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TECHNOLOGY BEHIND 10 GIGABIT ETHERNET

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Abstract
The 10 Gigabit Ethernet Alliance (10GEA) was established in order to promote standards-based 10 Gigabit Ethernet technology. The technologies behind the 10 Gigabit includes the Ethernet layer protocol, MAC frame format, Physical layer architecture and physical media such as fibers which are included in this paper.

KEYWORDS- MAC,PCS,PMA,PMD

1. INTRODUCTION

The 10 Gigabit Ethernet Alliance (10GEA) was established in order to promote standards-based 10 Gigabit Ethernet technology and to encourage the use and implementation of 10 Gigabit Ethernet as a key networking technology for connecting various computing, data and telecommunications devices. The charter of the 10 Gigabit Ethernet Alliance includes:

(i) Supporting the 10 Gigabit Ethernet standards effort conducted in the IEEE 802.3 working group
(ii) Contributing resources to facilitate convergence and consensus on technical specifications
(iii) Promoting industry awareness, acceptance, and advancement of the 10 Gigabit Ethernet standard
(iv) Accelerating the adoption and usage of 10 Gigabit Ethernet products and services
(v) Providing resources to establish and demonstrate multi-vendor interoperability and generally encourage and promote interoperability and interoperability events
(vi) Fostering communications between suppliers and users of 10 Gigabit Ethernet technology and products

2. THE 10 GIGABIT ETHERNET STANDARDS

The Ethernet protocol basically implements the bottom two layers of the Open Systems Interconnection(OSI) 7-layer model i.e., the data link layer and physical sublayers. The protocol layer depicts the typical Ethernet protocol stack and the relationship to the OSI model.
Details of each layer are given below:

4.1.1 Medium Access Control (MAC)
The media access control sub layer provides a logical connection between the MAC clients of itself and its peer station. Its main responsibility is to initialize, control and manage the connection with peer station.

4.1.2 Reconciliation Sub layer
The reconciliation sub layer acts as a command translator. It maps the terminology and commands used in the MAC layer into electrical formats appropriate for the physical layer entities.

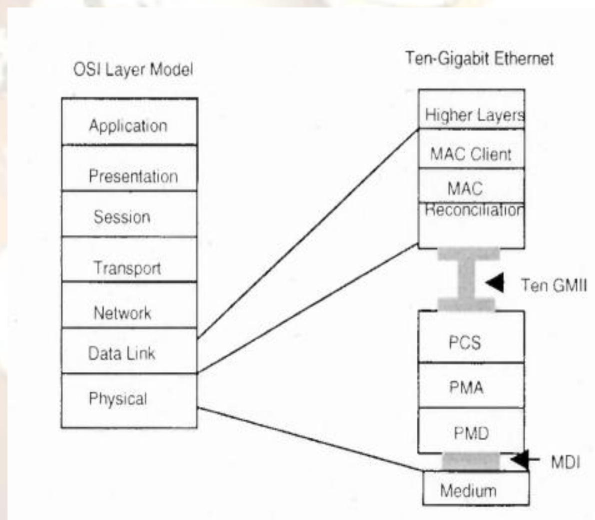

Figure1: Ethernet Protocol Layer

4.1.3 Media Independent TenGMII (10-Gigabit Interface)
Ten-GMII provides a standard interface the MAC layer and the physical layer. Itisolates the MAC layer and the physical layer, enabling the MAC layer to be used with various implementations of the physical layer.

4.1.4 PCS (Physical Coding Sub laver)
The PCS sub layer is responsible for coding and encoding data stream from the MAC layer. Several coding techniques is explained later.

4.1.5 PMA (Physical Medium Attachment)
The PMD sub layer is responsible for serialize code groups into bit stream suitable for serial bit-oriented physical devices and vice versa. Synchronization is also done for proper data decoding in this sub layer.

4.1.6 PMD(Physical Medium Dependent)
The PMD sub layer is responsible for signal transmission. The typical PMD functionality includes amplifier, modulation and wave shaping. Different PMD devices may support different media.

4.1.7 MDI(Medium Dependent Interface)
MDI is referred as a connector. It defines different connector types for different physical media and PMD devices.
More on 10 Gigabit Ethernet MAC Layer
The medium access control layer of 10 Gigabit Ethernet is similar to the MAC layer of previous Ethernet technologies. It uses the same Ethernet address and frame formats, but it does not support full duplex mode. It will support data rate of 10 GB/s and lower, using pacing mechanism for rate adaptation and low controls.
In the Ethernet standard there are two modes of operation: half duplex and full duplex modes. The half-duplex mode has been defined since the original version of Ethernet. In this mode, data are transmitted using the popular Carrier-Sense Multiple access/Collision Detection (CSMA/CD) protocol on a shared medium. Its simplicity contributed to the success of the Ethernet standard. The main disadvantages of the half-duplex are the efficiency and distance limitation.
In this mode, the link distance is limited by the minimum MAC frame size. This restriction reduces the efficiency drastically for high rate transmission. Most of thelinks at this rate are point-to-point over optical fibers. In this case, the full duplex operation is preferred. In the full duplex operation, there is no contention. The MAC layer entity can transmit whenever it wants, provided that its peer is ready to receive. The distance of the link is limited by the characteristic of the physical medium and devices, power budgets and modulation.

