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Synchronous Ethernet explained

1. FROM ASYNCHRONOUS TO SYNCHRONOUS ETHERNET

Synchronous Ethernet is an ITU-T standard that provides mechanisms to transfer frequency over the Ethernet physical layer, which can then be made traceable to an external source such as a network clock. On this case Ethernet links are part of the synchronization network (see Figure 2). The proposal to specify the transport of a reference clock over Ethernet links was brought by operators to ITU-T Study Group 15 in September 2004. The aim of Synchronous Ethernet is to avoid changes to the existing IEEE Ethernet, but to extend to work as a proper synchronous network.

On many respects the evolution to a synchronous Ethernet network is equivalent to the one that occurred from PDH/T-Carrier to SDH/SONET and the causes are similar. The higher bit rates are the most important is to keep transmission synchronized by a unified clock in order to keep clock fluctuations and offsets under control as they are a main cause of errors a poor QoS.

Despite being an IEEE standard, Ethernet architecture has been described in ITU-T G.8010 as a network made up of an ETH layer and a ETY layer. Written in simple terms, the ETY layer corresponds the physical layer as defined in IEEE 802.3, while the ETH layer represents the pure packet layer. Ethernet MAC



Figure 1 ALBEDO Ether.Sync is a field tester for Synchronous Ethernet equipped with all the features to deploy SyncE infrastructures, Precision Time Protocol (PTP / IEEE 1588v2) and Gigabit Ethernet supporting legacy while new test such as eSAM Y.1564

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frames at the ETH layer are carried as a client of the ETY layer. In OSI terminology, ETY is layer 1, ETH layer 2. Synchronous Ethernet is based on the ITU-T G.8010 description of the Ethernet architecture.

A key issue in Synchronous is the definition of the mechanisms necessary to achieve internetworking between SDH and Synchronous Ethernet equipment in order for them to have a unified synchronization network to manage. These mechanisms and procedures are found fundamentally in three different recommendations: ITU-T G.8261, G.8262 and G.8264. The aspects covered there include the following:

- Extension of the synchronization network to consider Ethernet as a building block (ITU-T G.8261). This enables Synchronous Ethernet network equipment to be connected to the same synchronization network that SDH. Synchronization for SDH can be transported over Ethernet and vice-versa.
- ITU-T G.8262 defines Synchronous Ethernet clocks compatible with SDH clocks. Synchronous Ethernet clocks, based on ITU-T G.813 clocks, are defined in terms of accuracy, noise transfer, holdover performance, noise tolerance, and noise generation. These clocks are referred as Ethernet Equipment Slave clocks. While the IEEE 802.3 standard specifies Ethernet clocks to be within ±100 ppm. EECs accuracy must be within ±4.6 ppm. In addition, by timing the Ethernet clock, it is possible to achieve Primary Reference Clock (PRC) traceability at the interfaces (see Figure 2).





Figure 2 Synchronous Ethernet Architecture and comparison with conventional Ethernet.

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Figure 3 ITU-T G.8262 states MTIE and TDEV limits for EECs verified with ALBEDO Ether. Sync and Ether. Genius.

• *ITU-T G.8264 extends the usability of the ITU-T G.707* Synchronization Status Message (SSM) by Synchronous Ethernet equipment. The SSM contain an indication of the quality level of the clock that is driving the synchronization chain. The Ethernet Synchronization Message Channel (ESMC) is used for propagation of the SSM through the Synchronous Ethernet network.

Ethernet Synchronization Messaging Channel

In SDH, the SSM provides traceability of synchronization signals and it is therefore required to extend the SSM functionality to Synchronous Ethernet to achieve full interoperability with SDH equipment.

In SDH, the SSM message is carried in fixed locations within the SDH frame. However, in Ethernet there is no equivalent of a fixed frame. The mechanisms needed to transport the SSM over Synchronous Ethernet are defined by the ITU-T in G.8264 in cooperation with IEEE. More specifically, the ESMC, defined by the ITU-T is based on the Organization Specific Slow Protocol (OS-SP), currently specified in IEEE 802.3ay.

The ITU-T G.8264 defines a background or *heart-beat* message to provide a continuous indication of the clock quality level. However, event type messages with a new SSM quality level are generated immediately.

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The ESMC protocol is composed of the standard Ethernet header for a slow protocol, an ITU-T specific header, a flag field, and a type length value (TLV) structure (see Figure 5.). The SSM encoded within the TLV is a four-bit field whose meaning is described in ITU-T G.781.

2. HANDS-ON: TESTING SYNCHRONIZATION

Several phenomena in packet networks can affect the performance of packet timing, such as network congestion, outage, and routing changes, causing some disturbance in packet networks that can lead to packet loss, packet delay, and packet jitter (packet delay variation). The ALBEDO Ether.Genius deliver SyncE, Ethernet and E1 test functionality for metro and access applications in the field and lab.

