4 FC-BB-5 Structure and Concepts

4.1 FC-BB-5 backbone mappings

FC-BB-5 models (i.e., FC-BB_IP, FC-BB_GFPT, FC-BB_PW, and FC-BB_E), specified in this standard, define equipment capable of carrying Fibre Channel over different network technologies.

~~FC-BB-5 models (i.e., FC-BB_IP, FC-BB_GFPT, and FC-BB_PW), specified in this standard, define equipment capable of extending Fibre Channel switched networks and/or links over Wide Area Network infrastructures and over distance. One important distinction among the models discussed in this standard is the emphasis placed on the WAN type.~~

The FC-BB_IP model uses TCP connections over IP networks. The FC-BB_GFPT model makes use of the Asynchronous Transparent Generic Framing Procedure (GFPT) (see ITU-T Rec. G.7041/Y.1303). GFPT may be used for adaptation to different transport facilities including SONET, SDH, OTN and PDH. Details regarding the mapping of GFPT-adapted traffic to such transport facilities are elaborated in various ITU-T standards (see 2.4). The FC-BB_PW model uses PW connections over MPLS networks. The FC-BB_E model uses Lossless Ethernet links (i.e., full duplex Ethernet links extended to become lossless, see 4.4.4).

A second important distinction among the mappings discussed in this standard relates to supported architectures (i.e., network and/or link topologies) and the place of the defined devices within them. FC-BB_IP defines an FC Entity that consists of:

a) one or more Virtual E_Port (VE_Port) virtual ISL(s) that interconnect the E_Ports of external FC switches and N_Ports of external end devices; or
b) one or more B_Access virtual ISL(s) that interconnect the E_Ports of external FC switches.

The B_Access virtual ISL(s) are part Fabric bridge device with resident switch-facing interfaces called B_Ports. B_Ports have selected Fabric functions (see FC-SW-4). B_Ports are Fabric ports, and FC-BB_IP devices are components of an FC Fabric. FC-BB_IP also defines support for FC bridge devices with Fabric-facing B_Ports. However, FC-BB_IP also supports functional integration within an FC Switch. Thus FC-BB_IP devices may also have E_Ports and F_Ports.

FC-BB_GFPT and FC_BB_PW define a device that is not a component of a Fabric, and supports no Fabric functionality. Instead, it interconnects two Fibre Channel physical ports (i.e., attached FC_Ports), appearing architecturally as a wire to those ports.

FC-BB_E defines end devices (i.e., ENodes) and Fabric devices (i.e., FCFs). ENodes are Fibre Channel nodes (see FC-FS-3) able to carry Fibre Channel over Lossless Ethernet. FCFs are Fibre Channel Switching Elements (see FC-SW-5) able to carry Fibre Channel over Lossless Ethernet.

4.2 FC-BB-5 reference models

FC-BB-5 defines reference models corresponding to the FC-BB_IP, FC-BB_GFPT, FC-BB_PW, and FC-BB_E models. These reference models are shown in figure 1, figure 2, figure 3, and figure 4 respectively.

The FC-BB_IP model supports the attachment of FC switches (i.e., E_Ports) via one or more B_Ports or E_Ports and the attachment of N_Ports via one or more F_Ports. The FC-BB_GFPT and FC-BB_PW models support the attachment of N_Ports, F_Ports, and E_Ports, and the following Fibre Channel port interconnections:

a) N_Port to N_Port;

b) N_Port to F_Port; and
c) E_Port to E_Port.

The FC-BB_E model supports the operation of VN_Ports (see FC-FS-3) in ENodes and of VF_Ports and VE_Ports (see FC-SW-5) in FCFs.

Table 1 summarizes the resident FC_Port types for the different FC-BB-5 models.

Table 1 – Models and resident FC_Port types

	Reference Model			
	FC-BB_IP	**FC-BB_GFPT**	**FC-BB_PW**	**FC-BB_E**
Resident FC_Port Type(s)	B_Port, E_Port, F_Port	None (FC Physical Interface)	None (FC Physical Interface)	N_Port, E_Port, F_Port

In figure 1 (i.e., FC-BB_IP), frames destined for a remote FC network enter a B_Port, an E_Port, or an F_Port, and are forwarded on the IP network to their destination.

