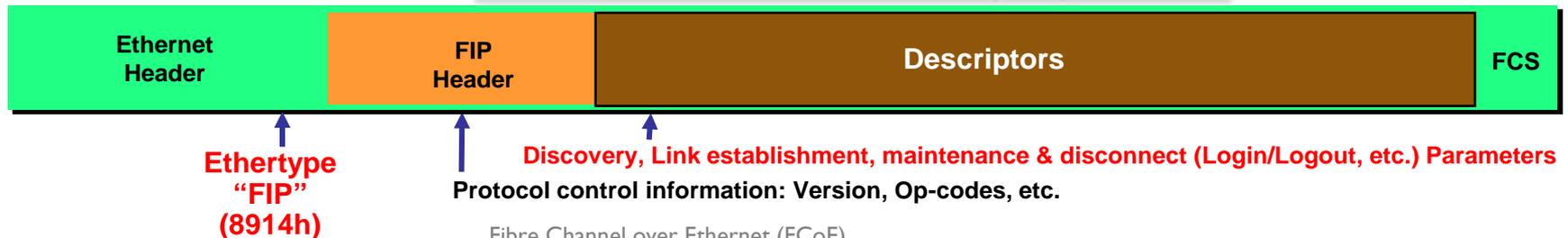
FC Encapsulation Into Ethernet Frames (2 FCoE Related Packet types)



Fibre Channel over Ethernet (FCoE) Packets



FCoE Initialization Protocol (FIP) Packets



➤ Discovery Phase

- ◆ FCFs Discover each other, & VLANs (if any) then form a Fabric
- ◆ ENodes Discover VLANs (if any) & then ENodes & FCFs Discover
 - Potential VN_Port $\leftarrow \rightarrow$ VF_Port pairing
 - Capabilities of Potential pairing

➤ Login Phase

- ◆ ENodes chose among discovered FCFs' Ports
- ◆ Creates association between ENode Ports and FCF Ports
 - VN_Port $\leftarrow \rightarrow$ VF_Port Logical FC Link
- ◆ Allowed methods for the ENode MAC Addressing
 - Fabric Provided MAC Addresses (FPMA) – Assigned by the Fabric
 - ~~Server Provided MAC Addresses (SPMA) – Assigned by the Server~~
- ◆ Uses: FLOGI, FLOGI ACC, LOGO, ELS, ...

➤ End-to-End path control & Data Transfer Phase

- ◆ PLOGI/PRLI
- ◆ All other FC protocol frames (FC4 ULPs. etc.)

FCoE
Initialization
Protocol
(FIP)

FCoE
Protocol

FC's Encapsulation in Ethernet (FCoE)

Optional IEEE 802.1q
4 Byte Tag goes here →

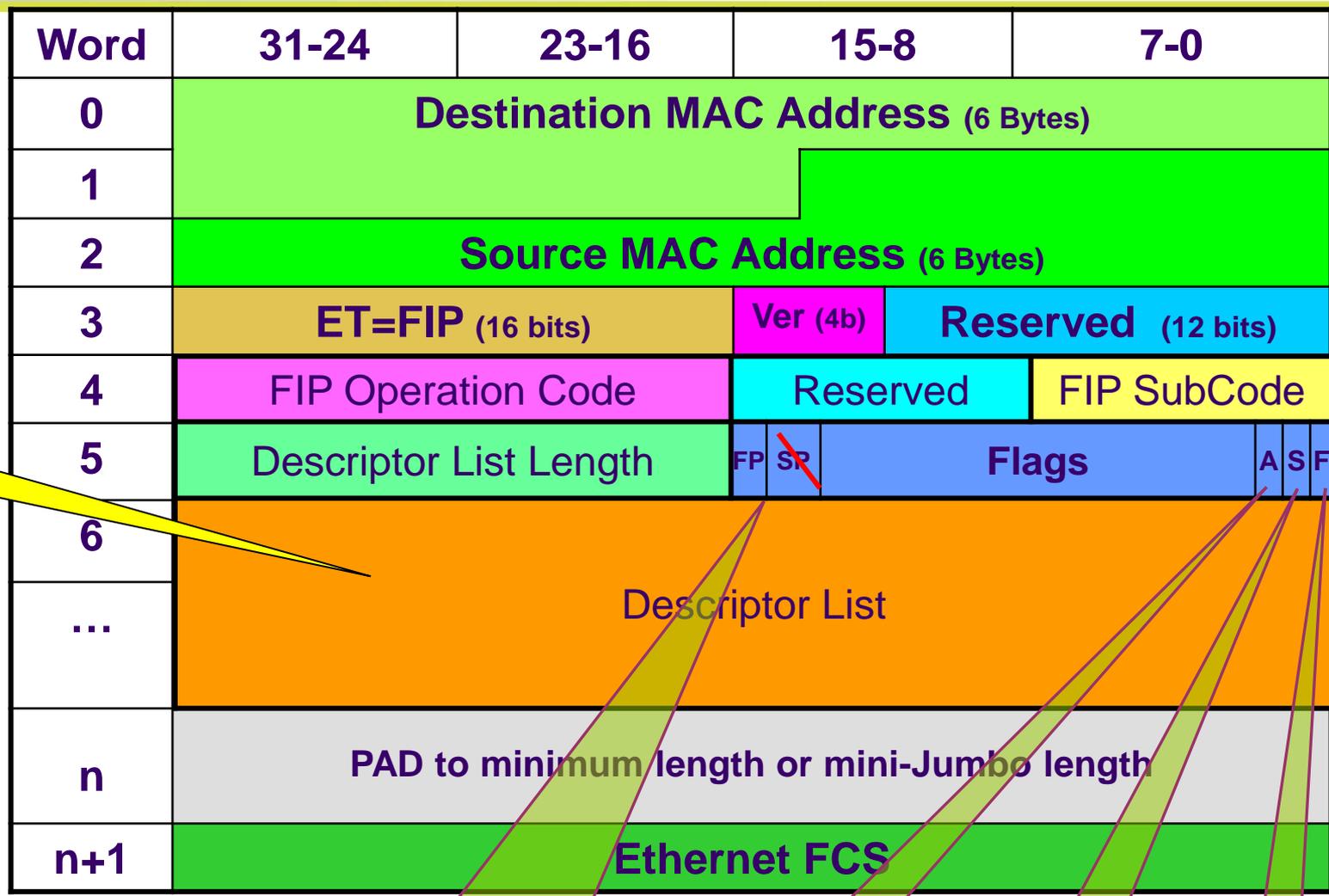
This field varies
In size →

Ethernet frame
Size is 64 Bytes to
2220Bytes →

Word	31-24	23-16	15-8	7-0
0	Destination MAC Address (6 Bytes)			
1				
2	Source MAC Address (6 Bytes)			
3	ET=FCoE (16 bits)		Ver (4b)	Reserved (12 bits)
4	Reserved			
5	Reserved			
6	Reserved			SOF (8 bits)
7	Encapsulated FC Frame FC Frame = Minimum 28 Bytes (7 Words) → Maximum 2180 Bytes (545 Words) (including FC-CRC)			
...				
n				
n+1	EOF (8 bits)	Reserved		
n+2	Ethernet FCS			



FIP Operation Format



Optional IEEE 802.1q
4 Byte Tag goes here →

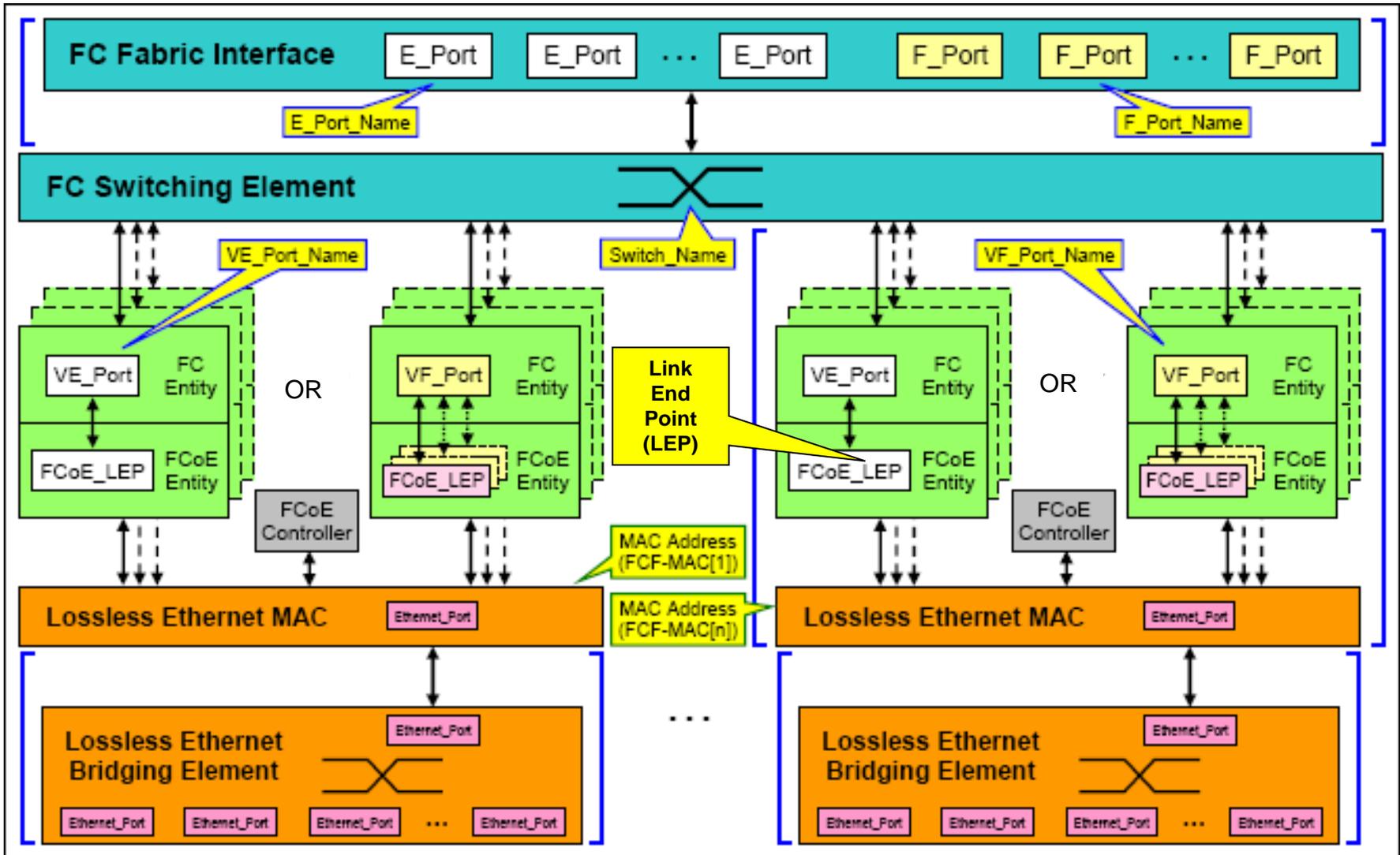
See Appendix Below for Descriptor list items

Descriptor list varies In size →

Ethernet frame size Is 64Bytes to 2220Bytes →

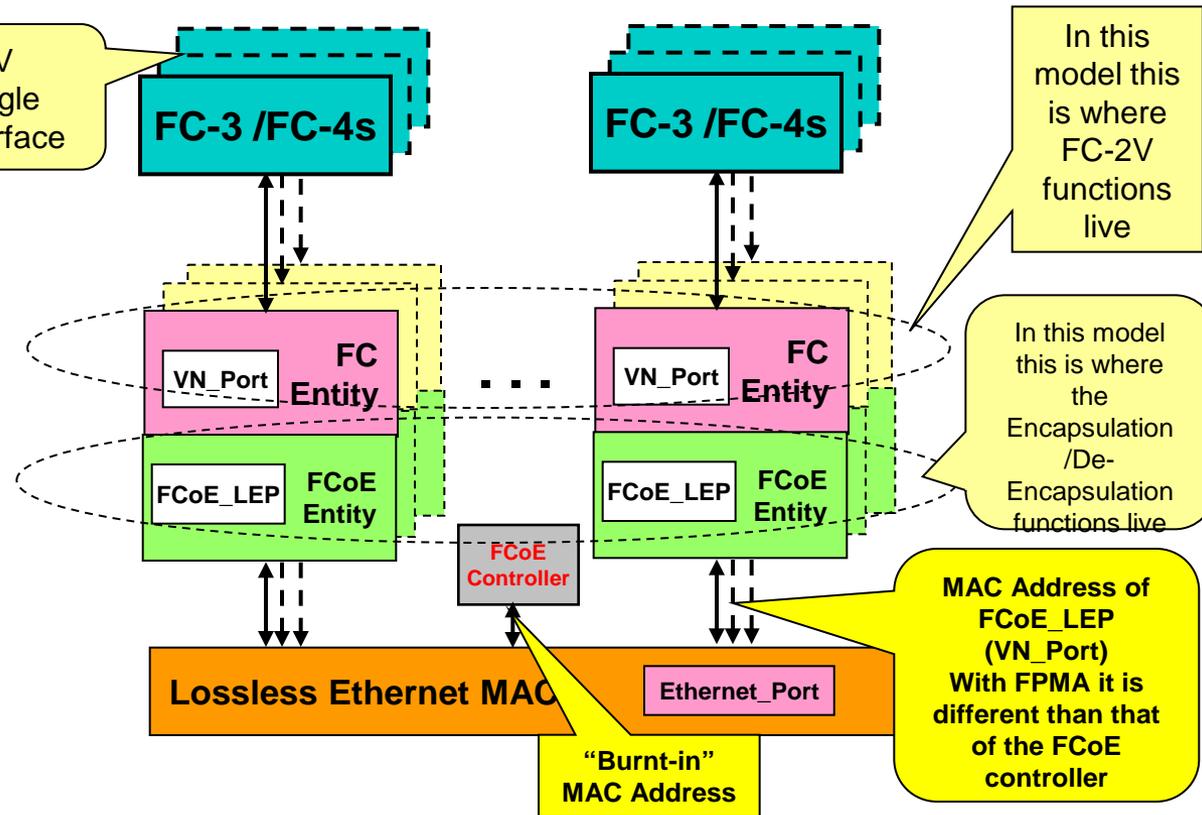
Capability Bits (~~SPMA~~ or FPMA) Available bit Solicited bit FCF bit

FCF Model

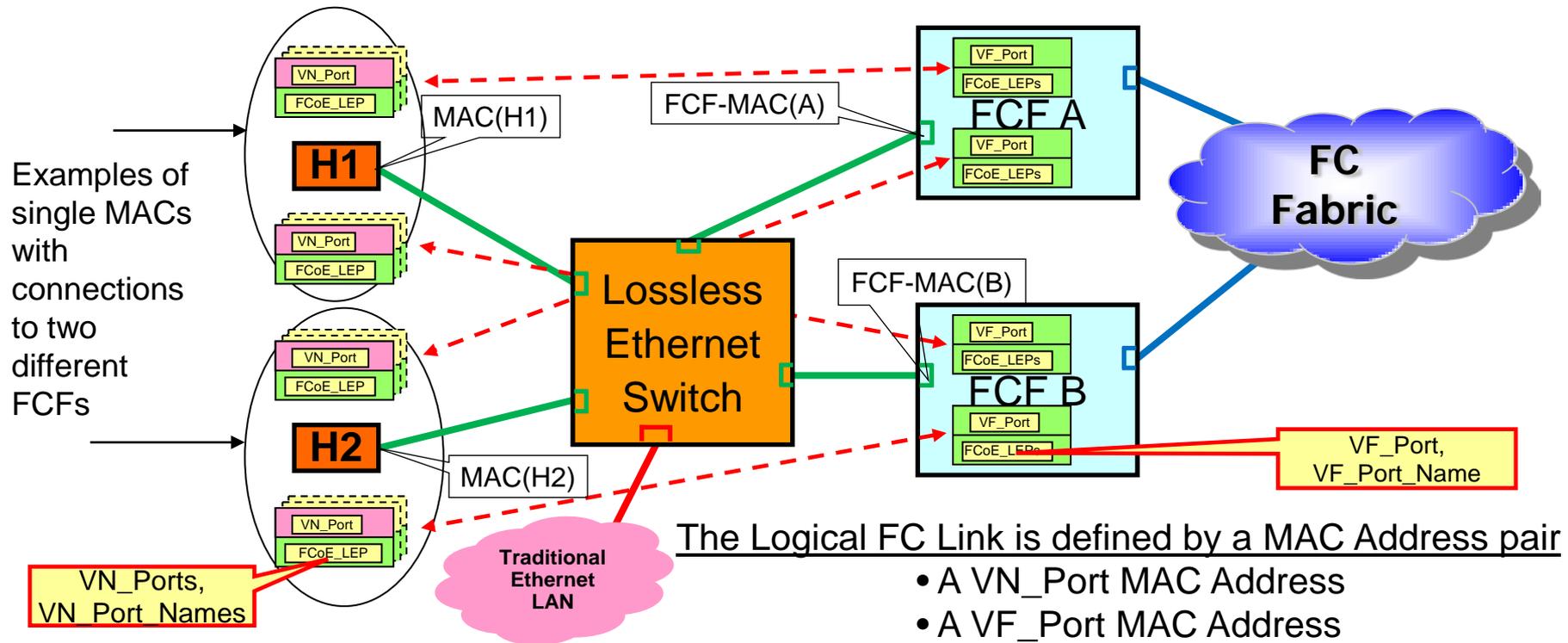


HBA Model of the ENODE with Multiple Logical FC interfaces

- For each logical N_Port (VN_Port) there is one FLOGI and perhaps 100's of FDISC
- Each VN_Port is seen by the Host as a separate (logical) FC Login/FDISK connection
- The number of (logical) FC connections is implementation dependent
- Only one MAC Address is required for the FCoE Controller
- FCF will supply MAC addresses for each VN_Port
- May also have Multiple implementations of this if HBA has **Multiple Physical Ports**



