10 Gigabit Fibre Channel and Testing

Gaoyao Tang, Applications Engineer, Innocor Ltd.
gtang@innocor.com

Abstract: This article introduces 10 Gigabit Fibre Channel, compares it with 1G/2G FC, and draws parallels with 10G Ethernet. It also discusses the tests that are needed to validate the compliance of 10GFC equipment to the standard, as well as the method to evaluate error performance.

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

To fully understand how the move to a 10 Gigabit Fibre Channel will impact the optical industry, we must first consider the requirements for 10 Gigabit Fibre Channel technologies and the changes to the Fibre Channel standards.

10 Gigabit Fibre Channel

The 10 Gigabit Fibre Channel protocol runs at the signal rate of 10.518 Gbps and follows the same structure that is defined for all Fibre Channel rates (Figure 1). The Fibre Channel protocol has defined five levels of functions, these are the FC-0, FC-1, FC-2, FC-3 and FC-4, each containing 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.

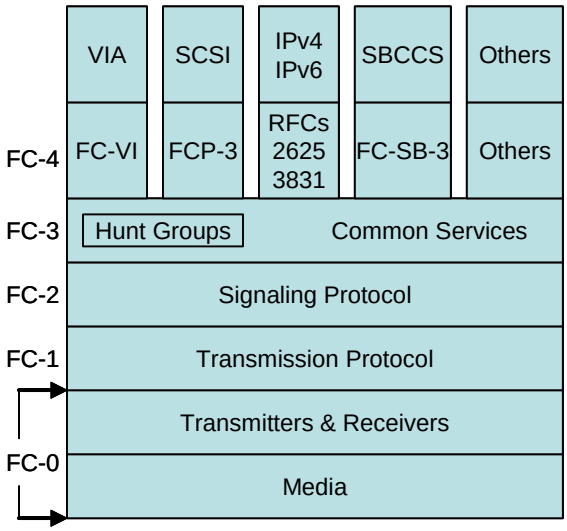

Figure 1 Fibre Channel Structure

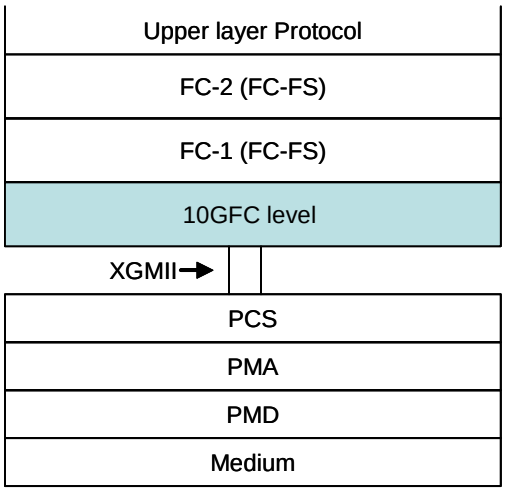

Figure 2 10Gigabit Fibre Channel

For 10 Gigabit Fibre Channel, minor changes are made to the FC-1 functions as defined in FC-FS. The major change in 10 Gigabit Fibre Channel is the creation of the ANSI INCITS 364-2003 (10GFC) standard which specifies the physical layer requirements to

the 10Gigabit Fibre Channel interfaces. In addition the arbitrated loops topology defined for lower rates is not supported by the 10 Gigabit Fibre Channel protocol either. Figure 2 describes the protocol components within a 10 Gigabit Fibre Channel port as defined in the 10GFC standard. Besides ANSI, ISO/IEC also has documents that define the Fibre Channel protocol.

The 10GFC standard

The 10GFC standard describes the signaling and physical interface requirement to transport data at a rate in excess of 10 gigabits per second 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 that are made hereafter may not apply to the first two variants.

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

Within the 10GFC standard, a 10GFC level is created to adapt the FC-1 information defined in FC-FS to the XGMII. This permits standard operations of the FC-1 functions, as defined in FC-FS as well as XGMII functions defined in 10GE, to remain unchanged.

Changes to the FC-1 function as defined in FC-FS

With single lane 10 Gigabit Fibre Channel, 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 10GFC level

The 10GFC level provides the necessary translations between the FC-1 and the XGMII. There is no need to translate user data that come from FC-2 as XGMII will pass them 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 determine the meanings of the ordered_sets. However in 10GE there is one control code

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 needs to be translated into the format that can be delivered to the FC-1 functions. The 10GFC level also qualifies Primitive Sequences received from XGMII before delivering to the FC-1 functions.

The NOS (Not Operational) ordered_set that is defined in FC-FS does not appear on XGMII, it is mapped by the 10GFC 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 10GFC utilizes the XGMII defined in 10GE, rules governing the information flow that can appear on XGMII for 10GFC and for 10 Gigabit Ethernet (10GE) are different. For example, the two technologies have different rules on the generation of Inter-Frame Gaps (IFG), Primitive Sequences and Primitive Signals. Detailed requirements on XGMII, PCS, PMA and PMD can be found in IEEE Std. 802.3ae—2002

Testing 10 Gigabit Fibre Channel

Testing of 10 Gigabit Fibre Channel 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 DUT's ability 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 standard.

Before protocol testing can be performed, the physical layer performance requirements must be satisfied. The 10 Gigabit Fibre Channel physical layer includes the FC-1, XGMII, PCS, PMA and PMD. Evaluation of the PMD requires the use of optical instruments for the measurement of 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 in 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 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 since 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 10GFC protocol tester is used to evaluate its ability to establish and release a connection, handle traffic and map user data to the Fibre Channel signal in accordance with the standard. What must be tested depends largely upon the nature of the DUT and its expected functionalities.

Summary

We have discussed the 10 Gigabit Fibre Channel technology focusing on the 10GFC level. The major change to the Fibre Channel protocol is the adoption of the 64B/66B transmission code defined in 10GE and the creation of the 10GFC level as a result. Therefore specialized tools which can provide the PCS analysis become essential in examining compliance to the standard. In addition, the introduction of the stressed receiver conformance testing in the 10GE standard also constitutes a challenge to the testing of the 10Gigabit Fibre Channel receivers. The readers are encouraged to refer to the relevant documents for further information on 10 Gigabit Fibre Channel and 10GE.

Innocor Ltd., 362 Terry Fox Drive, Suite 210, Ottawa, Ontario, Canada. K2K 2P5
www.innocor.com