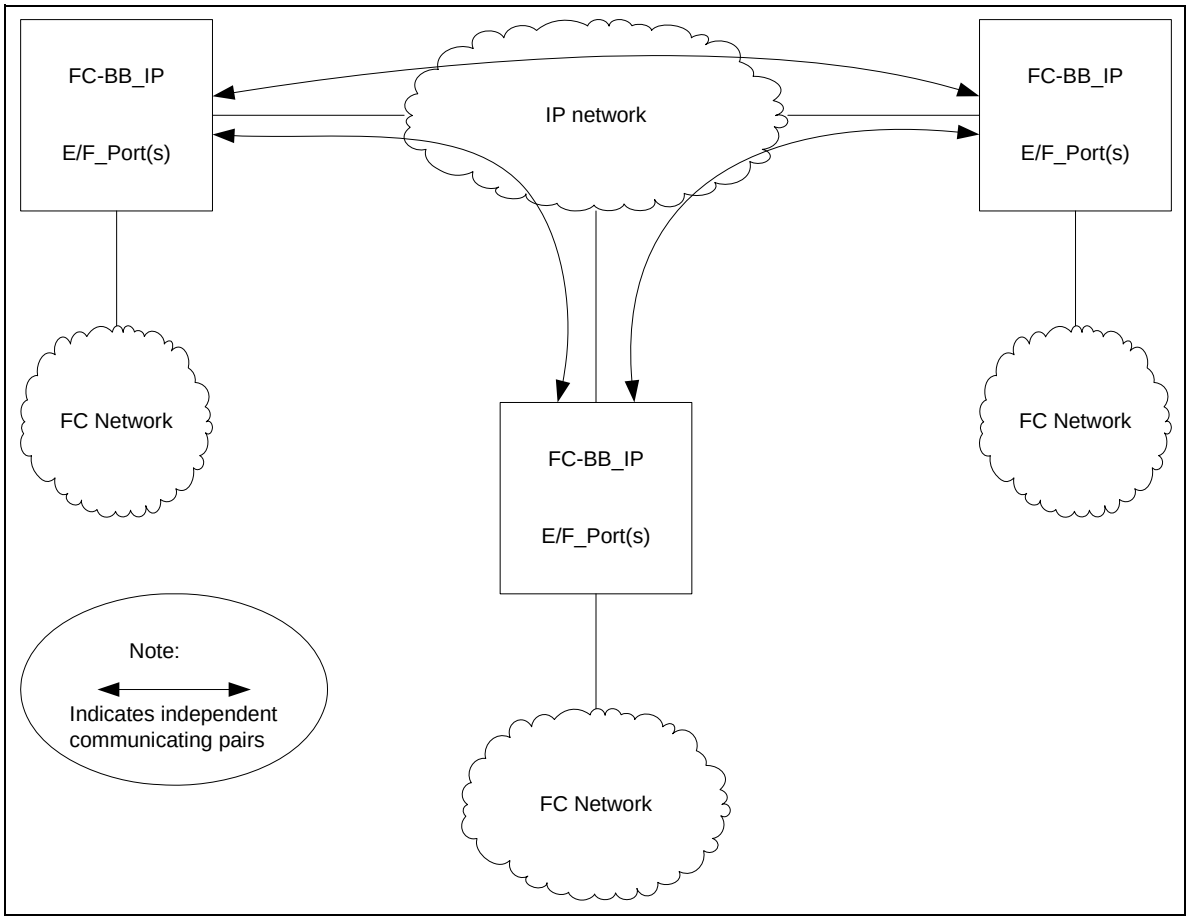

Figure 1 – FC-BB_IP reference model

In figure 2 (i.e., FC-BB_GFPT), FC physical signals (i.e., relevant 8B/10B codewords) enter an FC physical port on an FC-BB_GFPT device, and are forwarded on the SONET/SDH/OTN/PDH network to their destination.