Multiple Logical FC connections via a single Ethernet MAC

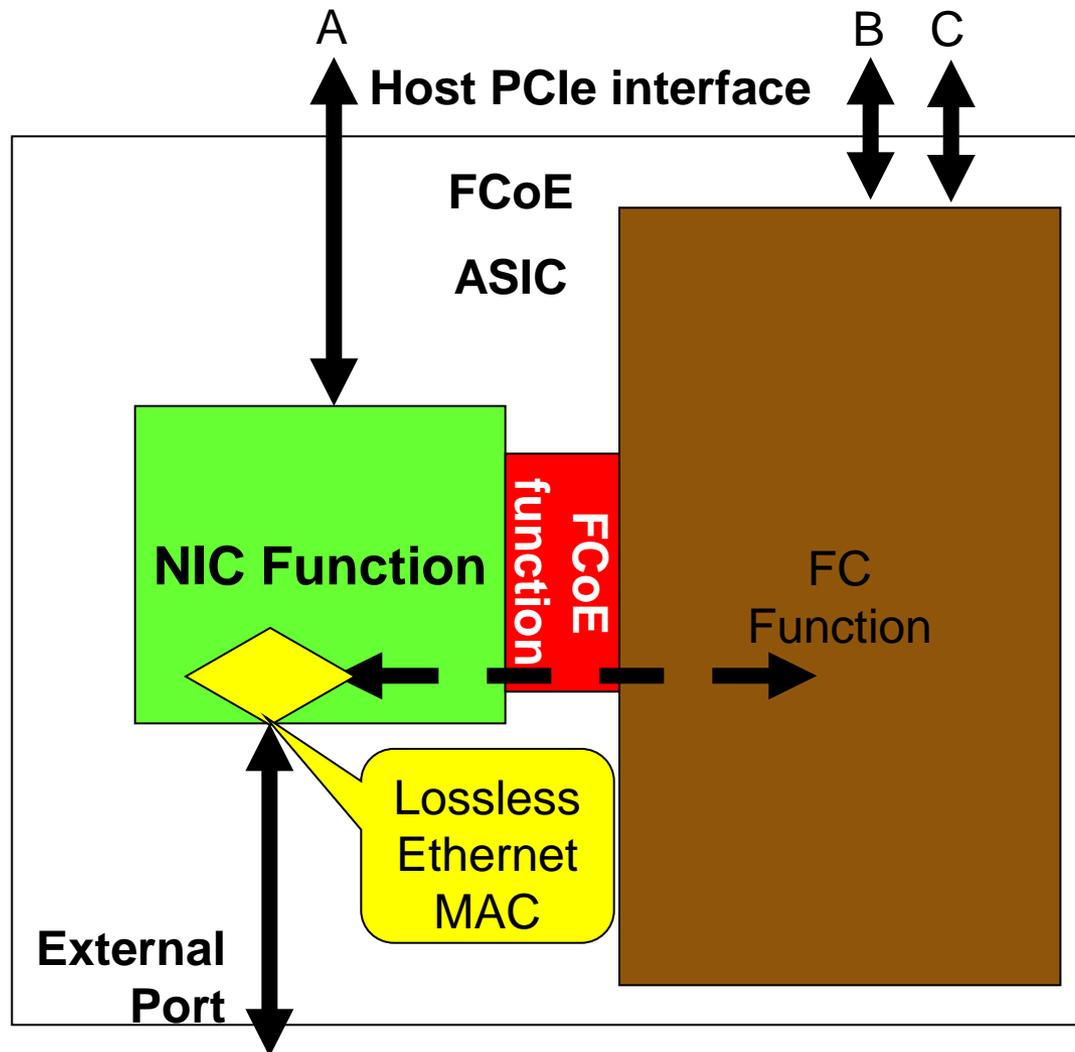


For a logical FC link the FCoE Frames are always sent to and received from a specific FCF's MAC Address

- Therefore, pathing to and from the FC driver is always defined by the MAC Address of the partner FCF's VF_Port

Note: VF ports get created off of the FLOGI from the VN_Port and multiple VF_Ports can sit behind a single FCF physical interface with a single MAC address

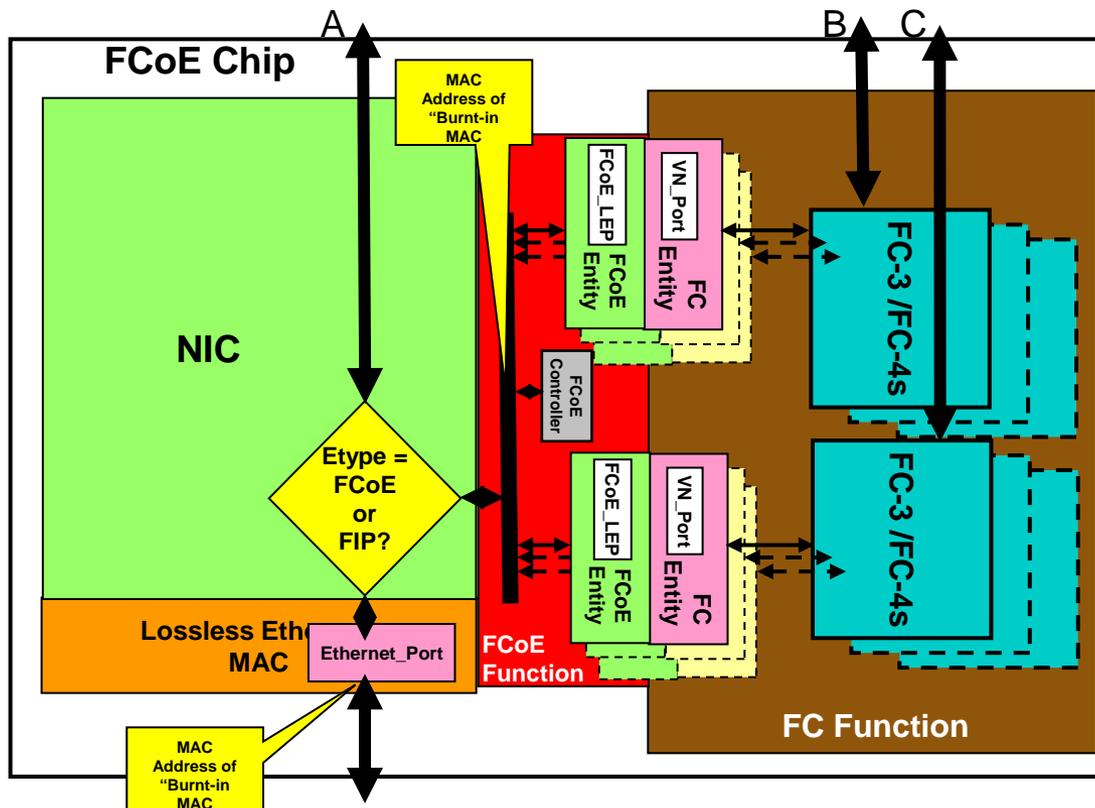
Functions of an FCoE Converged Network Adapter (CNA) in the Initiator



- Has a Normal NIC interface (A) to the Host
- Has one or more Normal FC interfaces (B,C) to the Host
- FCoE functions not seen by the Host
- FCoE functions perform the Encapsulation and De-encapsulation
- The FCoE function Instantiates Logical FC N_Ports, called VN_Ports

CNA with Multiple Logical Interfaces

- The FCoE controller will perform the FIP functions and will instantiate new VN_Ports as FCoE Link End Points (LEP)
 - With a new MAC address specified by the FCF (FPMA)

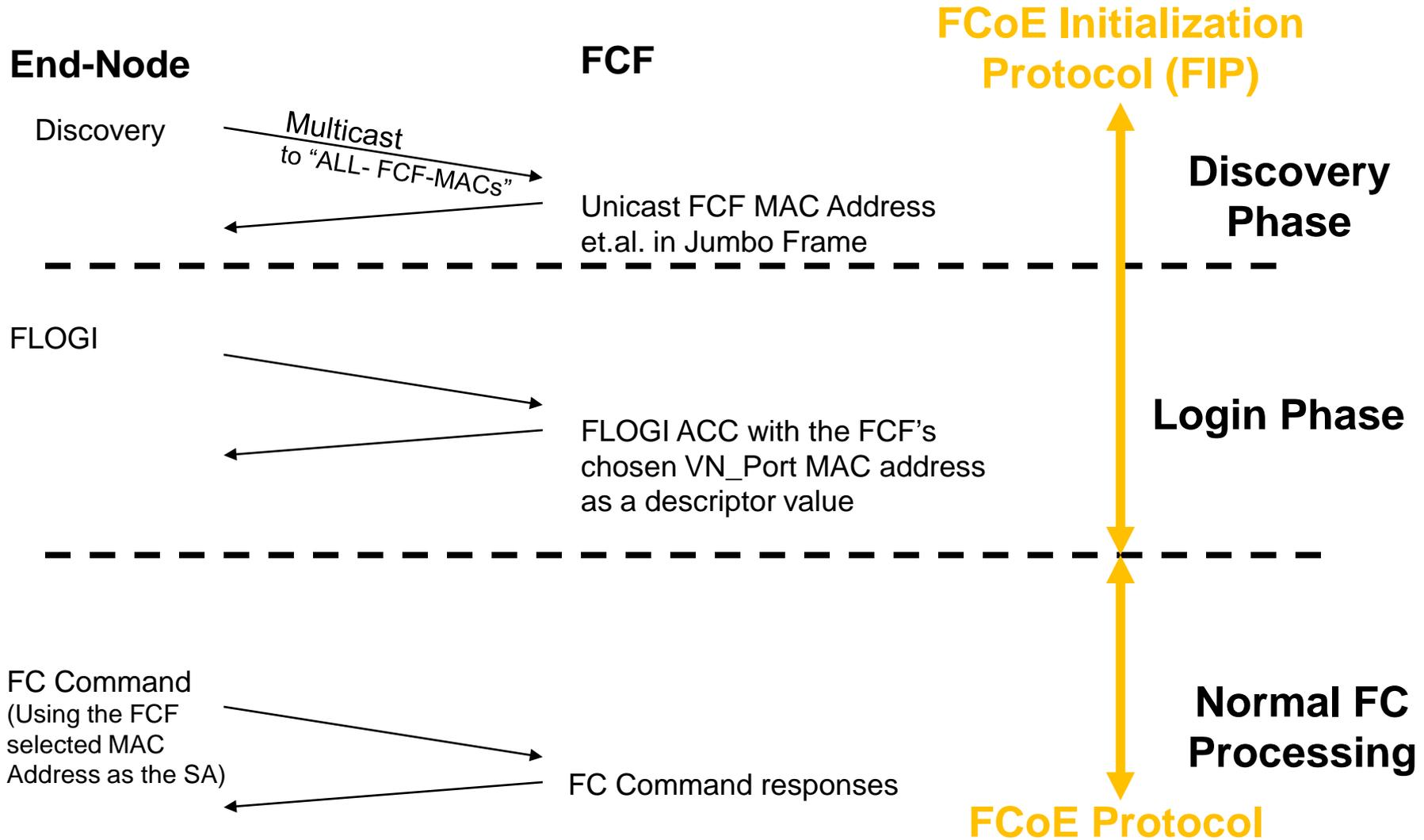


- MAY have one "burnt-in MAC address for both IP and FCoE/FIP packets
- Or
- MAY have different "Burnt-in" MACs for IP and FCoE/FIP packets
 - Used to separate HW based FCoE from other Ethernet Traffic
 - Most NICs come with several "Burnt-in" MAC Addresses

Discovery and Link Instantiation (FIP -- FCoE Initiation Protocol)

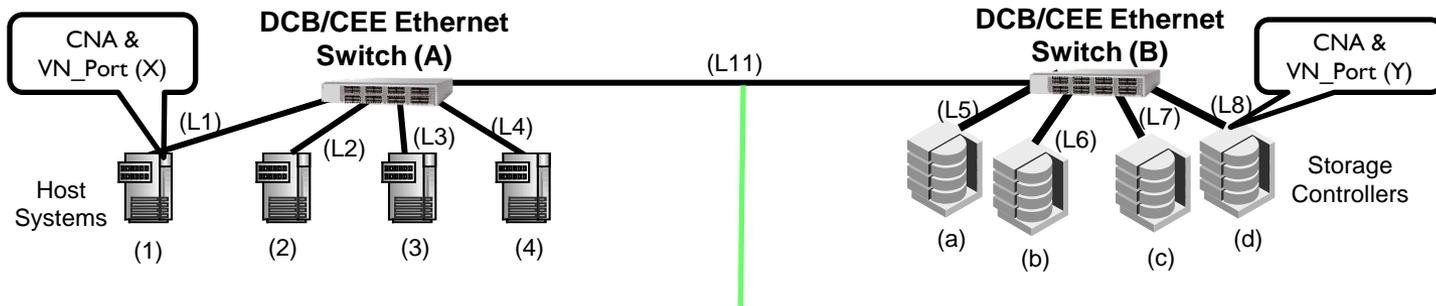
Initial Login Flow Ladder (2 FIP Phases)

(within any specific VLAN)

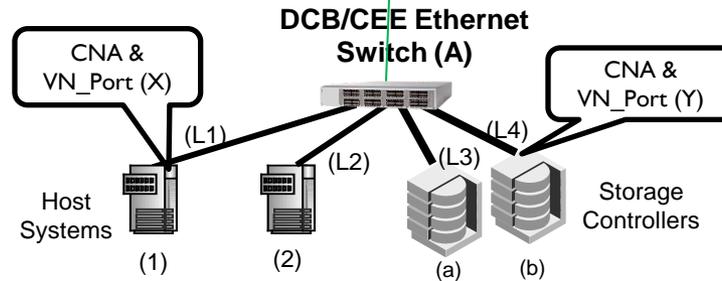


See Appendix for more details on [Discovery Consideration and Actions, including discovering VLANs](#)

New Direct VN_Port to VN-Port (VN2VN)



A CNA to CNA FCoE path between these Switch ports is now also possible even without an FCF using Direct VN2VN mode





New Initial Login Flow Ladder

(Direct End-to-End → VN2VN)

End-Node

Probe & Claim

(after Randomly computing ID)



(repeat until no conflicts)

Multicast
to "ALL-VN2VN-Enode-MACs"

End-Node

Unicast Probe & Claim responses

FCoE Initialization Protocol (FIP)

Discovery Phase

FLOGI

to chosen VN_Port Peer

FLOGI ACC to accepted VN_Port

Login Phase

FC Command

to chosen VN_Port Peer

FC Command responses

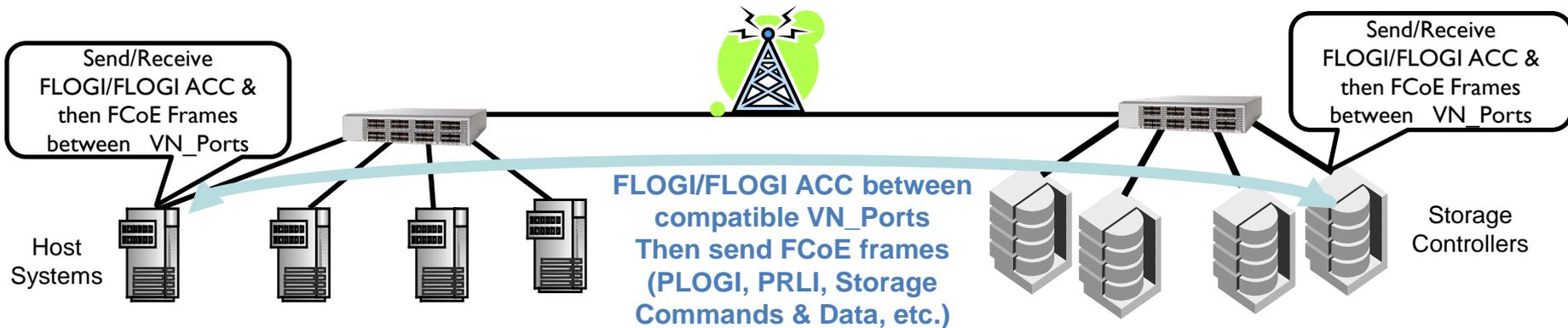
Normal FC Processing

FCoE Protocol

New Discovery and Link Instantiation (for VN2VN)



- Randomly chooses an identity (FC-ID & MAC Address)
 - Then uses a Multicast FIP processes called “Probe, & Claim” to insure ID uniqueness
 - This will announce the VN_Ports’ identities and the VN_Ports’ capabilities to other VN_Ports
 - A VN_Port will save the announcements from other VN_Ports for choosing a peer VN_Port
- Note: FC-ID & MAC Address should be saved, if possible, for next Reboot

