10 Gigabit Fiber Channel and Testing

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This article introduces 10 Gigabit Fiber Channel, compares it with 1 Gigabit and 2 Gigabit Fiber Channel, and draws parallels with 10 Gigabit Ethernet. It also discusses the tests required to validate the compliance of 10 Gigabit Fiber Channel equipment to the standard, as well as the method to evaluate error performance.

While 1 and 2 Gigabit Fiber Channels (1 and 2 GigFCs) have found applications in storage area networks (SAN), the Fiber Channel industry is turning to 10 Gigabit Fiber Channel (10 GigFC). What will this evolution be like and how will it impact the type of tests required in evaluating 10 GigFC products?

To fully understand how the move to a 10 GigFC will impact the optical industry, it is important to first consider the requirements for 10 GigFC technologies and the changes to Fiber Channel standards.

10 Gigabit Fiber Channel

The 10 GigFC protocol runs at the signal rate of 10.518 Gbps and follows the same structure that is defined for all Fiber Channel rates (Figure 1). The Fiber Channel protocol has defined five levels of functions—FC-0, FC-1, FC-2, FC-3, and FC-4. Each contains functions as described in Figure 1. The ANSI INCITS 373-2003 (FC-FS) standard specifies the functions for FC-1, FC-2, and FC-3 levels.chain are on the front lines of enabling this transition.

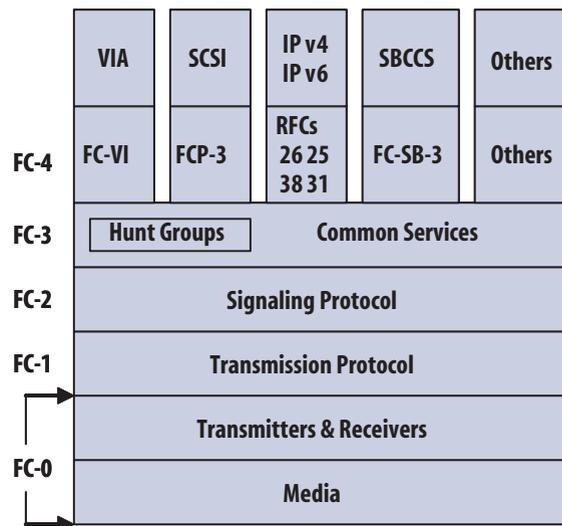|					
	VIA	SCSI	IP v4 IP v6	SBCCS	Others
FC-4	FC-VI	FCP-3	RFCs 26 25 38 31	FC-SB-3	Others
FC-3	Hunt Groups		Common Services		
FC-2	Signaling Protocol				
FC-1	Transmission Protocol				
FC-0	Transmitters & Receivers				
	Media				

Figure 1. Fiber Channel protocol functions.

For 10 GigFC, minor changes are made to the FC-1 functions as defined in FC-FS. The major change in 10 GigFC is creation of the ANSI INCITS 364-2003 standard which specifies physical layer requirements for 10 GigFC interfaces. In addition, the 10 GigFC protocol does not support the arbitrated loops topology defined for lower rates. Figure 2 describes the protocol components within a 10 GigFC port as defined in the ANSI 10 GigFC standard. Besides ANSI, ISO/IEC also has documents that define the Fiber Channel protocol.
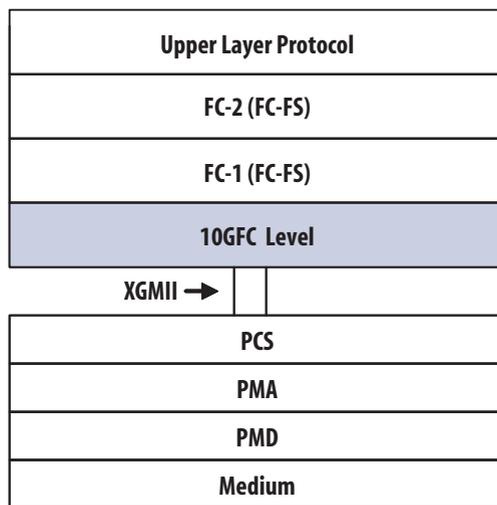
| Upper Layer Protocol |
| FC-2 (FC-FS) |
| FC-1 (FC-FS) |
| 10GFC Level |
| XGMII → |
| PCS |
| PMA |
| PMD |
| Medium |

Figure 2. 10 GigFC protocol components.

The 10 GigFC Standard

The 10 GigFC standard describes signaling and physical interface requirements to transport data at a rate in excess of 10 Gbps over a family of FC-0 physical variants. Optional port management functions are introduced at the FC-3 level as well. The standard has defined two formats of the four quarter-speed lanes optical physical variants, as well as the one full-speed lane over one fiber variant. This article will focus on the one full-speed lane over one fiber variant as it is the most popular among the three formats. Statements written hereafter may not apply to the first two variants.