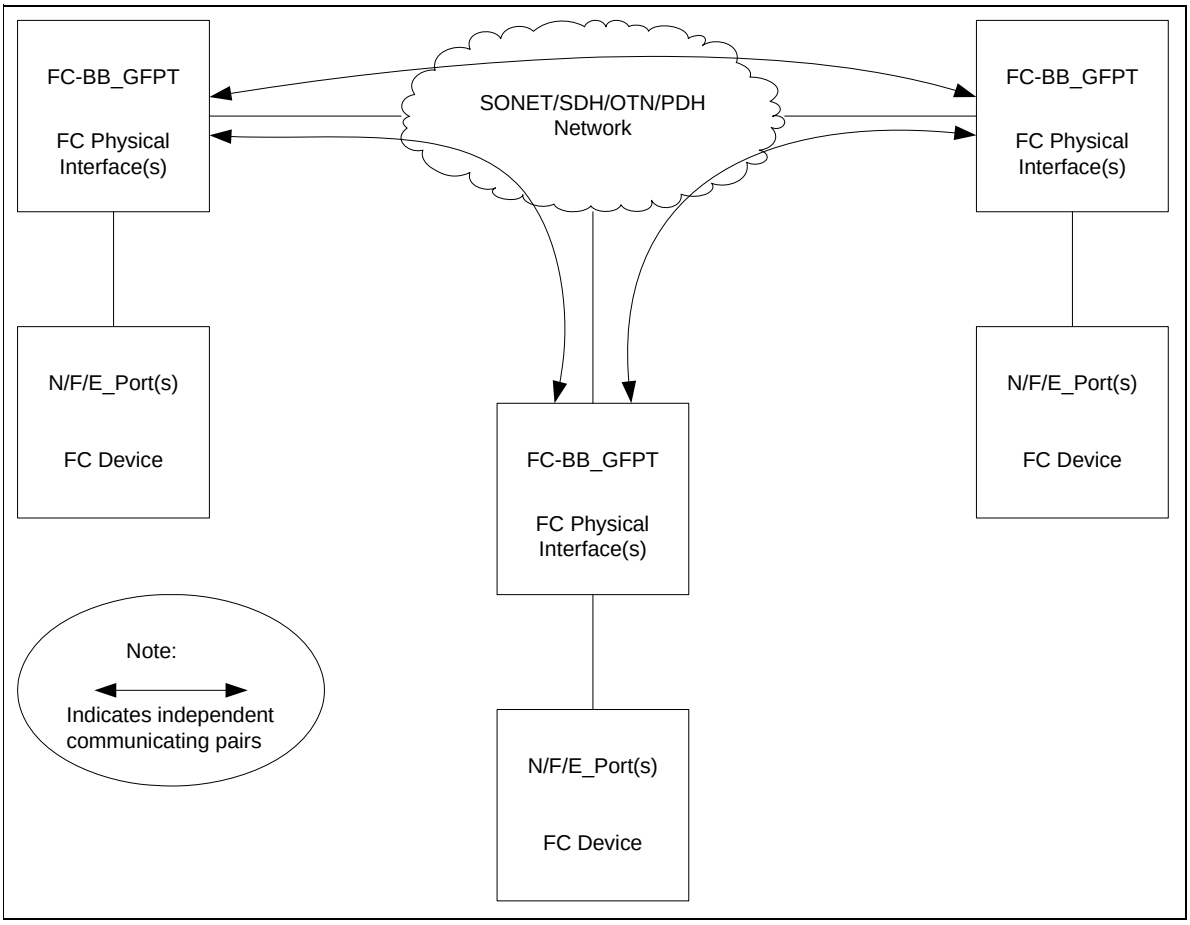

Figure 2 – FC-BB_GFPT reference model

In figure 3 (i.e., FC-BB_PW), FC physical signals enter an FC physical port on an FC-BB_PW device, and are forwarded on the PSN network to their destination.