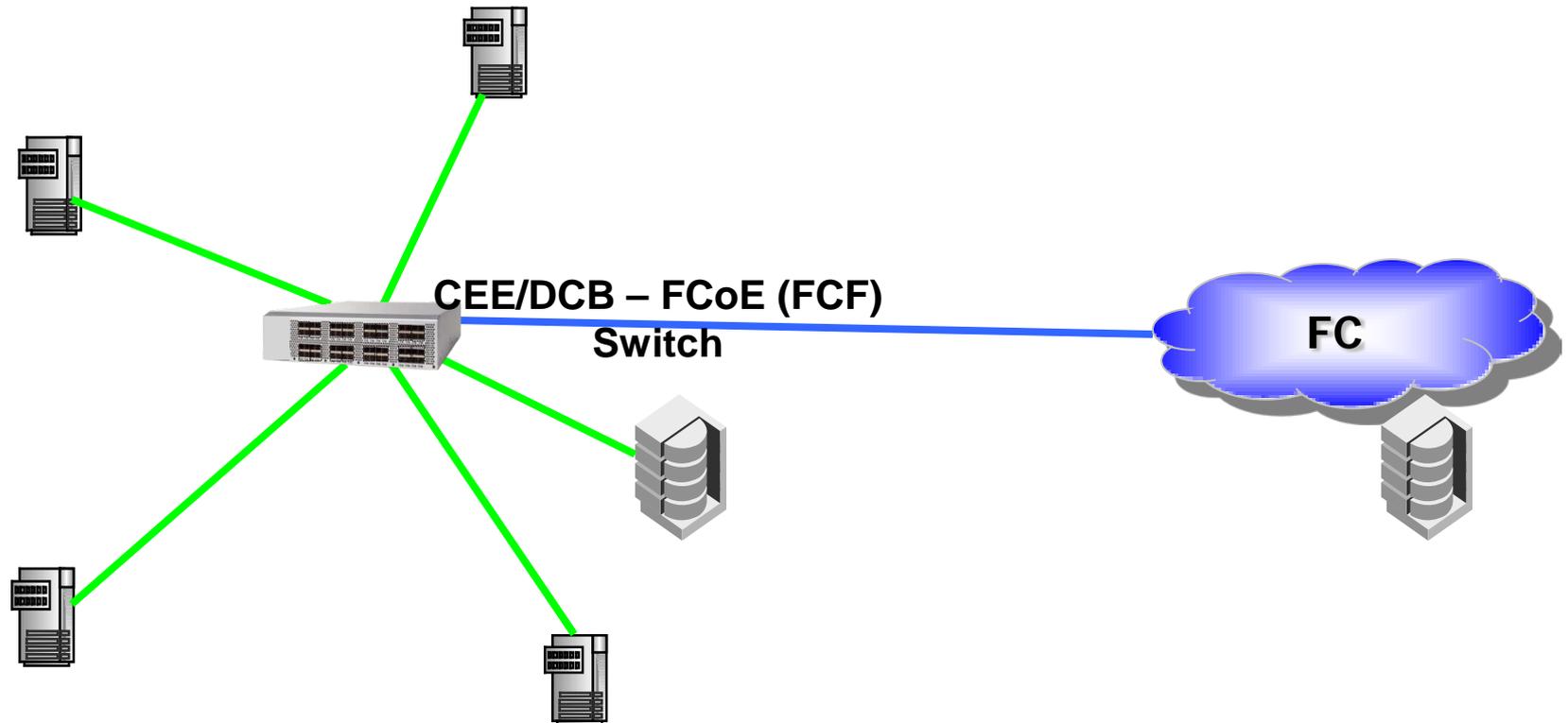


After IDs and Potential Partners (VN_Ports) are identified within the Level 2 Ethernet:

- FLOGI FIP frames, & FCoE frames will be exchanged directly between the VN_Ports
- After Link Instantiation the IDs will be Periodically Beaconsed (Multicast)
- Beaconsing permits detection of link loss (via time-outs) & incorrect LAN joins

Topologies with FCFs

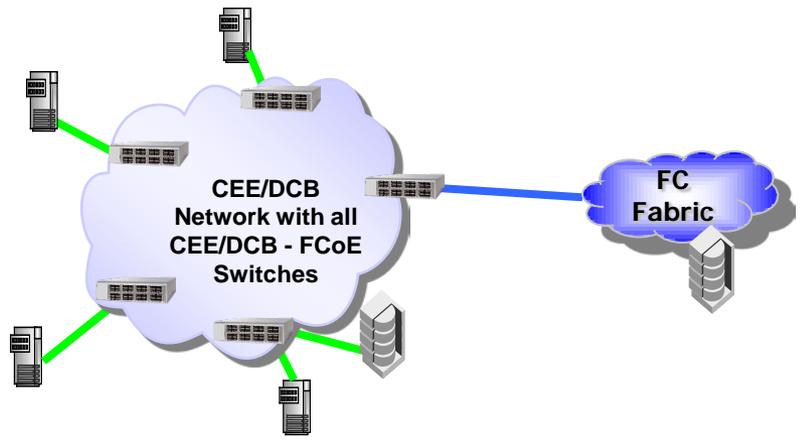
A Simple CEE/FCoE (FCF) Fabric



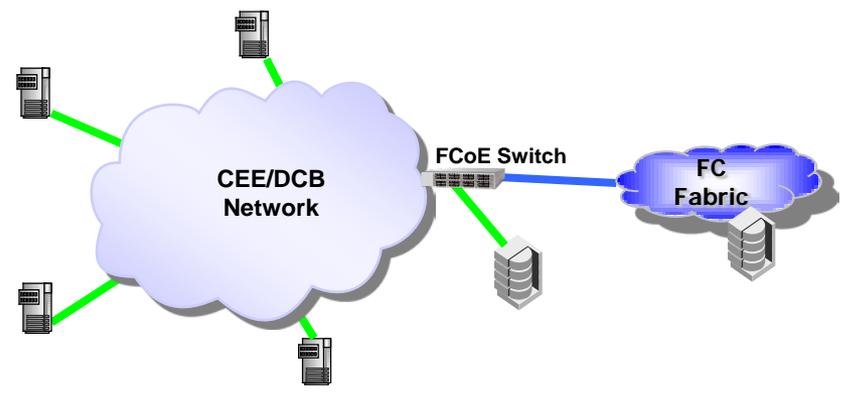
An CEE/DCB - FCoE (Integrated) Switch may connect to a Traditional FC switch/fabric via the FC E-Port

— Ethernet
— FC

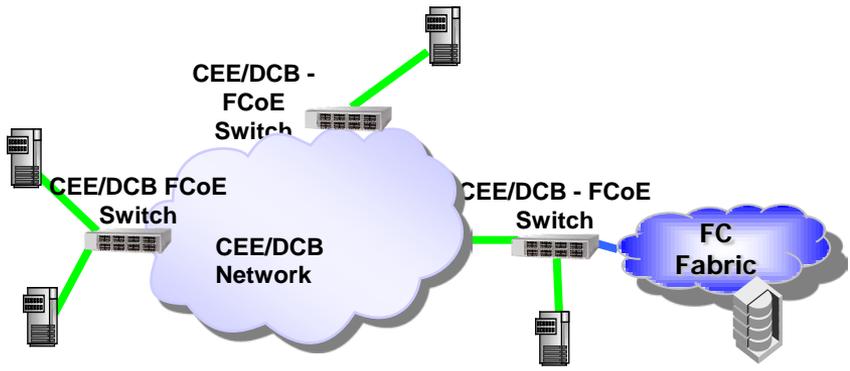
Multiple Topologies using FCoE Switches (FCFs)



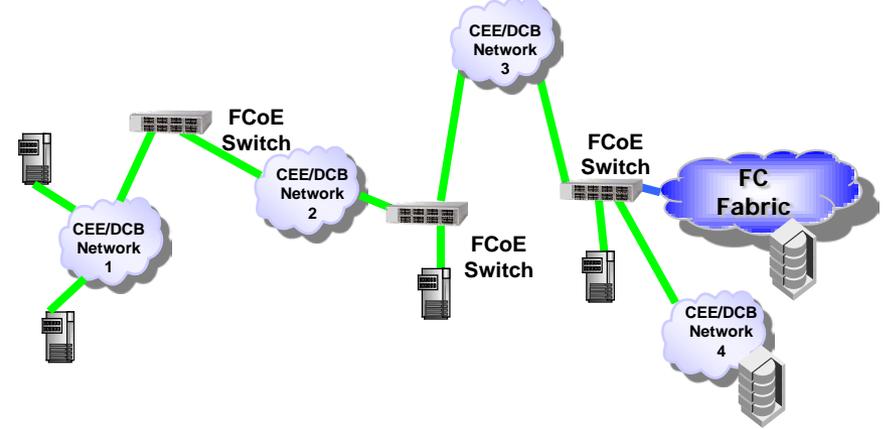
A Lossless Ethernet Network can be made up of all CEE/DCB - FCoE (Integrated) Switches



Lossless Ethernet (CEE/DCB) switches configured into a Lossless Ethernet (CEE/DCB) Network can Front the FCoE Switch



CEE/DCB - FCoE (Integrated) Switches deployed at the edges of the Lossless Ethernet CEE/DCB Network
 CEE/DCB - FCoE Switches connected via VE_Ports and a Lossless Ethernet CEE/DCB Network

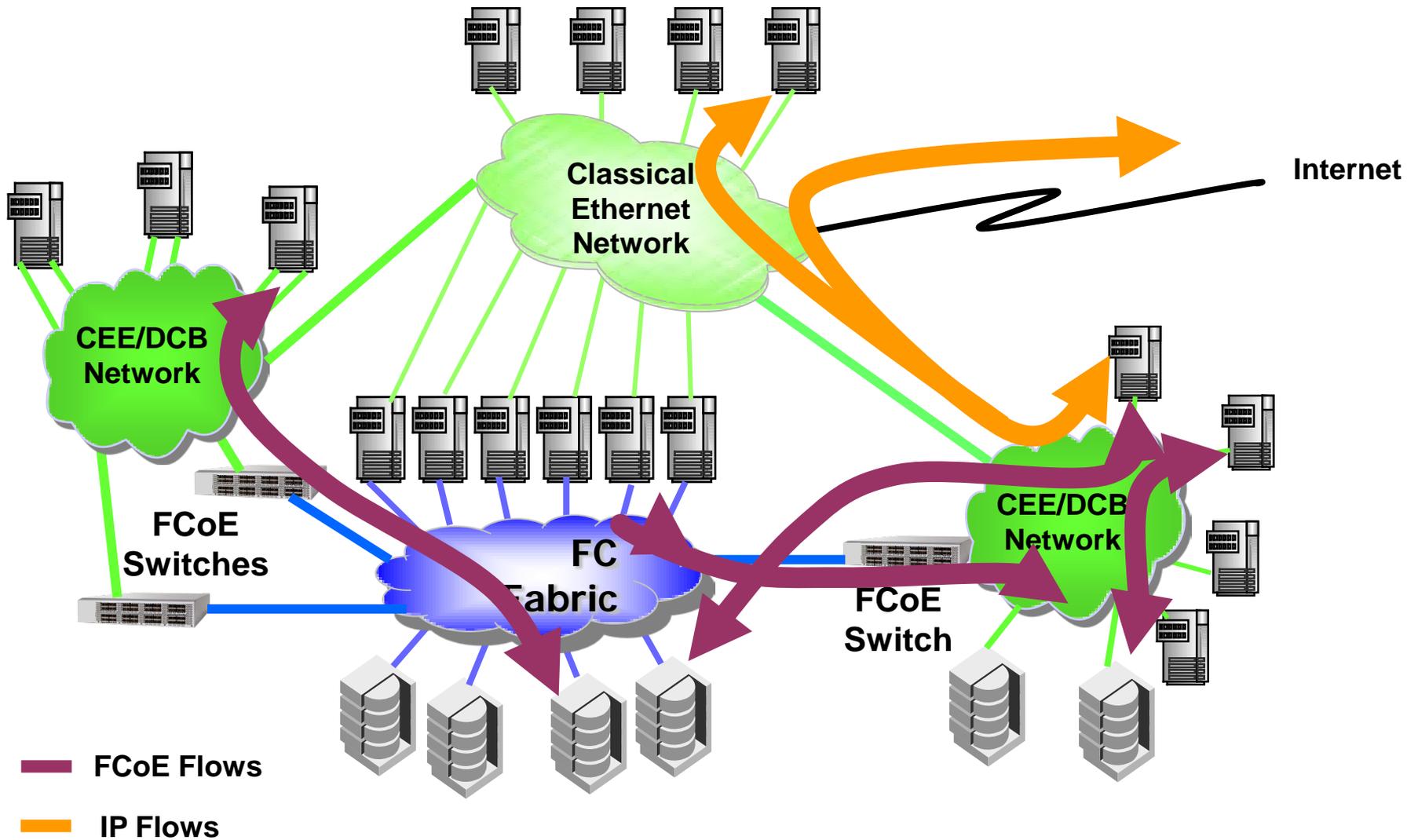


A VE_Port in an FCF may connect to another VE_Port in another FCF
 And an FCF FC E_Port may connect to an FC switch E_Port in the FC Fabric

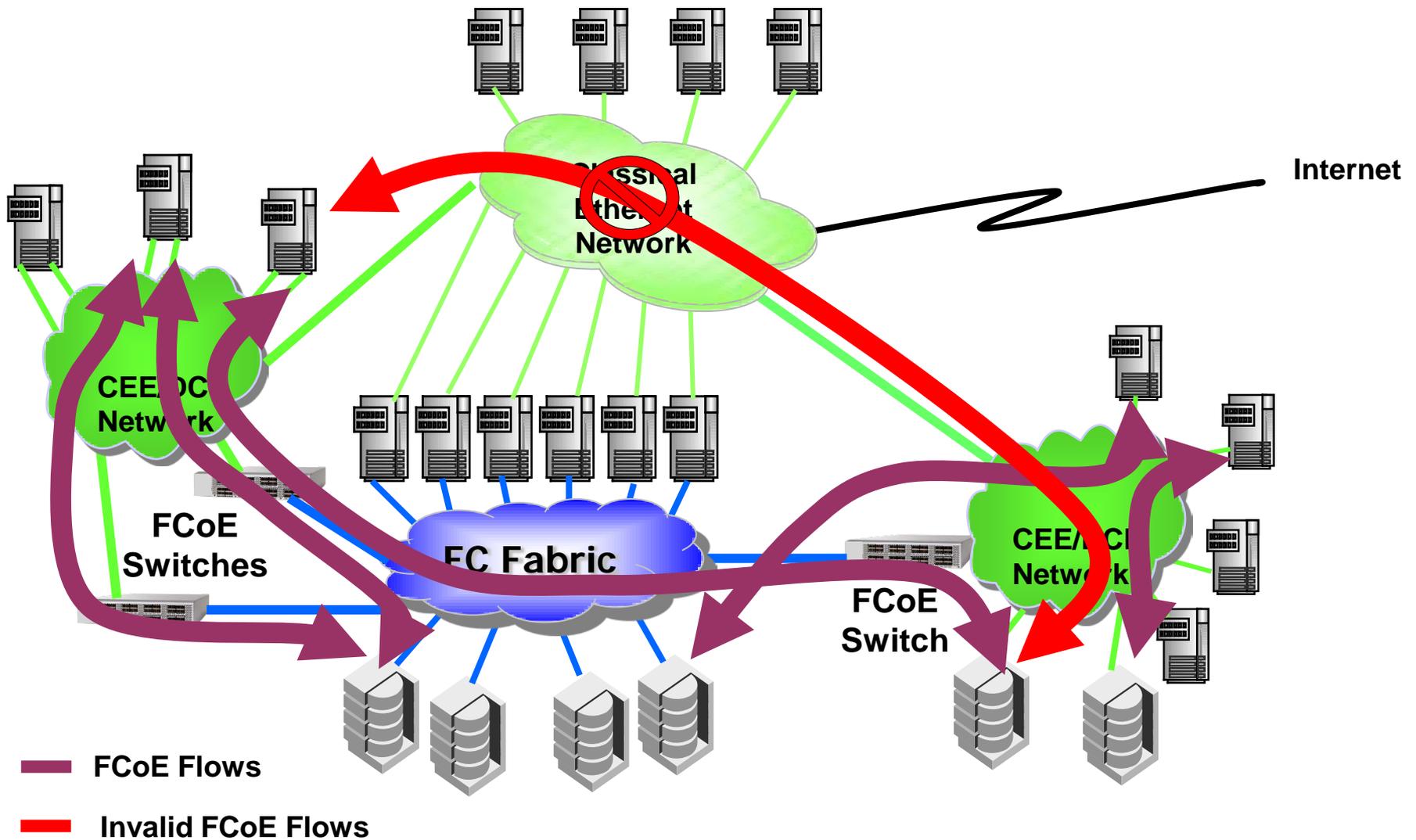
 Ethernet
 FC

Scenarios with FCFs

Scenario 1: FCoE & IP Flows



Scenario 2: FCoE Right & Wrong



Summary

- ◆ T11.3's FC-BB-5 Ad-Hoc Working Group completed the specification in June 2009
 - ›
- ◆ FCoE is a simple, efficient mechanism for encapsulating Fibre Channel in Ethernet frames on a New Ethernet type Network
 - ◆ Not a traditional Ethernet Interface or fabric
 - ◆ A New Network – the Converged Enhanced Ethernet (CEE) Network
 - ◆ CEE (also called DCB) defined in the IEEE 802.1 standards working group
 - ◆ FC protocol frames will just be inserted into these Ethernet frames
- ◆ An evolutionary deployment model was designed into FCoE
 - ◆ Specification permits the installation to evolve from FC to FCoE
 - › Any Fabric mix of FC and FCoE is possible
 - › May only need FCoE at the Server Edge with a Converged Interface
 - › But a total FCoE SAN is also possible (using FCFs)
 - › Value in reduced Server Edge Cables, Adapters, Power, and Cooling
 - ◆ All FCoE devices should interoperate with Real FC devices
- ◆ FCoE is made for a Data Center Fabric – Not applicable for the Outfacing Network
- ◆ T11.3's FC-BB-6 Ad-Hoc Working Group accepted VN2VN for the next specification
 - ◆ Look for VN2VN to provide viable FCoE SANs for the Entry/Low-End IT Environment
 - ◆ Will be seen to be competitive with iSCSI, especially with the SW version of FCoE
 - › Expect CEE/DCB to be included in 1Gb Ethernet Switches

- Please send any questions or comments on this presentation to SNIA: tracknetworking@snia.org

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SNIA Education Committee

Claudio DeSanti
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Walter Dey
Silvano Gai
Joe White

- For additional information refer to
<http://www.t11.org/fcoe>



Unified Storage-Infrastructure

Thank You!