Key factors for verifying packet timing include:

- Connectivity at TDM and packet interfaces
- TDM jitter/wander
- Synchronous Ethernet jitter/wander

Basic TDM and Packet Test

The very first step in verifying TDM service is to conduct a bit error rate test (BERT) between the end (TDM) nodes. If bit errors are present, performing various tests within the enclosed packet network such as basic Ping test can verify connectivity at Ethernet (OAM Loopback) or IP (ICMP Ping) layer. Further characterization of the packet network involves testing the throughput delay, and delay variation (jitter) across the packet network.

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D	1 D2	2 D3			D1	^	۸	D2	۸		D3		
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Bź	2 K1	1 K2			B2	B2	B2	K1			K2		
D	4 D5	5 D6			D4			D5			D6		
D	7 D8	3 D9			D7			D8			D9		
D1	0 D1	1 D12			D10			D11			D12		
∍ S′	1 M [·]	1 E2		9	S1					M1	E2	Х	Х

Figure 4 Sections overheads in SDH / SONET. Synchronization Status Messages (SSM): This is used to inform the remote multiplexer on the quality of the clock used to generate the signals. 0x: Unknown, 2x: G811, 4x: G.812 transit, 8x: G.812 local, Bx: G.813, Fx: Not used for synchronization.

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TDM Jitter / Wander Measurements

A range of standards including ITU-T G.823/G.824 specify the performance of timing and synchronization nodes in TDM networks, which define the test setups, test pattern, measurement parameters, as well as the limits for network elements at traffic and synchronization interfaces.

The ALBEDO Ether.Sync conduct jitter/wander measurements up to GbE in compliance with ITU-T recs.O.171, O.172, and O.173. MTIE and TDEV are key parameters for verifying synchronization function. MTIE is useful in capturing the phase transients in a timing signal, because it describes the maximum phase variation of a timing signal over a period of time. However, MTIE proves inadequate for verifying noise on the timing signal. TDEV characterizes better random noise because it is a root mean square (RMS) power estimator rather than peak estimator. TDEV tends to remove transients in the test signal, therefore, a better estimator of the underlying noise processes.

The ITU-T specifies requirements for TDM network timing and synchronization limits in standards G.810-813 and G.823. ITU-T Recommendation G.8621 defines synchronization aspects in packet networks and specifies the maximum network limits of jitter and wander, which must not be exceeded. G.8261 also specifies the maximum equipment tolerance to jitter and wander that must be provided at the boundary of these packet networks at TDM interfaces.



Figure 5 Ethernet Synchronization Message Channel (ESMC) protocol data unit rec. ITU-T G.8264.

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Figure 6 ALBEDO Ether.Sync and ALBEDO Ether.Genius are testers to test SyncE circuits by decoding and displaying the SSM, capturing ESMC messages, and measuring the received frequency offset (ppm).

Jitter/Wander measurements

The Synchronous Ethernet jitter/wander measurements defined by the ITU are equivalent to SONET/SDH measurements and the IEEE 802.3 specifies jitter requirements from asynchronous Ethernet interfaces. However no wander requirement exists for asynchronous Ethernet interfaces.

The ITU-T G.8262 describes timing devices used in synchronizing network equipment for Sync Ethernet. It also defines the requirements for clocks, such as bandwidth, frequency accuracy, holdover, and noise generation.

Use Case: Verify Network Reference Timing

In the Synchronous Ethernet testing scenario, the ALBEDO Ether.Sync is testing a Synchronous Ethernet circuit. The master clock (time reference) provides reference timing for the network, which is propagated throughout the network via the enhanced physical layer specifications of SyncE circuits. Information identifying the qualify level (QL message) of the master clock driving the synchronization chain is passed through the network via sync status messages (SSM) in the Ethernet synchronization messaging channel (ESMC) that are contained in specialized Ethernet frames sent periodically, one per second.

Telecom field experts can verify SyncE circuits by decoding and displaying the SSM, capturing ESMC messages, and measuring the received frequency offset (ppm). It also can during Ethernet service turn-up test traffic can be generated using an external reference or recovered SyncE timing to ensure proper SyncE traffic propagation (see Figure 6).

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Alternatively engineers may also use ALBEDO Net.Shark which is a is a FPGA based Tap with filtering capabilities, that connected in pass-through mode, is able to capure SSM and ESMC messages at wire-speed Packets are transmitted through two ports and traffic compliant with one of the filters is sent to Wireshark where they can be decoded (see Figure 7).



wireshark decoding

Figure 7 ALBEDO Net.Shark is a wiretap that can capture ESMC messages at wirespeed to be save internally or fully decoded in an external PC equipped with Wireshark.

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