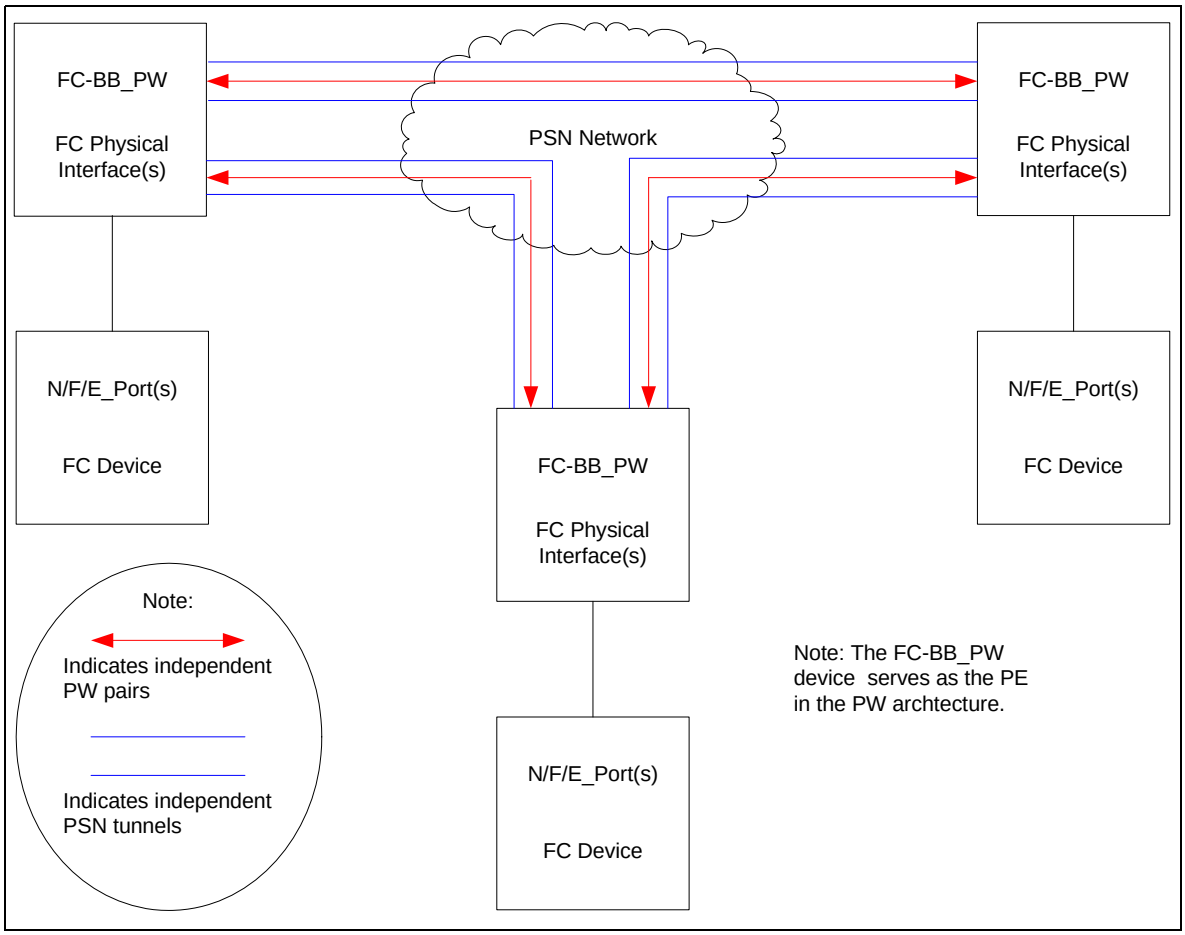

Figure 3 – FC-BB_PW reference model

Figure 4 (i.e., FC-BB_E), shows the VN_Port to VF_Port reference model and the VE_Port to VE_Port reference model. FCoE frames originated by a VN_Port are carried over the Lossless Ethernet network to the VF_Port the VN_Port is logged in. FCoE frames originated by a VE_Port are

carried over the Lossless Ethernet network to the VE_Port with which the VE_Port is logically connected.