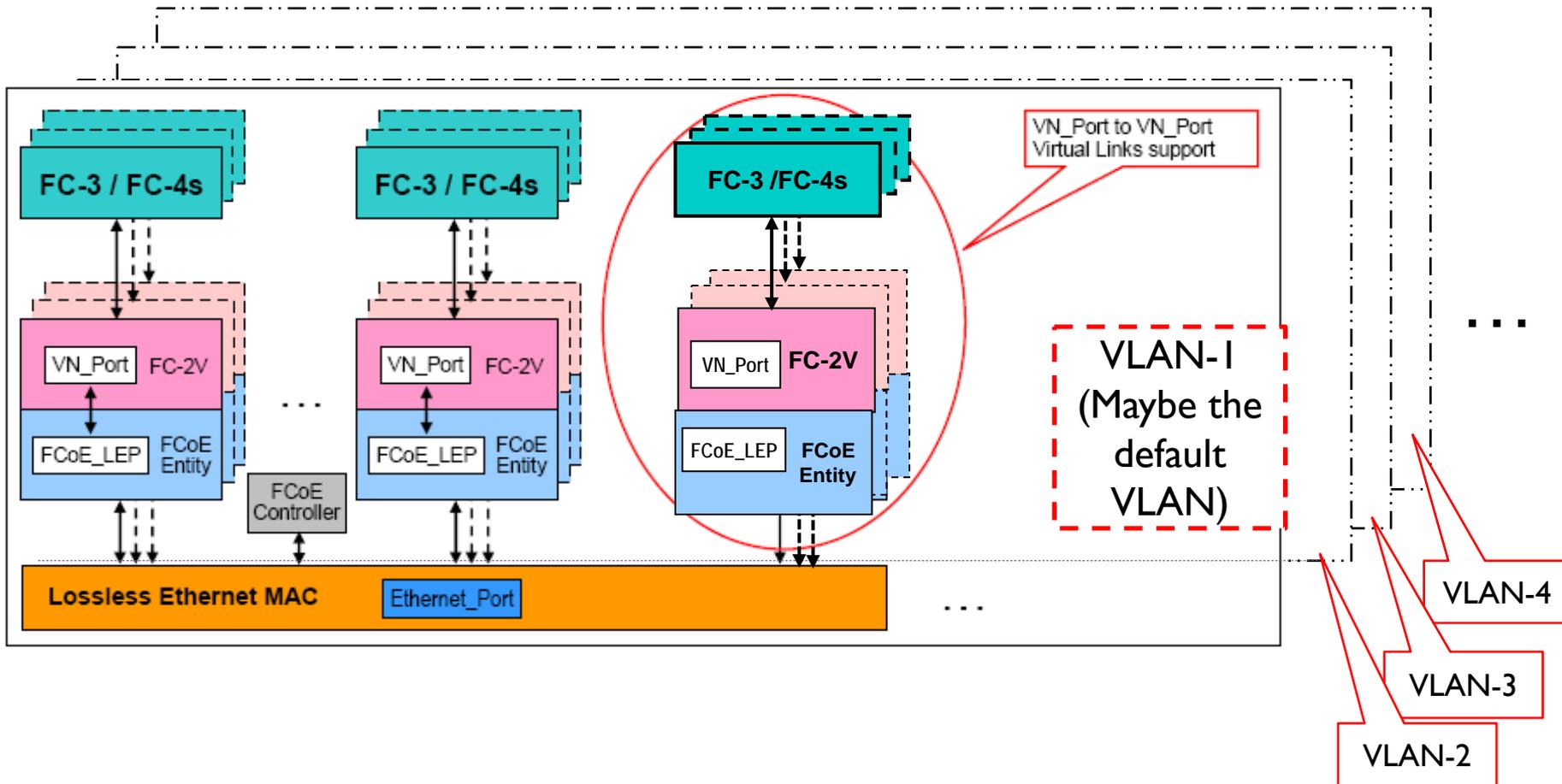
Education

- Full ENode Model
 - » (with VN2VN)
- Additional Info on FCoE Fabrics
- FCoE Relation to ISO Layers
- Flows
- Additional Topologies
- FSPF and STP
- FIP Considerations and Actions
- FIP Descriptors
- Pause vs BB_Credit



Full ENode Model

(with VN2VN & multiple VLANs depicted)



Each instantiation's N_Port_ID & MAC Address is independent of the others
There can be duplicates (if they are in different VLANs)

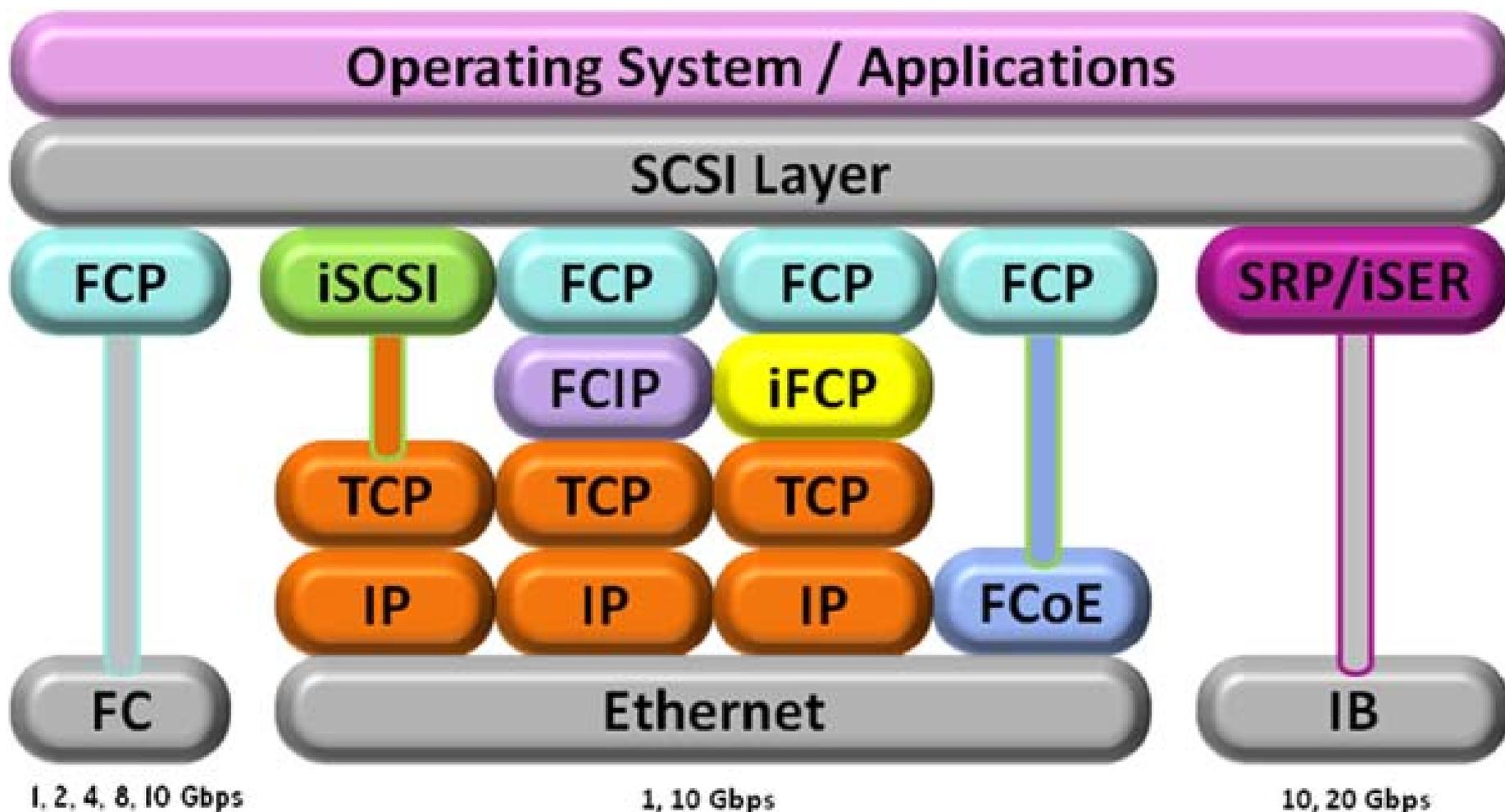


FCoE Fabrics (part 3)

- FCoE is a **direct mapping** of Fibre Channel over an Ethernet network
- FCoE is layered on top of a Lossless Ethernet
 - ◆ FSPF used to route FCoE packets
 - ◆ Ethernet Spanning Tree type protocol, RSTP, MSTP, etc, is at a layer below
- FCoE allows an **evolutionary** approach towards consolidation of fabrics
 - ◆ The Fibre Channel N_Port, F_Port and E-Port constructs must be retained
 - › With FCoE, ports may be connected with Logical Ethernet Links
 - May pass through Lossless Ethernet NICs & Switches
 - Identified by pairs of end point MAC addresses
 - ◆ Physical Ethernet Links can replace physical FC Links
 - ◆ Physical Ethernet Links can carry all Ethernet traffic, including FCoE, but combined traffic needs the CEE/DCB capabilities

- “Integrated FCoE Switches” are being built that support traditional Ethernet traffic, FCoE traffic , & FC traffic
- The FCoE solutions appear as a Fibre Channel to a Fibre Channel experienced customer
- FCoE keeps the Fibre Channel operations independent from Ethernet forwarding
 - ◆ Keeps Management /Troubleshooting simple
 - ◆ Common physical structures, different logical structures
 - › Based on Ethertype (Ethertype = FCoE, or FIP)
- Storage Management should be unchanged

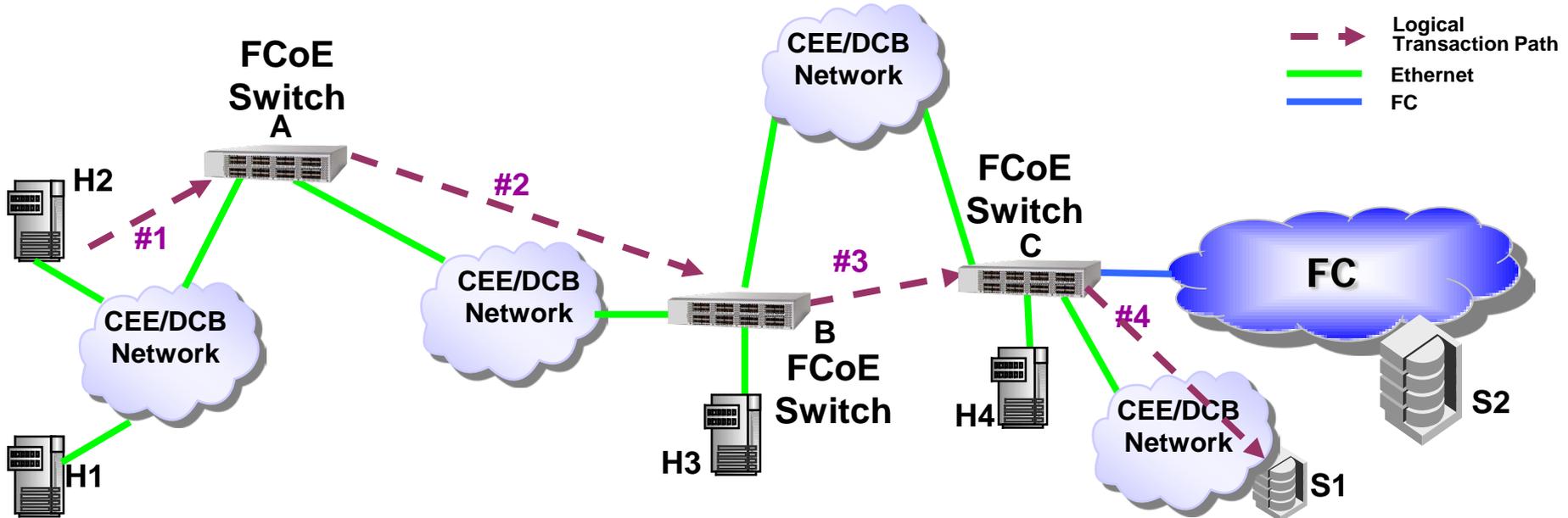
FCoE Relation to ISO Layers



Flows

Logical Fabric Topology

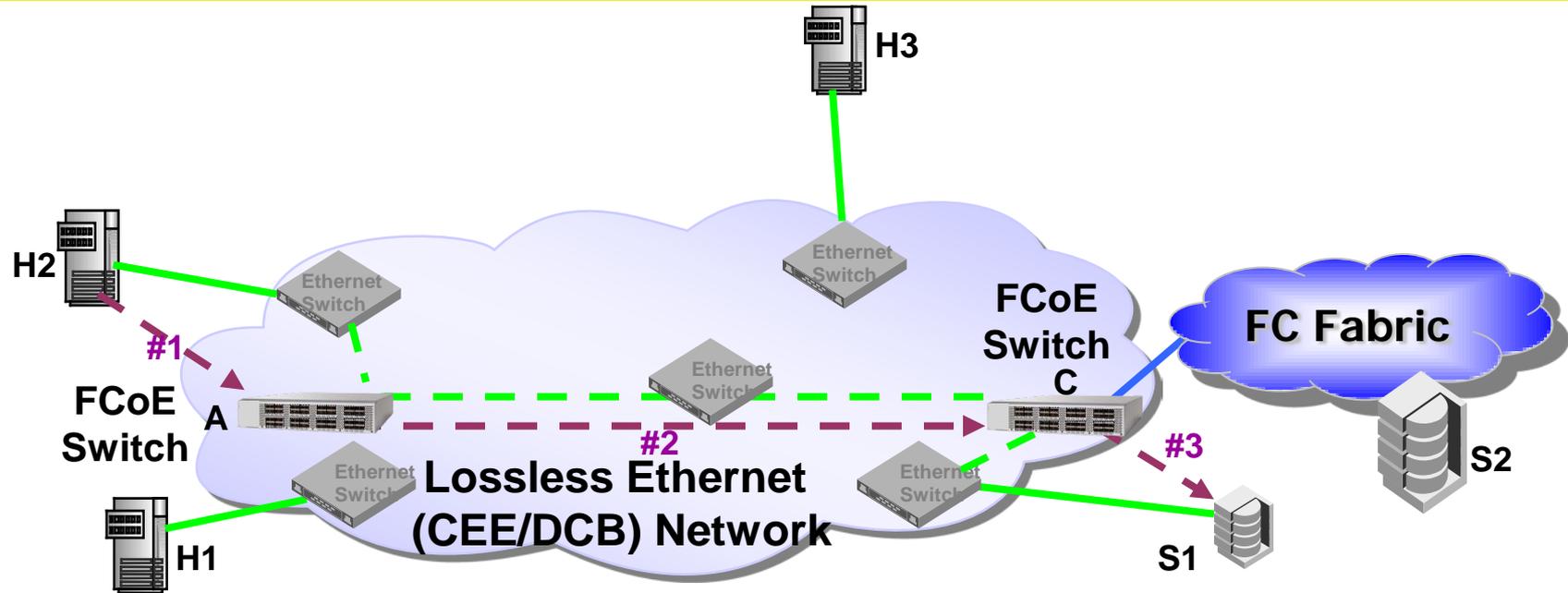
An FCoE Switch receives FCoE frames addressed to its FC-MAC address and forwards them based on the D_ID of the encapsulated FC frame