3. MAC FRAME FORMAT
The key purpose for developing 10-Gigabit Ethernet standard is to use the same MAC frame format as specified in the preceding Ethernet standards. This will allow a seamless integration of the 10-Gigabit Ethernet with the Existing Ethernetnetworks. There is no need for fragmentation or reassembling and the address translation, implying faster switching. The minimum MAC frame format is made equal to 64 octets as specified in the previous Ethernet standards.

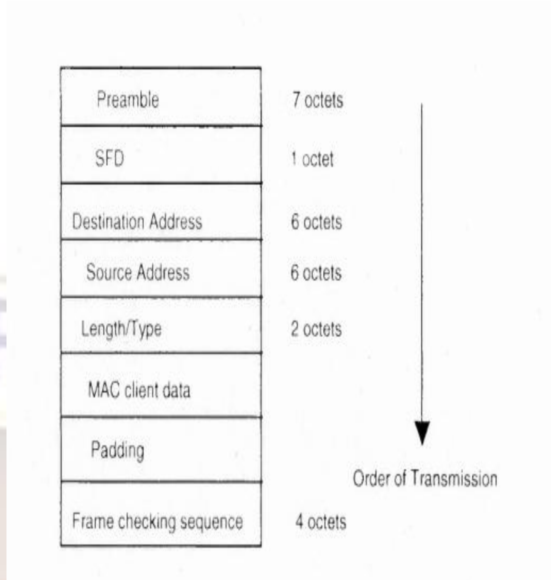

Figure2: Ethernet Frame Format

The Ethernet frame format consists of the following fields:

(i) Preamble
A 7-octect preamble pattern of alternating 0's and 1's that is used to allow receiversynchronization to reach a steady state.

(ii) Start frame delimiter (SFD)
The SFD field is the sequence TenTenTen 11, used to allow receiver timing to indicate a start of frame.

(iii) Address fields
Each MAC frame contains the destination and source addresses. Each address is 48 bits long. The first of which is used to identify the address as an individual address (0) or a group address (1). The second of which is used to indicate whether the address is locally (1) or globally (0) defined.

(iv) Length/Type
If the number is less than maximum valid frame size, it indicates the length of the MAC client data. If the number is greater than or equal to 1536 decimal, it represents the type of the MAC client protocol.

(v) Data and padding
Padding is optional. It is only necessary when the data packet is smaller than 38 octets to ensure the minimum frame size of 64 octets as specified in the existing standards.

(v) Frame Checking Sequence (FCS)

The FCS field contains a 32-bit cyclic redundancy check (CRC) value computed from all fields except the preamble, SFD and CRC. The encoding is defined by a generating polynomial.

(vi) Data Rate

LAN's require a 10 Gigabit Ethernet so that a 10 Gigabit Ethernet switch can support exactly ten One Gigabit Ethernet ports, while WANs require the 9.584640 Gb/s data rate so that it is compatible with the OC-192 rate. The solution to this problem supports both the rates. This can be done by specifying the data rate at 10 Gb/s and utilizing pacing mechanism to accommodate the slower data rates.
The pacing mechanism allows the MAC layer to support transmission rates, for instance, 1 GB/s or 10 GB/s for LAN and 9.584640 GB/s for WAN. To achieve this, the MAC layer entity shall have an ability to pause data transmission for an appropriate period of time to provide a low control or rate adaptation. Two techniques for pacing mechanism are under consideration.
The first is the word-by-word hold technique and the second is the Inter-Frame GAP(IFG) stretch technique. In the word-by-word technique, the MAC layer entity pauses sending a 32-bit word of data for a pre-specified period of time upon request from the physical layer. In the IFG technique, the IFG is extended for a pre-defined period of time with or without a request from the physical layer. The main disadvantage of the IFG stretch technique is that a large data buffer is required because the algorithm operates between frames. The main advantages of the word-by-word mechanism are that it can support any encoding techniques, it does not need a large data buffer to hold multiple MAC frames, and the buffer size is independent of link speed.

The 10-Gigabit Ethernet Physical Layer

The main issues include 10 Gigabit Media Interface, parallel vs. serial architectures, wavelength division multiplexing (WDM) vs. parallel optic, coding techniques, devices, media and so on.