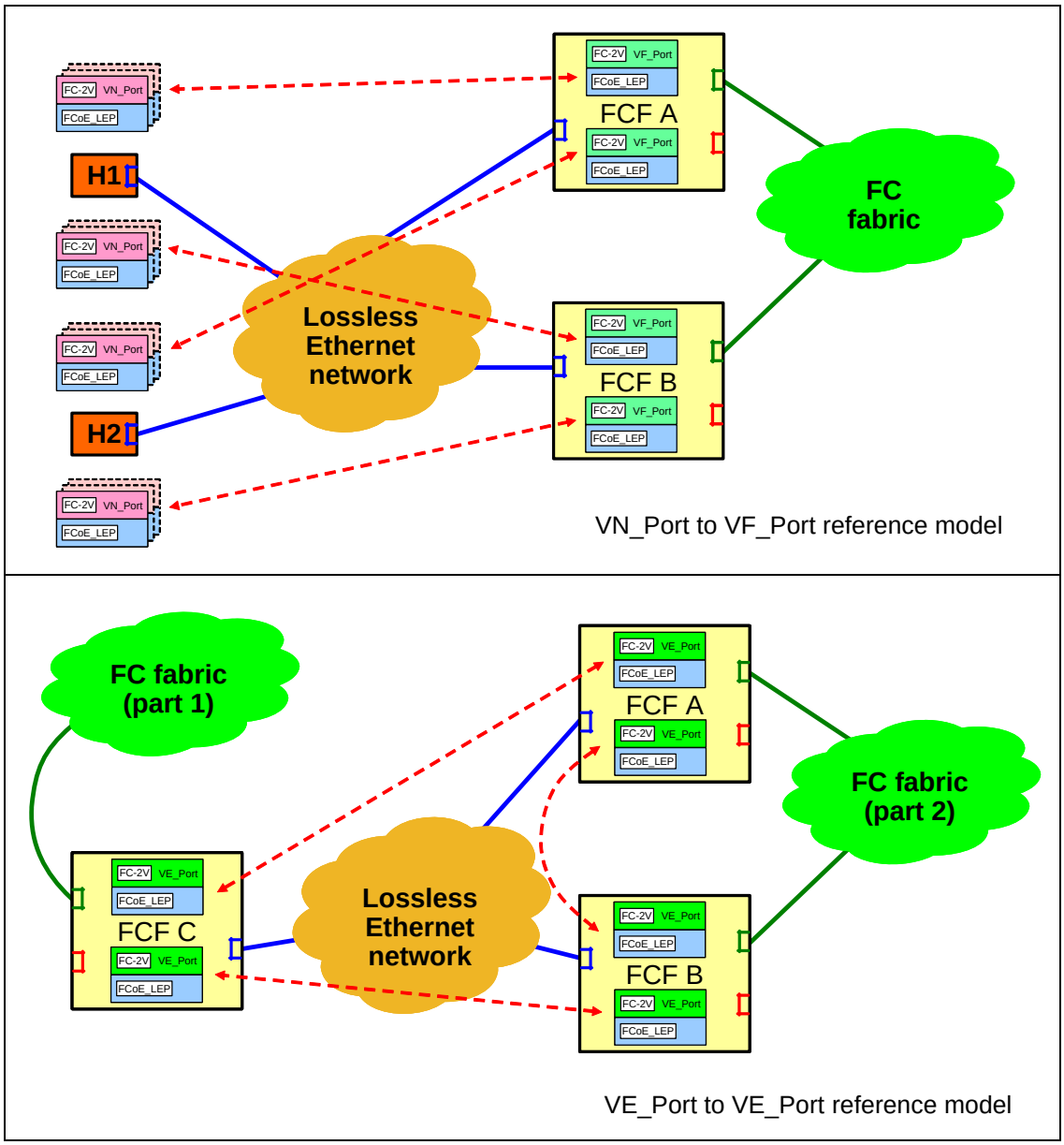

Figure 4 – FC-BB_E reference model

4.3 FC-BB-5 models overview

4.3.1 FC-BB_IP

The FC-BB_IP model defines the means by which Fibre Channel networks interface with and connect across an IP network. FC-BB_IP makes use of the FCIP standard (see RFC 3821) to define the mapping and control required by the TCP/IP protocol and the FC frame encapsulation standard (see RFC 3643) to define the encapsulation. FC-BB_IP also defines the connection management, addressing, time synchronization, discovery, security, switching, routing, and error recovery required

to support Fibre Channel over TCP/IP. FC-BB_IP is independant of the underlying physical technology that exists beneath the IP layer. In this sense, the IP network could use SONET, Gigabit Ethernet, or any other link-level technology below it.

FC-BB_IP encapsulates byte-encoded Class 2, 3, or F Fibre Channel frames into a suitable format (i.e., encapsulated FC frames) for carriage over the IP network. Subclause 5.5 describes encapsulated FC frames in detail. The TCP/IP protocol suite provides a reliable transport of frames over the IP network. TCP provides flow control and error recovery.