An FCoE Switch rewrites the SA and DA of an FCoE frame

	Path #1	Path #2	Path #3	Path #4
Ethernet Destination & Source	FCoE-A MAC	FCoE-B MAC	FCoE-C MAC	FCoE-S1 MAC
	FCoE-H2 MAC	FCoE-A MAC	FCoE-B MAC	FCoE-C MAC
Encapsulated FC Frame				
D_ID	FC_ID for S1	FC_ID for S1	FC_ID for S1	FC_ID for S1
S_ID	FC_ID for H2	FC_ID for H2	FC_ID for H2	FC_ID for H2

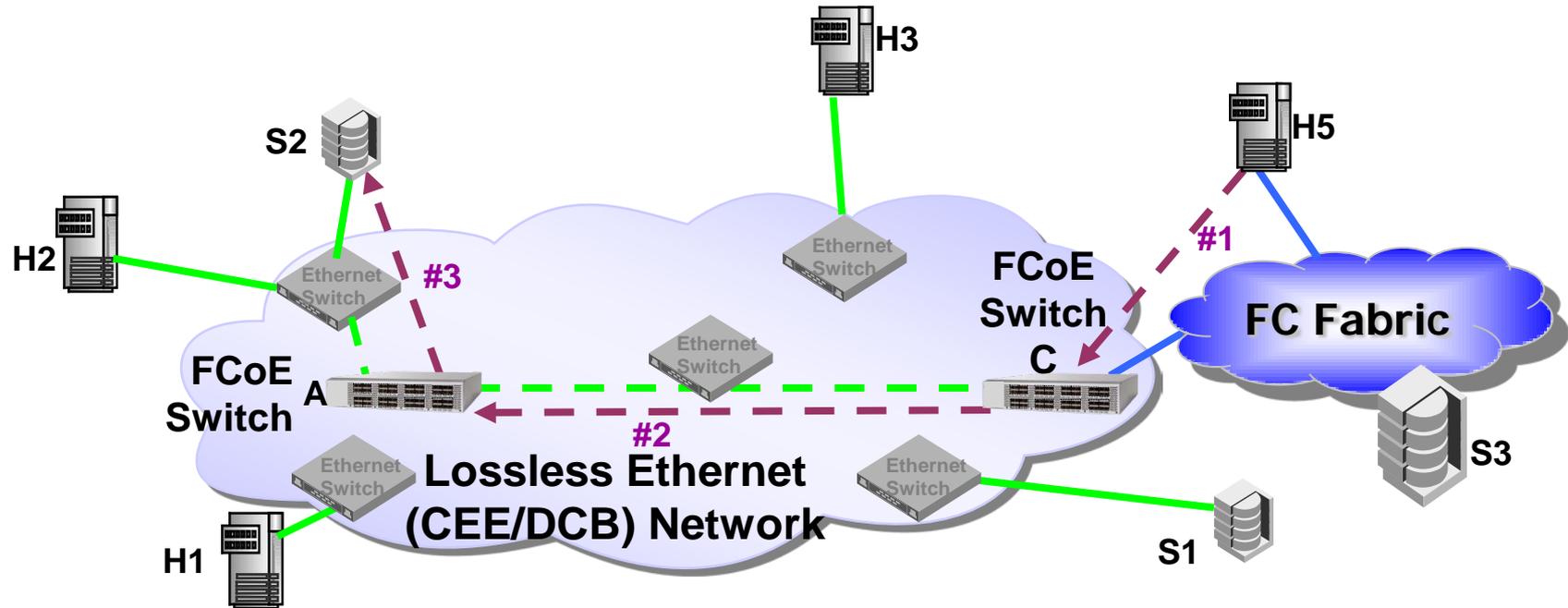
Single Ethernet Fabric with FCoE Switches



	Path #1	Path #2	Path #3
Ethernet Destination & Source	FCoE-A MAC	FCoE-C MAC	FCoE-S1 MAC
	FCoE-H2 MAC	FCoE-A MAC	FCoE-C MAC
Encapsulated FC Frame			
D_ID	FC_ID for S1	FC_ID for S1	FC_ID for S1
S_ID	FC_ID for H2	FC_ID for H2	FC_ID for H2



FC Host to FCoE Storage

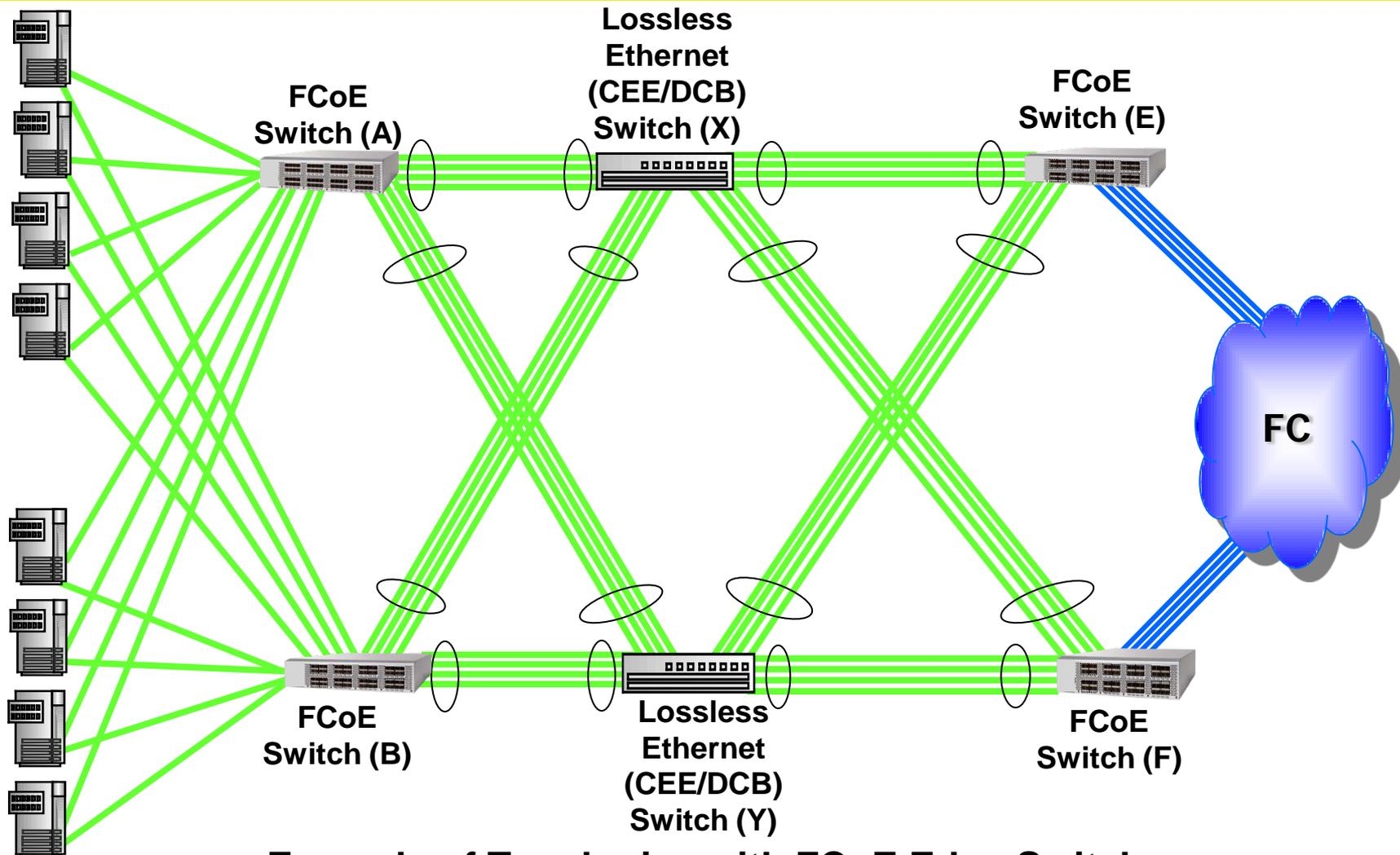


	Path #3	Path #2	Path #1
Ethernet Destination & Source	FCoE-S2 MAC	FCoE-A MAC	
	FCoE-A MAC	FCoE-C MAC	
Encapsulated FC Frame			
D_ID	FC_ID for S2	FC_ID for S2	FC_ID for S2
S_ID	FC_ID for H5	FC_ID for H5	FC_ID for H5



Additional Topologies

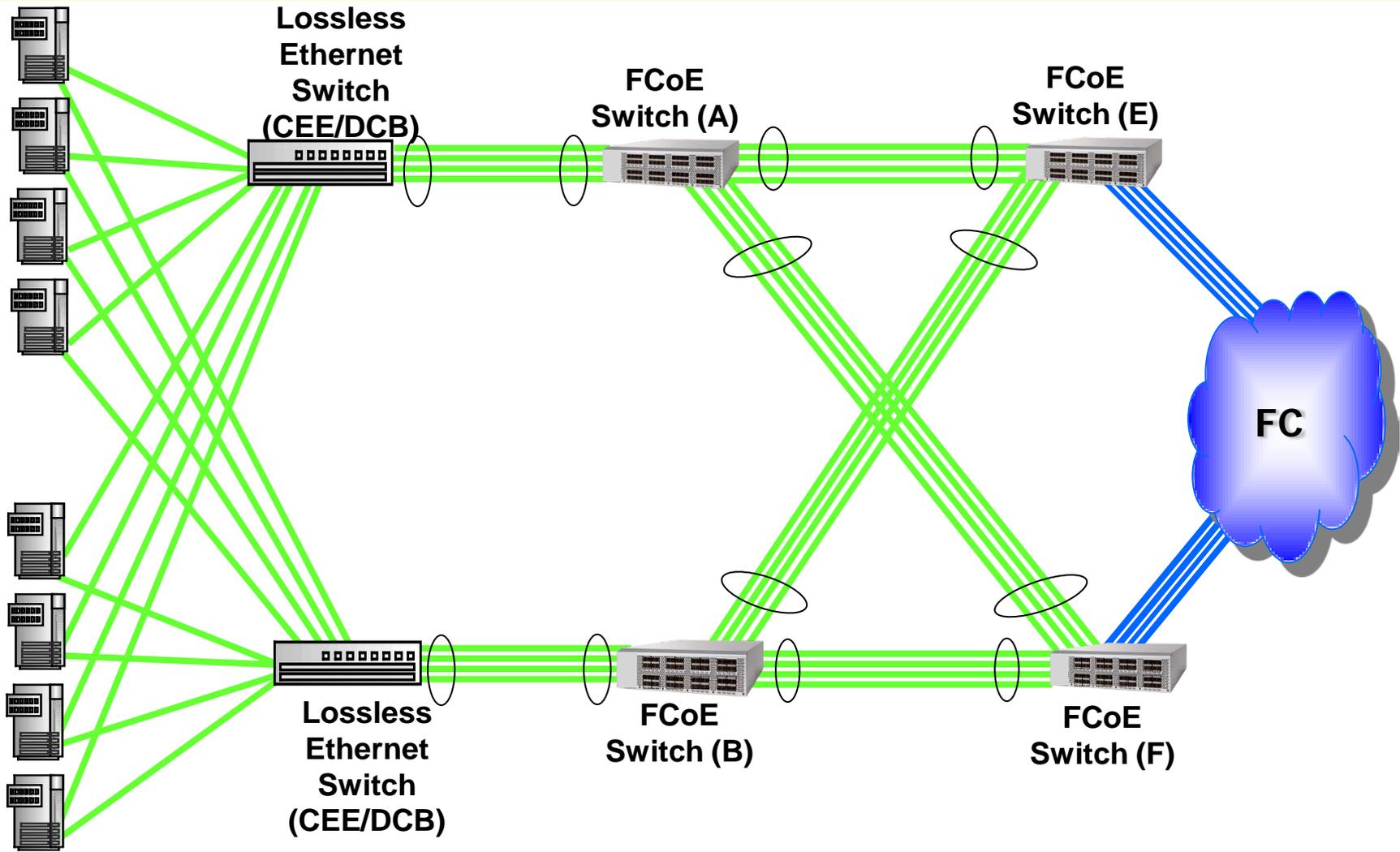
Additional Topologies (1)



Example of Topologies with FCoE Edge Switches



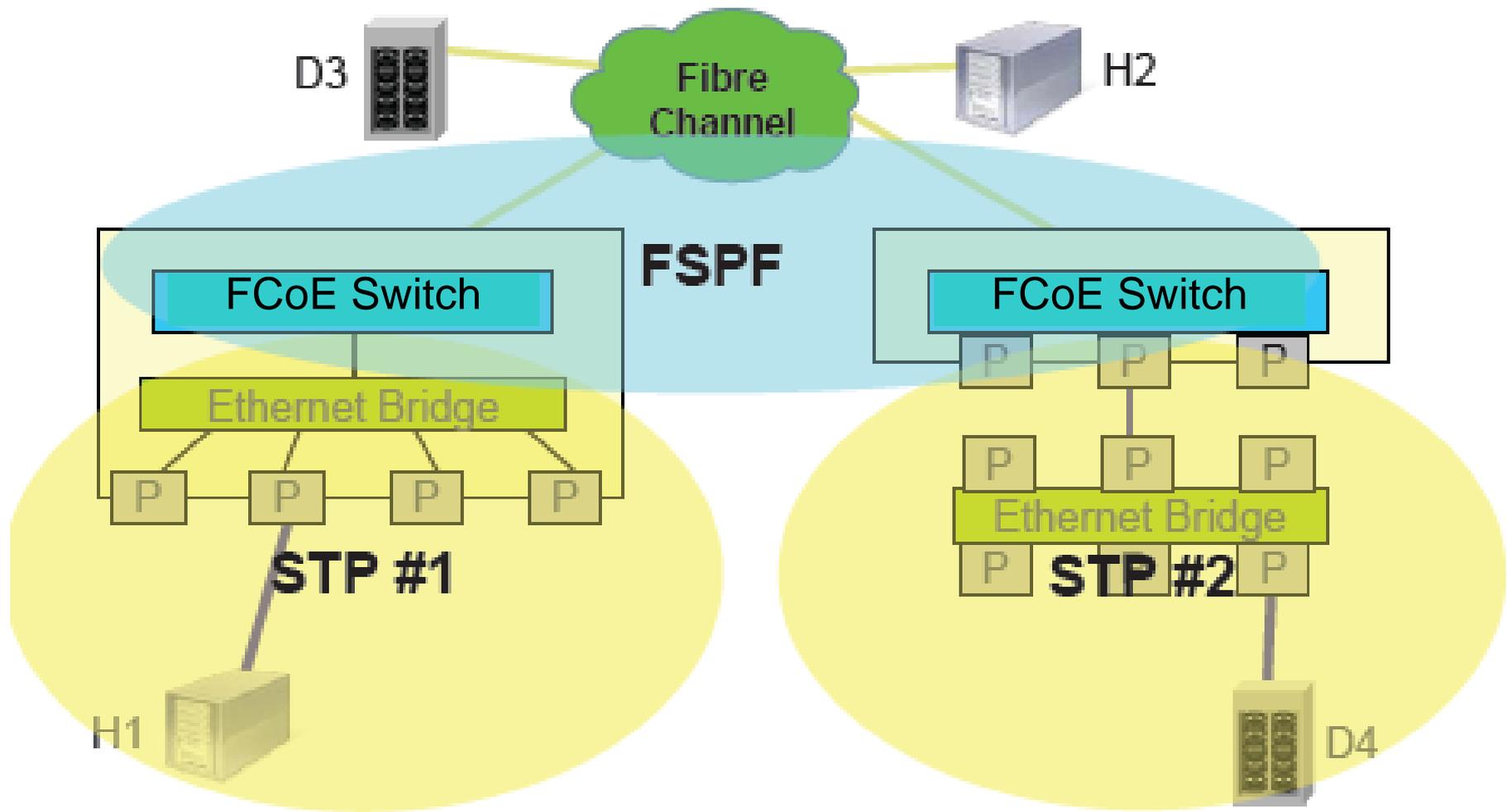
Additional Topologies (2)