The 10-Gigabit Media Independent Interface (TenGMII)

The GMII provides the interface between the MAC layer and the physical layer. It allows the MAC layer to support various physical layer variations. The TX word hold line is provided to support word oriented pacing mechanism. The 32-but data paths are provided for transmit and receive functions each with 4 control bits. The control bit is set to 1 for delimiters and special characters and 0 for data. Delimiters and special characters are determined from the 8 bit data value when the control bit is set to 0.
The delimiter and special characters include:
(i) IDLE which is signaled during the inter-packet gap and when there is no data tosend.
(ii) SOP which is signaled at the start of each packet
(iii) EOP which is signaled at the end of each packet
(iv) ERROR which is signaled when an error is detected in the received signal or when an error needs to be put to the translated signal.
These delimiter and special characters enables a proper synchronization or multiplexing and demultiplexing operations. It should be noted that the interface could also be scaled in speed and width.

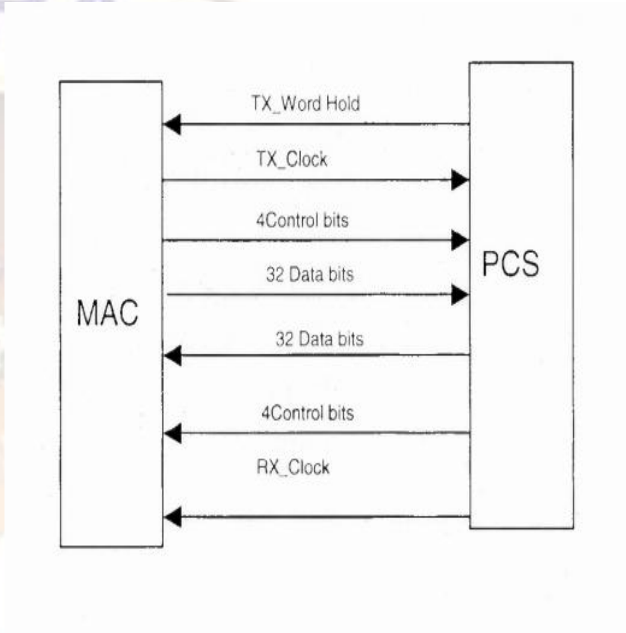

Figure3: GMII

Physical Layer Architecture

There are two structures for the physical layer implementation of 10-Gigabit Ethernet: the serial solution and parallel solution. The serial solution uses one high speed (10Gb/s) PCS/PMA/PMD circuit block and the parallel solution uses multiple PCS/PMA/PMD circuit blocks at lower speed.

(i) Serial implementation

In the serial implementation, there is one physical channel operating at 10 Gb/s. The operation is straightforward. For transmission, the reconciliation module passes the signals, corresponding to the MAC data, word-by-word to the PCS module. The PCS module then encodes the signals with pre-defined coding technique and passes the encoded signal to the PMA module. The PMA module then serializes the encoded signals and passes the stream to the PMD module.

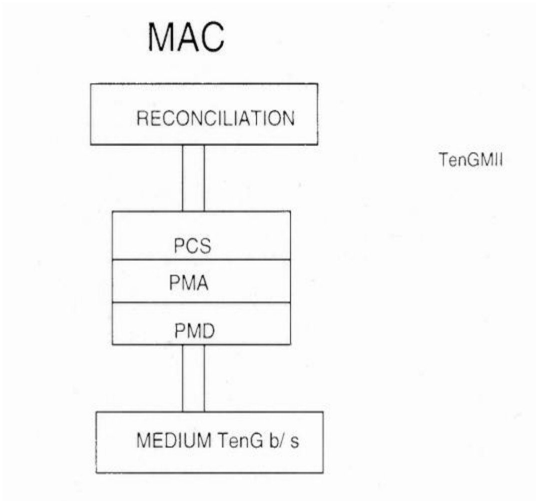

Figure4: Serial Physical Layer Implementation

The PMD module transmits the signal stream over the fiber at 10Gb/s. for receiving the process is the reverse. The main advantage of the serial architecture is that the transmitting/receiving operation is straightforward. It does not require a complicated multiplexing/ demultiplexing that is needed in the parallel implementation. Thus the timing jitter requirement is more relaxed. It also requires only one fiber channel and one set of laser equipment. The main disadvantage is the need of expensive high-speed logic circuits technology. To reduce transmission rate, higher-rate coding techniques such as PAM-5 and MB8Ten may be used. There are technologies, for example the 10G- SONET/OC-192, which currently support 10Gb/s operation. The technologies from these existing standards may be borrowed to aid the 10G Ethernet serial implementation.