The FC-BB_IP protocol provides mechanisms to create VE_Port or B_Access connectivity over the IP network (see 5).

The FC-BB_IP device interfaces to attached FC_Ports are FC physical interfaces operating at standard rates. The FC-BB_IP devices may support automatic WAN link speed negotiation with the attached IP networks.

4.3.2 FC-BB_GFPT

The FC-BB_GFPT model defines the means by which FC physical links may be extended over any WAN transport infrastructure for which GFP mapping is defined. FC-BB_GFPT supports the interconnection of arbitrary, legal, non-Arbitrated Loop FC_Port combinations, imposing no requirements, and making no suppositions regarding the topology, or even the presence of an FC Fabric. FC-BB_GFPT supports efficient transport of FC data over transport facilities of arbitrary bandwidths and potentially large distances. FC-BB_GFPT supports Class 2, 3, and F traffic.

FC-BB_GFPT devices do not generate FC frames and do not directly participate in port initialization or other Exchanges. FC-BB_GFPT devices are exempt from any requirements regarding FC_Port authentication (see FC-SP), and they do not impede or interfere with any such processes that may occur between the attached and interconnected FC_Ports. FC-BB_GFPT devices have no FC identity or visibility, and administratively they may be kept strictly separated and distinct from FC Fabrics and ports.

FC_Ports are interconnected pair-wise over SONET/SDH/OTN/PDH networks, via FC-BB_GFPT devices, in a point-to-point fashion. Although multiple FC_Ports may interface with a single FC-BB_GFPT device, each opposing FC_Port pair is connected via a dedicated Transport Trail (e.g., a contiguously or virtually-concatenated group). Since trail and access section configurations may differ, FC-BB_GFPT devices have both physical interfaces to the transport network, and individual FC-BB_GFPT devices may have more than one such physical interface, as well as logical interfaces associated with individual circuits. Logical interfaces are referred to as GFPT_WAN interfaces. A GFPT_WAN interface corresponds to a specific Transport Trail, and always to a single attached FC_Port pair. Governance of the relationship of GFPT_WAN interfaces to physical SONET/SDH/OTN/PDH interfaces, and of any changes of such relationships (e.g., as may occur during network protection events), is specified in the appropriate ITU-T and ANSI-T1 standards (see clause 2), and is therefore outside the scope of this standard. Multiple GFPT_WAN links originating on one FC-BB_GFPT device may be terminated on different, and geographically disparate, FC-BB_GFPT devices. The routing and provisioning of network facilities underlying GFPT_WAN links is outside the scope of this standard.

The FC-BB_GFPT device interfaces to attached FC_Ports are FC physical interfaces operating at standard rates. The FC physical interfaces on FC-BB_GFPT devices may support link speed negotiation with the attached FC_Ports.

4.3.3 FC-BB_PW

The FC-BB_PW model defines the means by which FC physical links may be extended over a wide area MPLS network. FC-BB_PW is specified in conjunction with draft-ietf-pwe3-fc-encap-06 to define the mapping and control required by the MPLS/PW protocol. According to this model the FC-BB_PW device serves as a PE network element in the PW architecture. FC-BB_PW is independant of the physical-level and link-level technologies that exist beneath the MPLS layer.

FC-BB_PW supports the interconnection of FC_Ports transporting Class 2, 3, and F traffic. FC-BB_PW encapsulates byte-encoded FC frames and a selected set of Primitive Signals and Primitive Sequences into PW PDUs for transport over the MPLS network. FC-BB_PW utilizes reliable transport of FC traffic over the MPLS network provided by the PW termination layer as specified in draft-ietf-pwe3-fc-encap-06.

The FC-BB_PW entity does not generate FC frames and does not directly participate in port initialization or other Exchanges. The FC-BB_PW entity is exempt from any requirement regarding FC_Port authentication (see FC-SP), and it does not impede or interfere with any such processes that may occur between the attached and interconnected FC_Ports. The FC-BB_PW entity has no FC identity or visibility, and administratively it may be kept strictly separated and distinct from FC Fabrics and ports.