Example of Topologies with CEE/DCB Edge Switches

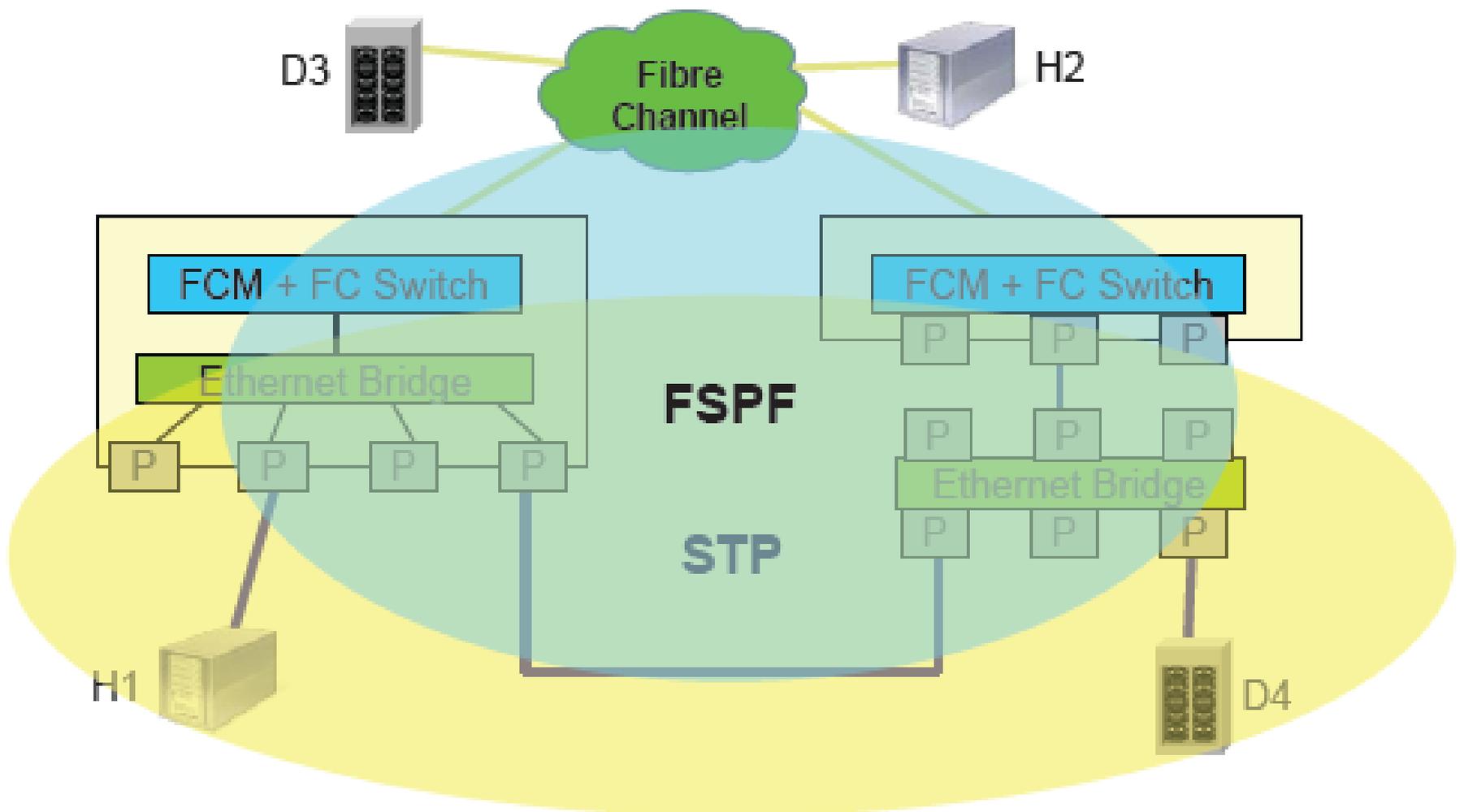
FSPF and STP

FSPF & STP Concepts with FCoE (basic)

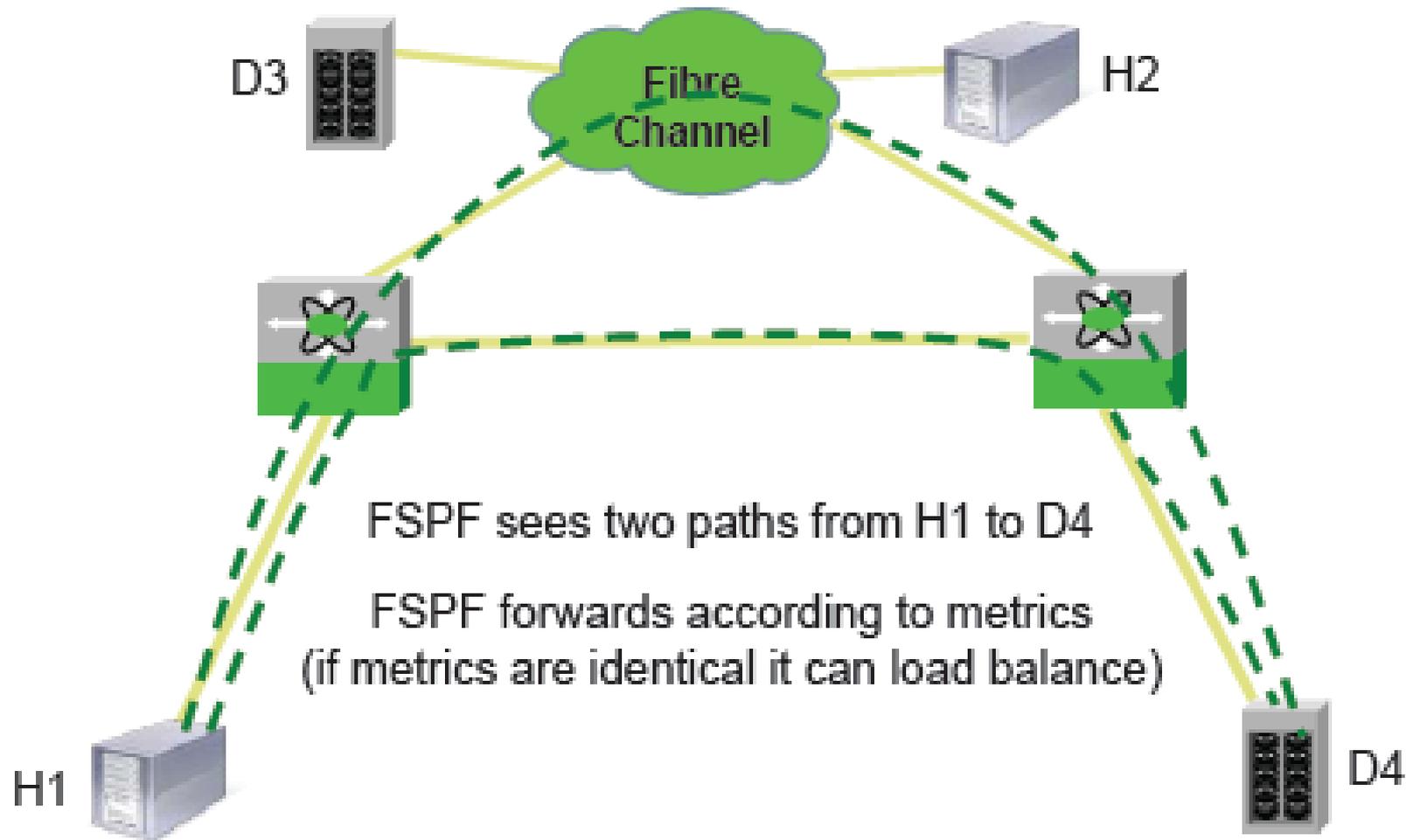




FSPF & STP Concepts with FCoE (Interconnected)



Equivalent FC Topology



FIP Considerations and Actions

VLAN Determination

- There may need to be a dynamic determination of what VLANs can be used for FCoE operations
 - ◆ But this is optional -- the FIP VLAN discovery protocol is not needed if these VLANs are already known or if VLANs are not used
 - ◆ Expect this to be administratively determined
- But if dynamic VLAN information is needed:
 - ◆ FCFs will issue a VLAN information “Request” to other FCFs
 - › Sent via a Multicast to “All_FCF_MACs”
 - › Receiving FCF VE_Port capable MACs will respond with a Unicast “Notification” which contains a list of VLANs that can be used
 - The receiving FCF VE_Port may use one or more of these VLANs
 - ENodes will issue a VLAN information “Request”
 - › Sent via a Multicast to “All_FCF_MACs”
 - › Receiving FCF VF_Port capable MACs will respond with a Unicast “Notification” which contains a list of VLANs that can be used
 - The ENode may use one or more of these VLANs

- ◆ After VLANs, if any, are determined, the discovery process uses two types of messages, **Solicitations** and **Advertisements**

- ◆ This part of the FIP Discovery Phase helps define the FCF Ports that are available for the Link instantiation Phase

- ◆ The ENodes discover the FCF ports that can become VF_Ports and FCFs discover other FCF ports that can become VE_Ports
 - ◆ ENodes Solicit (via Multicast of “All-FCF-MACs”) Advertisements from FCFs while specifying their capabilities
 - ◆ In response FCFs Advertise (via Jumbo Unicast) their VF_Port capable MACs availability and capabilities back to the soliciting ENode
 - ◆ FCF Multicast (to “All-FCF-MACs”) their VE_Port capable MACs existence to other FCFs

- ◆ Sometimes a New FCF will come on line and Multicast its availability to “ALL_ ENode_MACs” and “All_FCF_MACs”

- ◆ The FIP Discovery phase exchanges solicitation and/or Advertisements between (HBA’s and/or FCF’s) **“FCoE Controllers”**

FCF Discovery Actions

An FCF supporting VE_Ports:

- Discovers other VE_Port capable FCF-MACs, connected to the same Lossless Ethernet segment, by:
 - ◆ Transmitting a multicast Solicitation to ‘All-FCF-MACs’
(with the FCF bit set to one)
 - ◆ Receiving back Jumbo Unicast Advertisements from VE capable MACs
 - › Which also verifies the support of Ethernet Jumbo frames in the path
 - ◆ Sending Jumbo Unicast Advertisements from its own VE capable MACs
 - › In response to receipt of a Multicast to “All-FCF-MACs” from another FCF VE_Port
- Instantiates VE_Port to VE_Port connections and Exchanges FC ELP (Extended Link Protocol) and Fabric configuration (using Ethertype=FIP) with the other FCFs VE_Port capable MACs

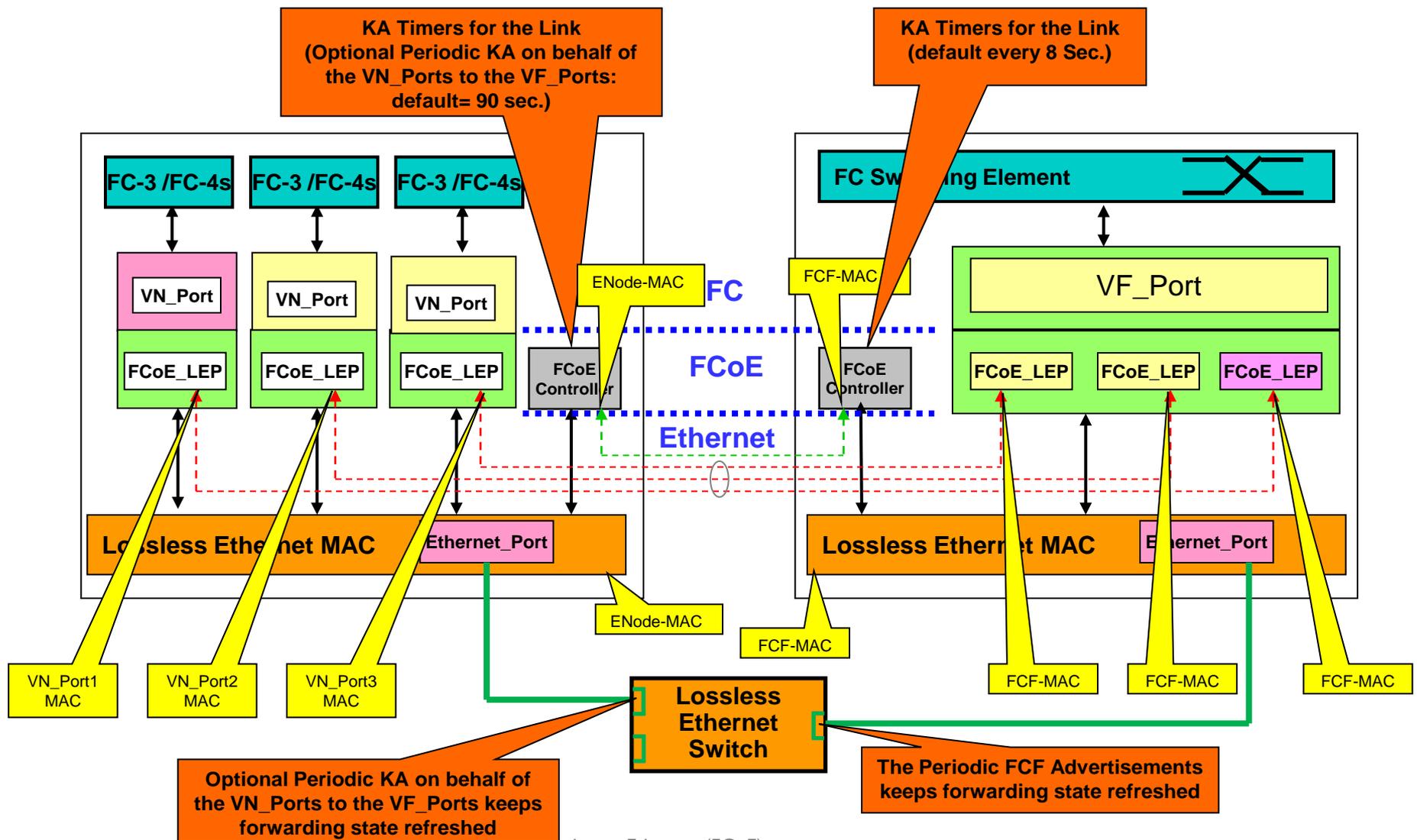
ENode Actions

- When an ENode becomes operational:
 - ◆ The ENode discovers the VF_Port capable FCF-MACs connected to the same Lossless Ethernet segment by:
 - › Transmitting a multicast Solicitation to 'All-FCF-MACs' (with the FCF bit set to zero)
 - › Receiving back Jumbo Unicast Advertisements from compatible VF_Port capable FCF-MACs
 - (May store the discovered FCF-MACs in an FCF port list)
- When an ENode receives an Advertisement that a new FCF port is available, it may send a Unicast Solicitation to it and receive a Jumbo Unicast Advertisement in reply
 - ◆ To verify the support of Ethernet Jumbo frames in the path
- May then perform FLOGIs (with Ethertype=FIP) to a vendor specific subset of the FCF-MACs in the FCF port list

- FCoE connections may not be directly attached to the FCF
 - ◆ May flow through intermediate Lossless Ethernet switches,
 - ◆ Needs to be a method to detect that something was wrong in the path
 - › Between VN_Ports and VF_Ports as well as between VE_Ports
- Timers connected to the ENodes & FCFs can determine that a port is sending messages
- Need to determine if a port is just dormant, but still alive
 - ◆ Therefore, a periodic message needs to be sent.
- The periodic unsolicited Advertisements from the FCF can be used for Keep Alive in the following directions
 - ◆ FCF → ENode
 - ◆ FCF ↔ FCF
- But something else is needed for the ENode → FCF direction
 - ◆ Because there is no periodic unsolicited Advertisement from an ENode
- So -- a special FIP Keep Alive Message was created to just inform the FCF that the ENode and its VN_Ports are still alive



FIP KAs (Keep Alives) & the FCoE Controllers



FIP Clear Virtual Link

- When a port connection is determined by a side to be not functional
 - ◆ There is a requirement for the side to attempt to clear all state,
 - › (Especially state which may have been established in any intermediate switches)

- The VN_Port can issue a FIP Logout (LOGO)

- But if the ENode is dead or its link busted, the FCF needs to clear things on its own

- But there is no FC capability for a FC switch to Logout a N_Port
 - ◆ So -- a special FIP function was created called **Clear Virtual Link**
 - › Can be issued by the FCF
 - ◆ When intermediate switches see this frame they should cleanup their ACLs etc.