Aside from the higher rate, the physical layer design for 10 Gigabit Ethernet (10 GigE) is adopted into the 10 GigFC standard. The 64B/66B transmission code is used in place of the FC-1 8B/10B transmission code described in FC-FS for 1 and 2 GigFCs. Although the 8B/10B code seems to be a more straight evolution to many existing Fiber Channel users, the 64B/66B code has higher bandwidth efficiency and leverages existing 10 Gig technologies. The 10 Gigabit Media Independent Interface (XGMII), Physical Coding Sublayer (PCS) where the 64B/66B coding/decoding functions reside), Physical Medium Attachment (PMA), and Physical Medium Dependent (PMD) layers shown in Figure 2 are defined in IEEE Standard 802.3ae—2002 for 10 GigE and expanded in 10 GigFC as they are capable of operating at 10.518 Gbps. It should be noted that a special jittery signal is introduced in the 10 GigE standard to evaluate performance of the receiver in a worse-case scenario.

Within the 10 GigFC standard, a 10 GigFC level is created to adapt the FC-1 information defined in FC-FS to the XGMII, which permits standard operations defined in 10 GigE, to remain unchanged.

Changes to the FC-1 Function as Defined in FC-FS

With single lane 10 GigFC, the 8B/10B transmission coding is no longer part of the FC-1 functions as defined in FC-FS. Primitive signals, primitive sequences, and port state machines remain within the FC-1 functions.

Functions of the 10 GigFC Level

The 10 GigFC level provides the necessary translations between the FC-1 and the XGMII. There is no need to translate user data that comes from FC-2, because XGMII will pass it on unchanged. However, FC-1 ordered sets such as frame delimiters, primitive signals, and primitive sequences are defined differently in FC-FS and XGMII. For example, all FC-FS ordered sets start with a leading K28.5 special character followed by 3 bytes that define the ordered sets. However in 10 GigE, one control code is defined for each ordered set; therefore, an ordered set from FC-1 must be translated into the format that is recognized and supported at the XGMII for transmission. Likewise an ordered set received from the XGMII must be translated into the format that can be delivered to the FC-1 functions. The 10 GigFC level also qualifies primitive sequences received from XGMII before delivering to the FC-1 functions.

The non-operational ordered set (NOS) that is defined in FC-FS does not appear on XGMII; it is mapped by the 10 GigFC level to the RF ordered set. Qualified LF received from XGMII is converted to the out-of-band signal "loss of sync" to the FC-1 level.

Although 10 GigFC utilizes the XGMII defined in 10 GigE, rules governing information flow that can appear on XGMII for 10 GigFC and for 10 GigE differ. For example, the two technologies have different rules on the generation of interframe gaps (IFG), primitive sequences, and primitive signals. Detailed requirements on XGMII, PCS, PMA, and PMD can be found in IEEE Standard 802.3ae—2002.

Testing 10 Gigabit Fiber Channel

Testing of 10 GigFC includes physical layer tests and protocol tests (FC-2 and above). Physical layer tests evaluate the ability of a device under test (DUT) to carry information, error free, from one place to another. Protocol tests evaluate the ability of the DUT to exchange information, to establish and release a connection, and its ability to forward and switch data frames in accordance with given recommendations, specifications, or standards.

Before protocol testing can be performed, physical layer performance requirements must be satisfied. The 10 GigFC physical layer includes the FC-1, XGMII, PCS, PMA, and PMD. Evaluation of the PMD requires the use of optical instruments for measuring transceiver characteristics such as waveform, clock, and sensitivity. It is more difficult to find instruments for receiver testing than for transmitter testing due to the fact that the special requirements for the input optical signal are not easily satisfied by most products on the market.

Testing the PCS and the XGMII require specialized tools that provide analysis of the 64B/66B code transmitted by the DUT. The ideal instrument should be able to report PCS errors and statistics, and it should capture and display the received 64B/66B code in a readable format. This allows for examination of compliance with the rules of IFG, primitive signals, primitive sequences, and link fault signaling as specified in the standard, because this information is embedded in the 64B/66B code stream. The instrument should also be able to generate the appropriate 64B/66B code, allow injection of error conditions, and allow editing of transmitted bits to force the DUT receiver into or out of specific states to verify its implementation in accordance with the standard. Client data performance can be determined by evaluating the bit error rate (BER) of the payload once the FC-1 level and below are tested.

Once the transport capability of the DUT is validated, a 10 GigFC protocol tester is used to evaluate its ability to establish and release a connection, handle traffic, and map user data to the Fiber Channel signal in accordance with the standard. What must be tested depends largely upon the nature of the DUT and its expected functionalities.

Summary

This article has reviewed 10 GigFC technology focusing on the 10 GigFC level. The major change to Fiber Channel protocol is adoption of the 64B/66B transmission code defined in 10 GigE and, as a result, creation of the 10 GigFC level. Specialized tools to analyze the PCS become essential in examining compliance to the standard. In addition, the introduction of stressed receiver conformance testing in the 10 GigE standard also constitutes a challenge for testing 10 GigFC receivers. Readers are encouraged to refer to the relevant documents for further information on 10 GigFC and 10 GigE.

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