(ii) Parallel Implementation

In parallel implementation, there are multiple physical channels, say sub-channels that may be implemented by using parallel cables or WDM multiplexing. For transmission, the distributor multiplexes the data (frames and idles) accepted from the MAC layer into n streams in the Round-Round motion. Each stream is given toeach PMA module for serialization. After serialization, each PMD module transmits each serialized data stream at the rate of 10/n Gb/s. The main advantage of the parallel implementation is that the operating rate in the PCS/PMA modules is reduced, which enables cheaper devices to be used. The disadvantages are the need of distributor/collector module that may be sensitive to timing jitters, and the usage of multiple sets of logic circuits and laser equipment. There are two techniques to achieve multiple channels, one of which is the parallel cabling and the other is the WDM.

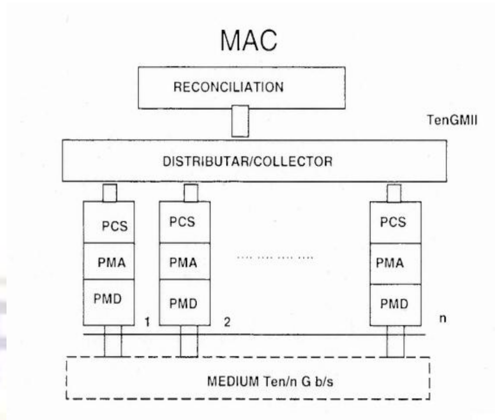

Figure5: Parallel Physical Layer Implementation

Lasers

An essential component for high speed transmission is laser. There are several types of lasers. The common ones are the Fabry-Perot(F-P) Laser, Vertical-Cavity Surface-Emitting Laser(VCSEL), and Distributed-Feedback (DFB) Laser.

(i) Fabry-Perot Laser

The Fabry-Perot laser is simple low cost multi-mode laser. It is optimized for single mode fibers but it can also operate over multi-mode fibers. The typical operatingwavelength is in the 1300-nm range. For this type of optical source, the distance limitation is due to dispersion and mode-partition noise.

(ii) Vertical-Cavity Surface Emitting Laser(VCSEL)

The VCSEL laser is traditionally a low cost solution for 850-nm application. It can operate on both multi-mode and single mode fibers. For this type of source, the link distance is quite limited.

(iii) Distributed-Feedback Laser

The Distributed-Feedback laser utilizes distributed resonators to suppress multimode source. It has high bandwidth-distance product and typically operates over the 1300-nm wavelength band on single mode and multi-mode fibers, and 1550-nm band on single mode fibers. The distance limitation is typically due to attenuation loss for the 1300-nm band and dispersion for the 1550-nm band.

Physical Media

The physical media for high speed transmission are typically fibers.

(i) 62.5-um Multi-mode Fiber

62.5-um multi-mode fiber is the cheapest among the applicable choices of fibers. Most of the existing fiber infrastructures for links up to 300 meters are 62.5-um multi-mode fibers. It typically supports operations in the 800 nm and 1300 nm wavelength bands. The performance of this type of fiber is typically limited at about 200MHz km limiting the link distance to less than 50 maters for a line rate about 10GBaud.

(ii) 50-um Multi-mode Fiber

The traditional 50-urn multi-mode fiber has sloght better performance than the62.5-urn multi-mode fiber. In this case, link distance is limited to less than 65 meters at about 10 Gbaud line rate. However, the new enhanced 50-um multi-mode fibers such as ZETA by Lucent have better performance. For this type of fibers, the line rate is 12.5 GBaud for link distance up to 300 meters.

(iii) Single Mode Fiber

The single mode fiber has smaller core than the multi-mode fiber, enabling signals to travel much longer distance. At the line rate about 10GBaud, the link can be as long as 40 km. in practice, the single-mode fibersare suitable for LAN backbones, MAN and WAN.

CONCLUSIONS

The huge of demand for high-speed networking has stirred development of the next generation 10-Gigabit Ethernet. The 10-Gigabit Ethernet standard will support the data rate of 10 Gb/s, which is 10 times faster than the current transmission rate of 1-Gigabit Ethernet, but the cost is targeted around 2 to 3 times the cost of the current 1-Gigabit Ethernet technology. It will not support the half-duplex operation, but it will maintain the compatibility with the preceding Ethernet technologies by using the same Ethernet frame format, enabling seamless integration among the existing networks and the new technology. 10-Gigabit Ethernet may be used in LAN, MAN, and WAN, implying technology convergence and faster switching.

In addition to the data rate of 10 Gb/s,10-Gigabit Ethernet shall be able to accommodate slower date rates such as 9.584640 Gb/s (OC-192). This is likely to be done by using the word-by-word pacing mechanism via the 10GMII interface. The current proposal for 10GMII uses 32-bit data paths with 4 control bits (one control bit per one data byte) and a TX_hold line. This structure provides scalability and can support various variations of the physical layer implementation. The discussions regarding issues in the physical layer are still ongoing. The standard may provide different specifications for different applications. The main considerations include the implementation architectures (serial, parallel, or WDM), coding techniques, supporting technologies, and media.

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