FIP Descriptors



FIP Operation Codes

Operation Code	Subcode	Operation
0001h	01h	Discovery, Solicitation
	02h	Discovery, Advertisement
0002h	01h	FLOGI/FDISC/LOGO/ELP, Request
	02h	FLOGI/FDISC/LOGO/ELP, Reply
0003h	01h	FIP Keep Alive
	02h	FIP Clear Virtual Link
0004h	01h	FIP VLAN Request
	02h	FIP VLAN Notification
FFF8h .. FFFEh	00h .. FFh	Vendor Specific
All others	All others	Reserved

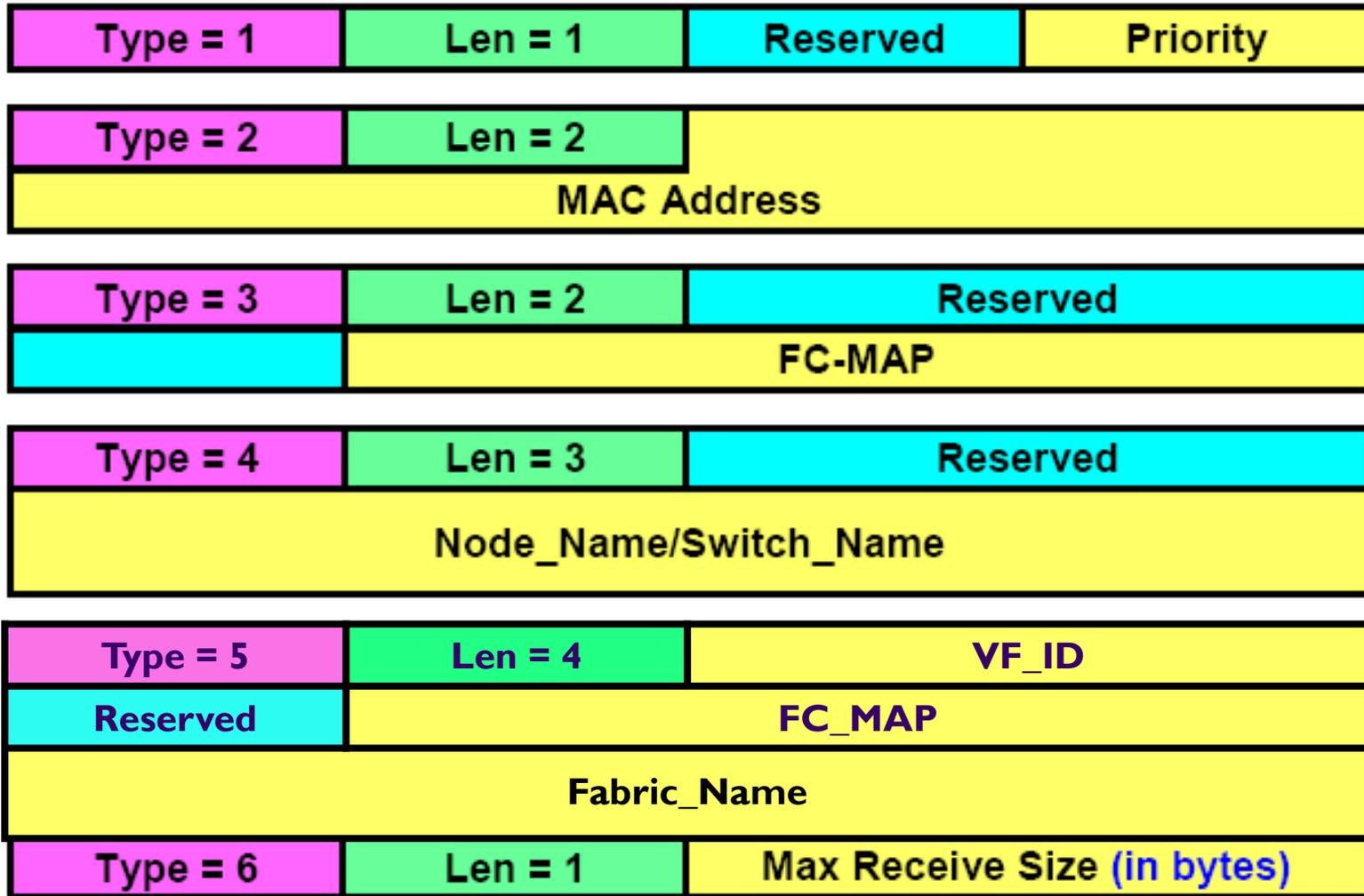


Type and Values of FIP Descriptors

Type	Value
00	Reserved
01	Priority
02	MAC Address
03	FC-MAP
04	Node_Name / Switch_Name
05	Fabric
06	Max FCoE Size
07	FLOGI
08	NPIV FDISK

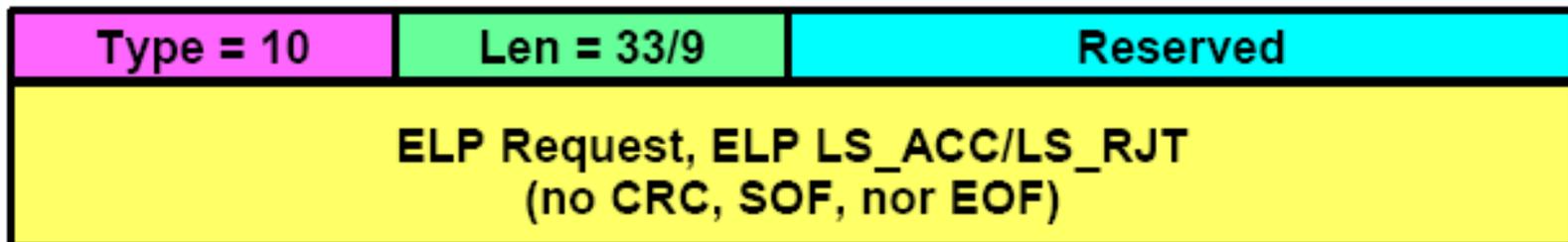
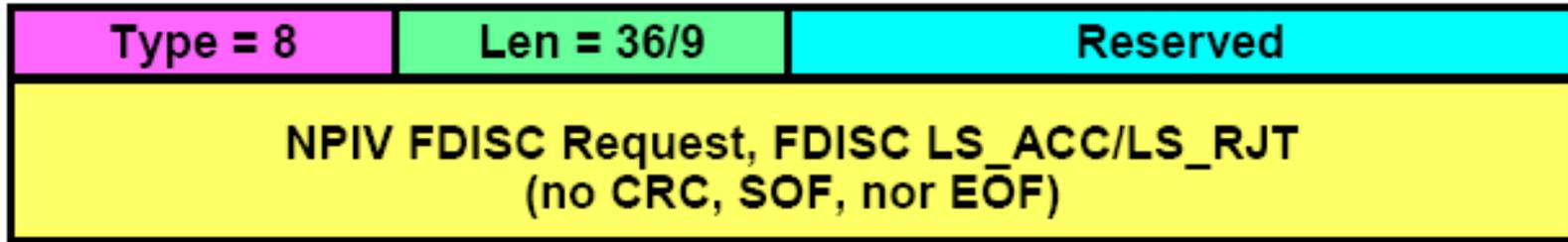
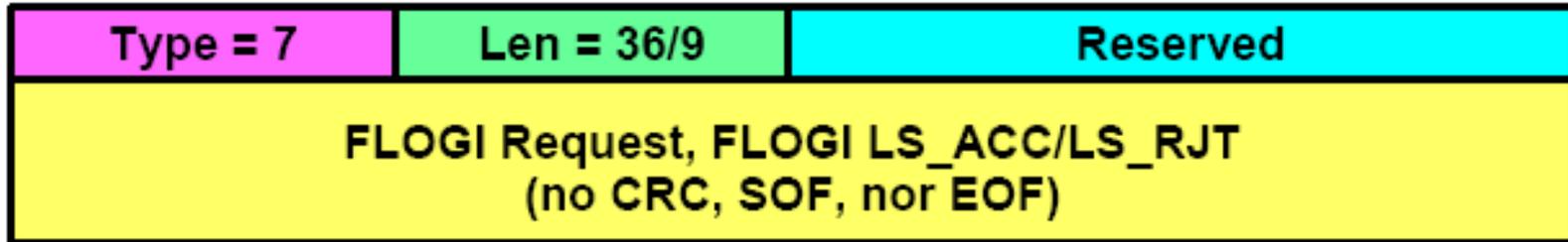
Type	Value
09	Fabric Log Out
10 (0Ah)	ELP
11 (0Bh)	VN_Port ID
12 (0Ch)	FKA_ADV_Period
13 (0Dh)	Vendor ID
14 (0Eh)	VLAN
15 (0Fh) – 240 (F0h)	Reserved (128-240 are Non Critical)
241 (F1h) – 254 (FEh)	Vendor Specific
255 (FFh)	Reserved

FIP Descriptors (1)



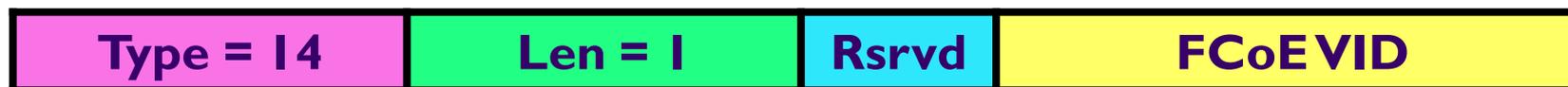
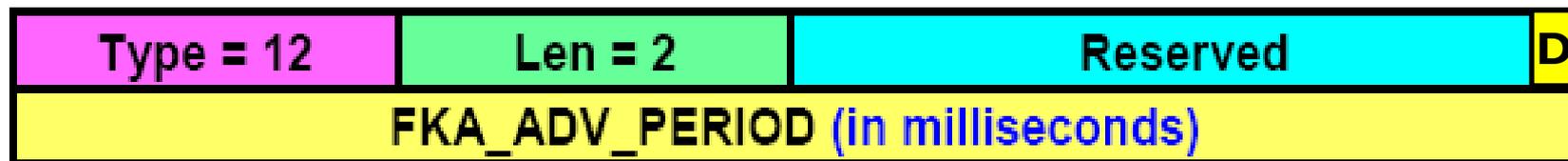
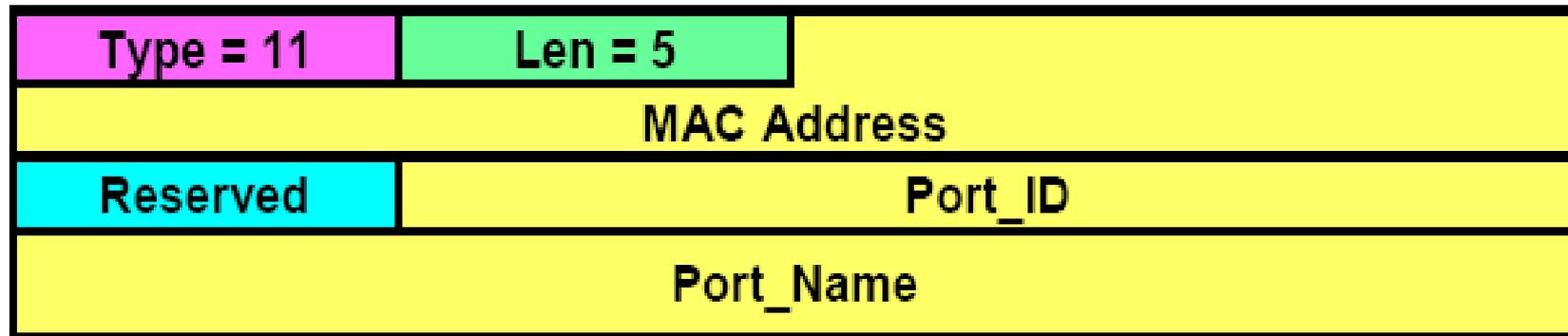
Lengths are measured in 32-bit words

FIP Descriptors (2)



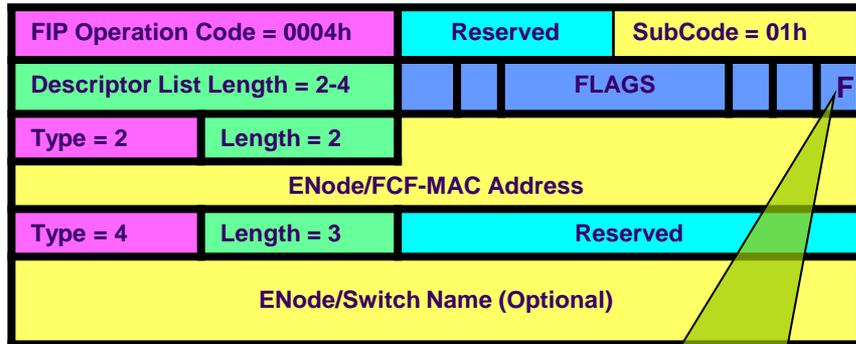


FIP Descriptors (3)



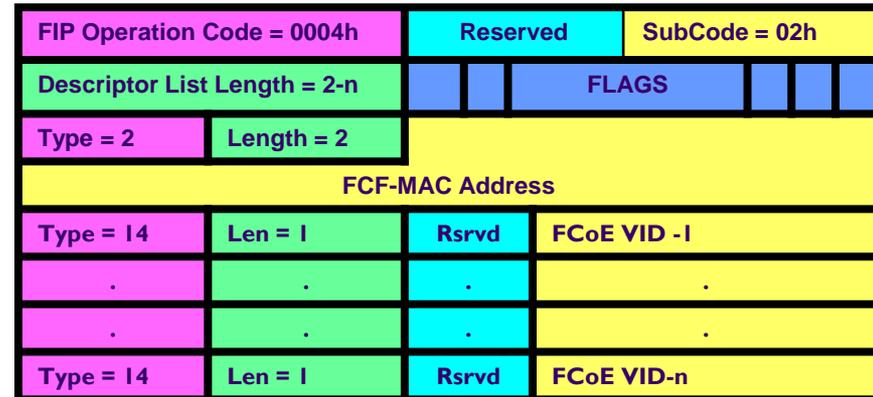
VLAN Request & Notification

VLAN Request ENode/FCF → FCF



F = 1b to indicate that the request is sent by a VE_Port capable FCF-MAC

VLAN Notification FCF → FCF/ENode



Solicitation ENode → FCF

ENode Capabilities:
FP = 1 if FPMA supported
SP = 1 is SPMA supported

F = 0b

FIP Operation Code = 0001h	Reserved	SubCode = 01h
Descriptor List Length = 6	FP	SP
Type = 2	Len = 2	Flags
ENode's MAC Address		
Type = 4	Len = 3	Reserved
Node_Name		
Type = 6	Len = 1	Max Receive Size

Advertisement

FCF Capabilities:
FP = 1 if FPMA supported
SP = 1 if SPMA supported

A = 1b if FCF available for Login/ELP

F = 1b

FIP Operation Code = 0001h	Reserved	SubCode = 02h
Descriptor List Length = 12	FP	SP
Type = 1	Len = 1	Reserved
Type = 2	Len = 2	Priority
FCF-MAC Address		
Type = 4	Len = 3	Reserved
Switch_Name		
Type = 5	Len = 4	VF_ID
Reserved	FC_MAP	
Fabric_Name		
Type = 12	Len = 2	Reserved
FKA_ADV_Period		
Padding to Max Receive Size of Soliciting Entity, if Solicited (i.e. if S=1b, otherwise no padding)		

Solicitation FCF → FCF

FIP Operation Code = 0001h	Reserved	SubCode = 01h
Descriptor List Length = 8	FLAGS	
Type = 2	Length = 2	FCF-MAC Address
Type = 3	Length = 2	Reserved
Reserved	FC-MAP	
Type = 4	Length = 3	Reserved
Switch Name		
Type = 6	Length = 1	Max Receive Size

F = 1b to indicate that the Solicitation is sent by a VE_Port capable FCF-MAC (i.e., it is soliciting VE_Port capable FCF-MACs)

FIP FLOGI

FP = 1 if FPMA requested, or
SP = 1 if SPMA requested

FP = 1 if FPMA granted, or
SP = 1 if SPMA granted

FIP Operation Code = 0002h	Reserved	SubCode = 02h
Descriptor List Length = 38	F S P P	Flags
Type = 7	Len = 36	Reserved
FLOGI LS_ACC (no CRC, SOF, nor EOF)		
Type = 2	Len = 2	
Granted MAC Address		

Accept (FCF → ENODE)

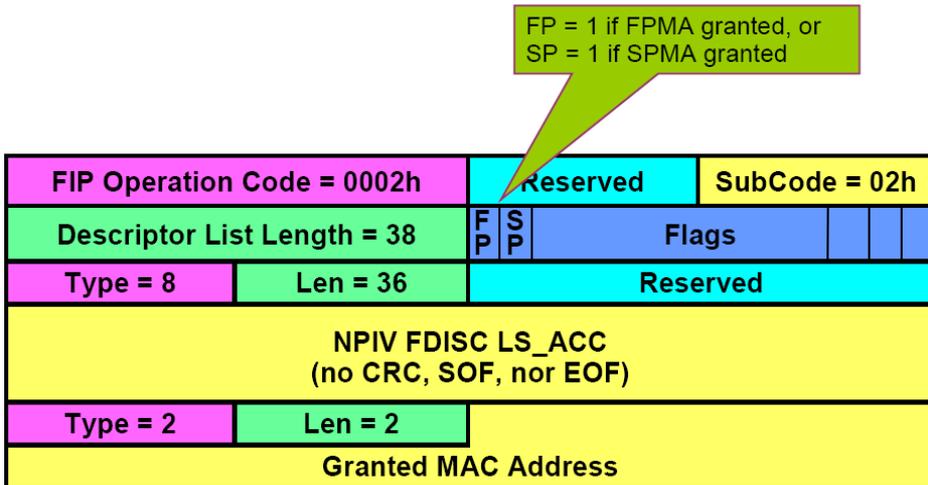
FIP Operation Code = 0002h	Reserved	SubCode = 01h
Descriptor List Length = 38	F S P P	Flags
Type = 7	Len = 36	Reserved
FLOGI Request (no CRC, SOF, nor EOF)		
Type = 2	Len = 2	
Proposed MAC Address		

Request (ENODE → FCF)

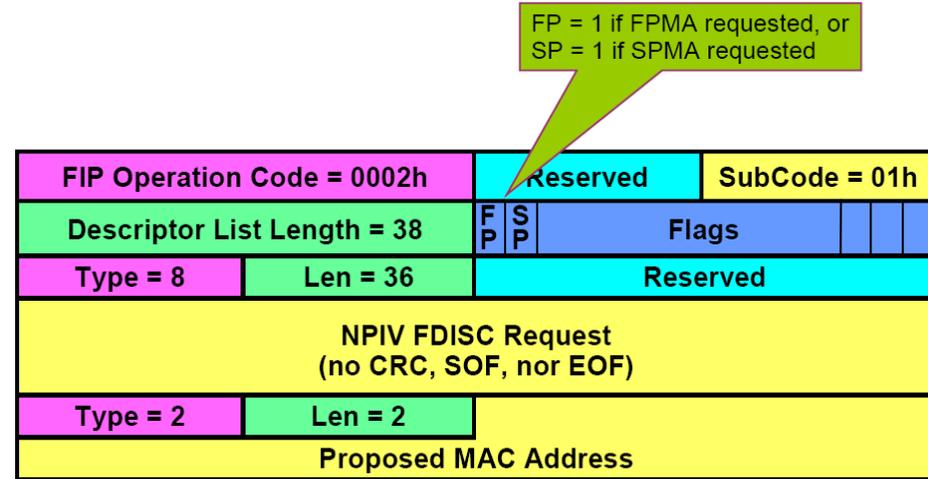
Reject (FCF → ENODE)