4.3.4 FC-BB_E

The FC-BB_E model defines the means by which Fibre Channel frames ar carried over a Lossless Ethernet network. Although a generic Ethernet network may lose frames due to congestion, a proper implementation of appropriate Ethernet extensions (e.g., the Pause mechanism defined in 802.3-2005) allows a full duplex Ethernet link to provide a lossless behavior similar to the one provided by the buffer to buffer credit mechanism in native Fibre Channel. The protocol mapping defined by FC-BB_E is referred to as Fibre Channel over Ethernet (FCoE) and requires the underlying Ethernet layer to be full duplex and lossless (i.e., to be composed only of full duplex links and to provide a lossless behavior when carrying Fibre Channel frames).

FC-BB_E encapsulates byte-encoded Class 2, 3, or F Fibre Channel frames into a suitable format (i.e., FCoE frames) for carriage over the Lossless Ethernet network. Subclause 7.6 describes FCoE frames in detail. The Lossless Ethernet network provides a lossless service similar to the one provided by native Fibre Channel Fabrics.

The FC-BB_E protocol provides mechanisms to create VN_Port to VF_Port virtual links and to create VE_Port to VE_Port virtual links.

4.4 FC-BB-5 requirements

4.4.1 Fibre Channel Class support

Class F shall be supported between ~~FC-BB-5~~FC-BB_IP, FC-BB_GFPT, and FC-BB_PW devices. Class 1 is not supported, and Class 2 and Class 3 may be supported between ~~FC-BB-5~~FC-BB_IP, FC-BB_GFPT, and FC-BB_PW devices.

Class 3 shall be supported between FC-BB_E devices. Class 1 is not supported, and Class 2 and Class F may be supported between FC-BB_E devices.

4.4.2 Payload transparency

4.4.2.1 FC-BB_IP

Arriving Class 2, 3, and F Fibre Channel frames from an FC network and destined to a remote FC network shall be encapsulated using the FC-BB_IP defined mechanisms and transmitted to the appropriate FC-BB_IP device.

Arriving encapsulated frames received from remote FC-BB_IP device shall be de-encapsulated and sent to an FC network.

Primitive Signals and Primitive Sequences shall not be transported between FC-BB_IP devices.

4.4.2.2 Transparent FC-BB (FC-BB_GFPT and FC-BB_PW)

FC frames inbound from one attached FC_Port shall be delivered to the remote FC_Port in native form (i.e., without further encapsulation) across the transport network according to the adaptation processes described in 6.4.8.1 for FC-BB_GFPT devices and 6.4.8.2 for FC-BB_PW devices. Frames received from remote Transparent FC-BB devices shall be forwarded to the attached FC_Port. Selected ELP, SW_ACC, FLOGI, PLOGI, and LS_ACC frames may be subject to inspection and/or minor modifications, in transiting one or the other Transparent FC-BB device, as described in 6.4.4.

Primitive Signals transmitted by an attached FC_Port are forwarded across the transport network for delivery to the remote FC_Port according to the rules described in clause 6. Primitive Signals are forwarded by an FC-BB_GFPT device in native form (i.e., without further encapsulation) according to the adaptation processes described in 6.4.8.1. Primitive Signals are forwarded by an FC-BB_PW device encapsulated within control frames as specified in draft-ietf-pwe3-fc-encap-06.

Primitive Sequences transmitted by an attached FC_Port are forwarded across the transport network for delivery to the remote FC_Port according to the rules described in clause 6. Primitive Sequences are forwarded by an FC-BB_GFPT device in native form (i.e., without further encapsulation) according to the adaptation (including rate adaptation) processes described in 6.4.8.1. Primitive Sequences are forwarded by an FC-BB_PW device encapsulated within control frames as specified in draft-ietf-pwe3-fc-encap-06.

4.4.2.3 FC-BB_E

Class 2, 3, and F Fibre Channel frames arriving from a VN_Port, a VF_Port or a VE_Port shall be encapsulated in FCoE frames and transmitted to the appropriate FC-BB_E device.

FCoE frames received from a remote FC-BB_E device shall be de-encapsulated and sent to the appropriate VN_Port, VF_Port of VE_Port.

Primitive Signals and Primitive Sequences shall not be transported between FC-BB_E devices.

4.4.3 Latency delay and timeout value

FC-BB_IP shall ensure that the incoming encapsulated FC frames whose FCIP Transit Time (FTT) exceeds 1/2 E_D_TOV shall be discarded and not admitted into the FC network. Fibre Channel timeout values shall be administratively set to accommodate the FTT.