FIP Operation Code = 0002h	Reserved	SubCode = 02h
Descriptor List Length = 9		Flags
Type = 7	Len = 9	Reserved
FLOGI LS_RJT (no CRC, SOF, nor EOF)		

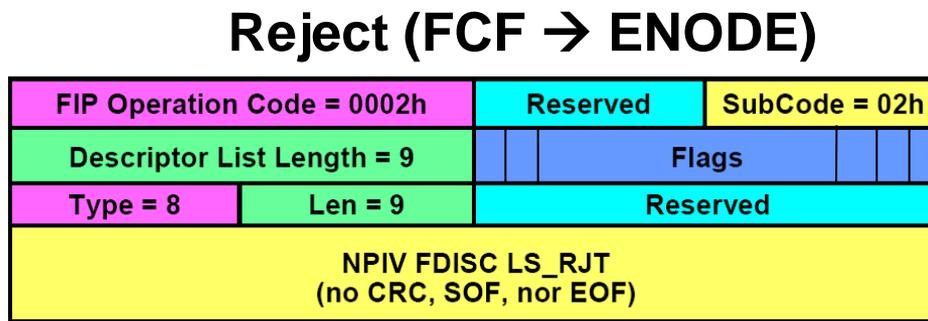
FIP NPIV FDISC



Accept (FCF → ENODE)

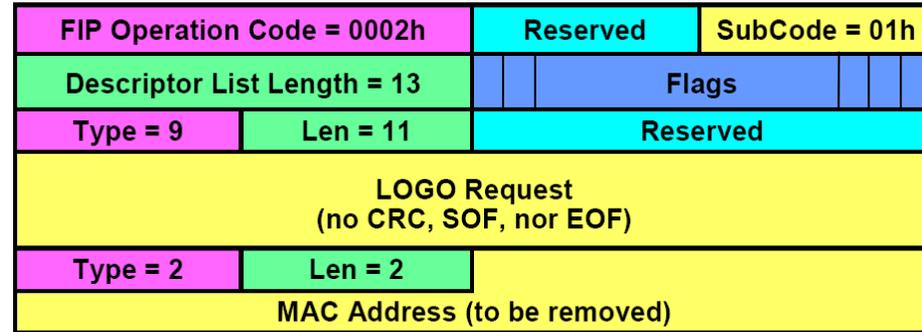


Request (ENODE → FCF)

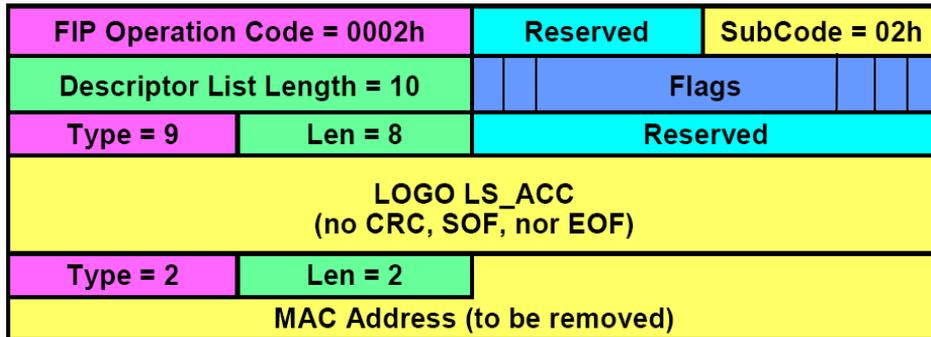


Reject (FCF → ENODE)

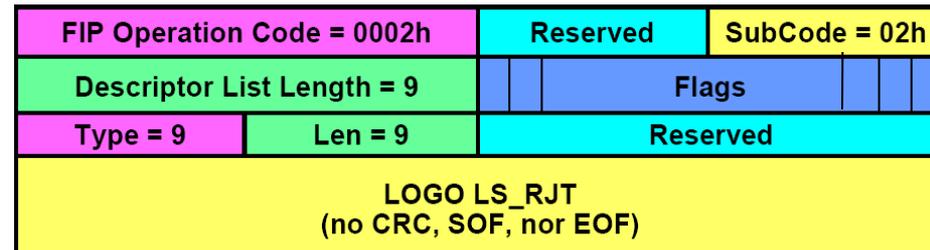
FIP Fabric LOGO



Request (ENODE → FCF)



Accept (FCF → ENODE)



Reject (FCF → ENODE)

FIP Operation Code = 0002h	Reserved	SubCode = 01h
Descriptor List Length = 35	Flags	
Type = 10	Len = 33	Reserved
ELP Request (no CRC, SOF, nor EOF)		
Type = 2	Len = 2	
MAC Address (to be used)		

Request (FCF \leftarrow \rightarrow FCF)

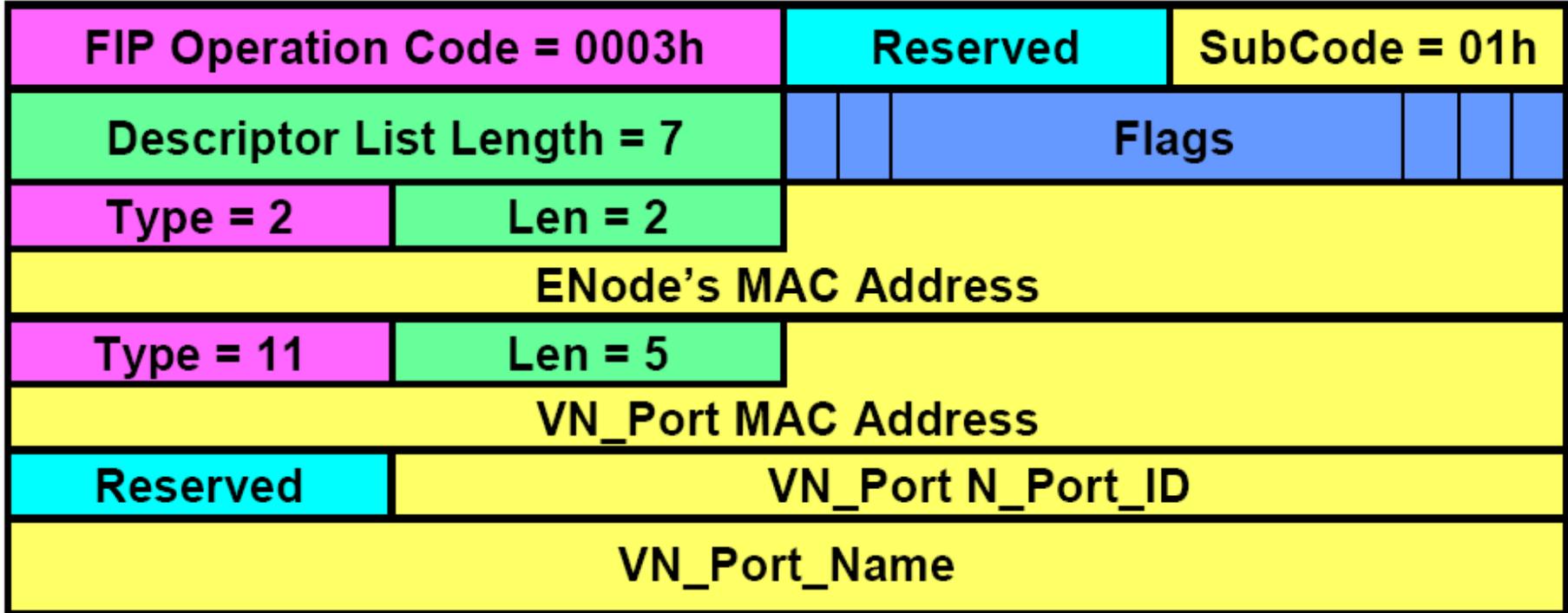
FIP Operation Code = 0002h	Reserved	SubCode = 02h
Descriptor List Length = 35	Flags	
Type = 10	Len = 33	Reserved
ELP SW_ACC (no CRC, SOF, nor EOF)		
Type = 2	Len = 2	
MAC Address (to be used)		

Accept (FCF \leftarrow \rightarrow FCF)

Reject (FCF \leftarrow \rightarrow FCF)

FIP Operation Code = 0002h	Reserved	SubCode = 02h
Descriptor List Length = 9	Flags	
Type = 10	Len = 9	Reserved
ELP SW_RJT (no CRC, SOF, nor EOF)		

FIP Keep Alive



ENode → FCF

(The Keep Alive from the FCF → ENode/FCF is a normal unsolicited Advertisement)

FIP Clear Virtual Link

FIP Operation Code = 0003h		Reserved	SubCode = 02h
Descriptor List Length = ...		Flags	
Type = 2	Len = 2	FCF-MAC Address	
Type = 4	Len = 3	Reserved	
Switch_Name			
Type = 11	Len = 5	VN Port #1 MAC Address	
Reserved	VN Port #1 N Port ID		
VN_Port_Name #1			
...			
Type = 11	Len = 5	VN Port #n MAC Address	
Reserved	VN Port #n N Port ID		
VN_Port_Name #n			

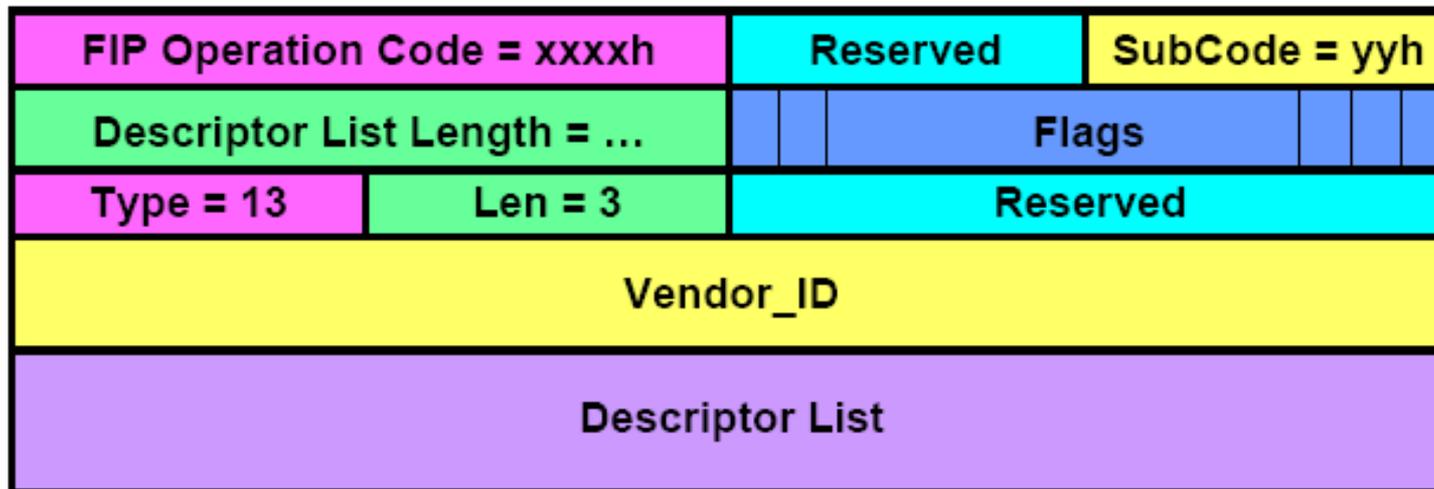
FIP Operation Code = 0003h		Reserved	SubCode = 02h
Descriptor List Length = 10		Flags	
Type = 2	Len = 2	Source FCF-MAC Address	
Type = 4	Len = 3	Reserved	
Source Switch_Name			
Type = 11	Len = 5	Destination FCF-MAC Address	
Reserved	FFFFFDh (Fabric Controller)		
Destination VE_Port_Name			

FCF ← → FCF

FCF → ENODE

(Note: the ENode uses FIP Fabric LOGO to Clear the Virtual Link from its side)

Vendor Specific FIP Message



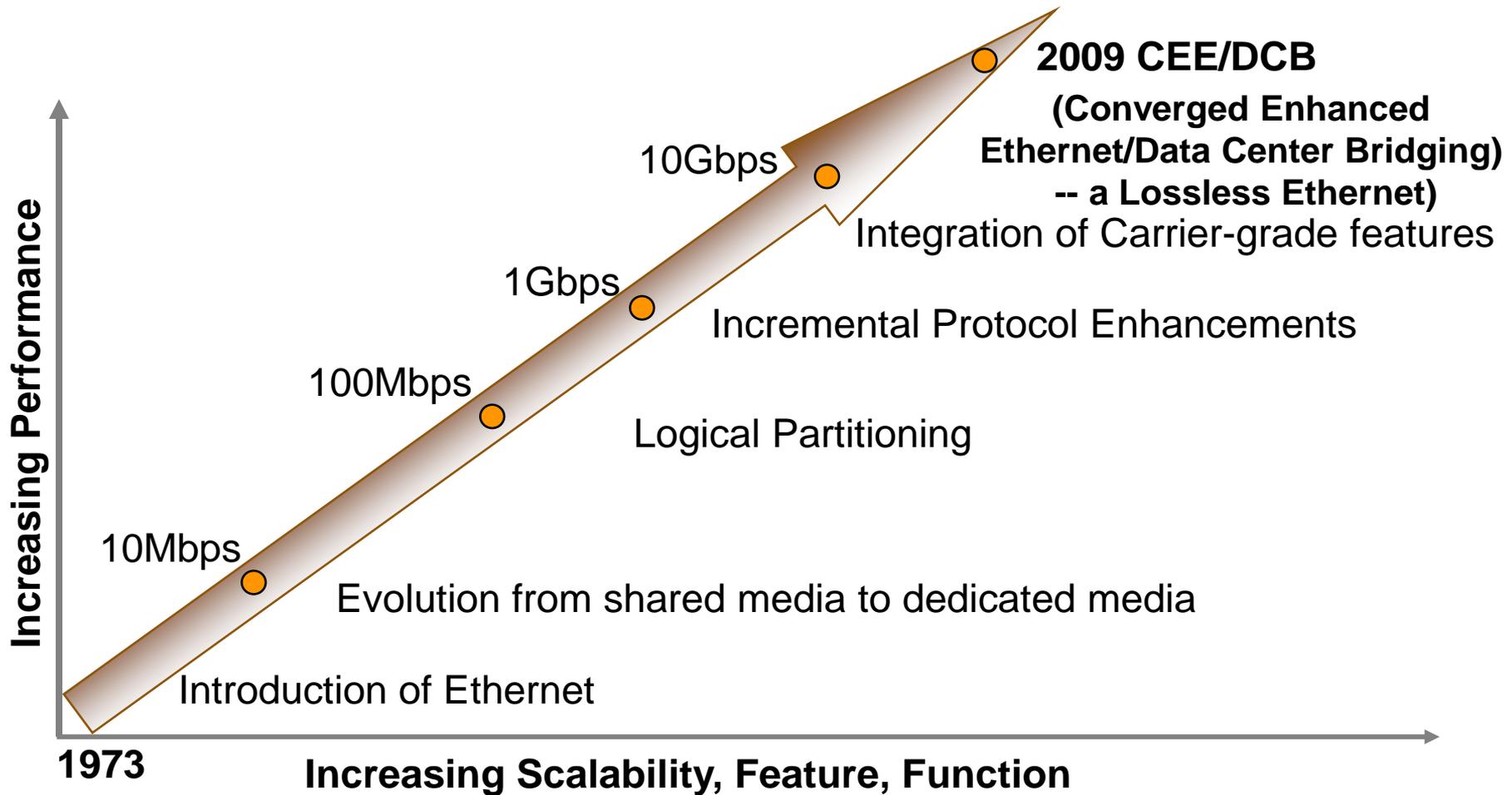
- An unknown Vendor Specific message shall be ignored
Normal operation will be the result
- A device is never required to generate a Vendor Specific message for normal operation

Vendor Specific Operation Code = FFF8 -- FFFE with any SubCode
Vendor Specific Type (in Descriptor List) = F1h – FEh
Reserved Types = 0Fh – F0h, & FFh

Pause vs. BB_Credit

- Both mechanisms are used to avoid dropping frames
 - ◆ With different trade-offs
- The Pause mechanism requires at least the $(2 \times \text{RTT} \times \text{bandwidth})$ product on a link as buffer space
 - ◆ But allows Buffer handling in an arbitrary way
 - ◆ Well suited for networks with limited (bandwidth x delay) product (e.g. within the data center)
- The Pause frame is handled by the MAC layer
 - ◆ Similar to the R_RDY handling by the FC-I level
- The BB_Credit mechanism prevents losing frames over any link
 - ◆ But links go under-utilized if link credits (& buffers) are $<$ that needed for $(\text{RTT} \times \text{BW})$
 - ◆ Requires buffer handling in maximum frame size units

The Origins of a Data Center Fabric



- *The technology has evolved continuously, showing a great ability to adapt to new technologies and increasing business requirements*