FC-BB_IP shall allow Class F encapsulated FC frames to be transmitted with a zero timestamp value.

Transparent FC-BB requires that the latency between two Transparent FC-BB devices be:

a) no more than one-half of the E_D_TOV value of the attached devices for frames;
b) no more than one-half of the R_T_TOV value of the attached devices for Primitive Sequences; and
c) within the R_A_TOV values of the attached Fabric(s), if any.

The Lossless Ethernet bridges used to build a Lossless Ethernet network suitable for FC-BB_E usage should enforce a maximum transit delay of 500 ms, according to the best practice used by Fibre Channel switches.

4.4.4 QoS and bandwidth

FC-BB_IP recommends that some form of preferential QoS be used for the FCIP traffic in the IP network to minimize latency and packet drops although no particular form of QoS is recommended. See RFC 3821.

FC-BB_GFPT has no specific transport service requirements.

FC-BB_PW recommends that Primitive Sequences are carried with low latency and no loss over the MPLS network. In addition to these properties, FC data traffic should be provided with assurance of some amount of bandwidth, however no specific recommendation is made in this standard. The Differentiated Services EF PHB (see RFC 3246) is an example of a mechanism that may be used for FC-BB_PW traffic management.

FC-BB_E requires the underlying Ethernet network to be Lossless. This may be done through the use of some Ethernet extensions. A possible Ethernet extension to implement Lossless Ethernet is the Pause mechanism defined in IEEE 802.3-2005. Another possible Ethernet extension to implement Lossless Ethernet is the Priority-based Flow Control (PFC) mechanism defined in IEEE 802.1Qbb. When PFC is used to implement Lossless Ethernet, FCoE frames shall use a lossless priority (see IEEE 802.1Qbb).

4.4.5 In-order delivery

FC-BB_IP shall guarantee in-order delivery of frames within the scope of any TCP connection.

FC-BB_GFPT shall provide in-order delivery within each provisioned Transport Trail for all transmitted data (i.e., frames, Primitive Signals and Primitive Sequences), as discussed and with the exceptions detailed in clause 6.

FC-BB_PW shall provide in-order delivery within each provisioned PW for all transmitted data (i.e., frames, Primitive Signals and Primitive Sequences), as discussed and with the exceptions detailed in clause 6.

FC-BB_E shall guarantee in-order delivery of frames within the Lossless Ethernet network.

4.4.6 Flow control

FC-BB_IP devices shall ensure that TCP flow control and error recovery acts in proper concert with the Fibre Channel BB_Credit flow control mechanism.

Flow control at E_Ports, F_Ports, VE_Ports, and B_Ports shall operate as defined in FC-SW-4.

The Alternate Simple Flow Control (ASFC) mechanism (see 6.4.4) shall be used between FC-BB_GFPT devices. Flow control on FC_Port-facing links is specified in clause 6.

Flow control at FC-BB_GFPT and FC-BB_PW physical interfaces to attached FC devices shall operate as defined in FC-SW-4 or FC-FS-2, as appropriate.

Flow control between two FC-BB_PW devices shall operate as specified in draft-ietf-pwe3-fc-encap-06.

FC-BB_E devices relies on Ethernet extension for proper flow control of FCoE frames. Ethernet extensions achieve the same level of service provided by native Fibre Channel buffer-to-buffer flow control. Suitable Ethernet extension for FC-BB_E usage are the Pause mechanism defined in IEEE 802.3-2005 and the Priority-based Flow Control mechanism defined in IEEE 802.1Qbb.

4.5 FC-BB-5 SW_ILS codes

Table 2 shows the SW_ILS codes allocated for FC-BB-5 use.

Table 2 – FC-BB-5 SW_ILS codes

Encoded Value (hex)	Description	Abbr.	Reference
28 03 00 00	Authentication Special Frame Request	ASF	5.6.2.3.2
28 01 00 00	Exchange B_Access Parameter	EBP	5.3.3.3.1

Table 3 shows the ELS codes allocated for FC-BB-5 use.

Table 3 – FC-BB-5 ELS codes

Encoded Value (hex)	Description	Abbr.	Reference
80 00 00 00	Link Keep Alive Request	LKA	FC-LS