# Optical Timing: Frequently Asked Questions

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## Introduction

This document provides the answers to some frequently asked questions for optical timing.

### Q. If voice traffic is still intelligible to the listener in a relatively poor communication channel, why isn't it easy to pass it across a network

## optimized for data?

**A.** Data communication requires very low Bit-error Ratio (BER) for high throughput but does not require constrained propagation, processing, or storage delay. Voice calls, on the other hand, are insensitive to relatively high BER, but very sensitive to delay over a threshold of a few tens of milliseconds. This insensitivity to BER is a function of the human brain's ability to interpolate the message content, while sensitivity to delay stems from the interactive nature (full-duplex) of voice calls. Data networks are optimized for bit integrity, but end-to-end delay and delay variation are not directly controlled. Delay variation can vary widely for a given connection, since the dynamic path routing schemes typical of some data networks may involve varying numbers of nodes (for example, routers). In addition, the echo-cancellers deployed to handle known excess delay on a long voice path are automatically disabled when the path is used for data. These factors tend to disqualify data networks for voice transport if traditional public switched telephone network (PSTN) quality is desired.

## Q. How does synchronization differ from timing?

**A.** These terms are commonly used interchangeably to refer to the process of providing suitable accurate clocking frequencies to the components of the synchronous network. The terms are sometimes used differently. In cellular wireless systems, for example, "timing" is often applied to ensure close alignment (in real time) of control pulses from different transmitters; "synchronization" refers to the control of clocking frequencies.

## Q. If I adopt sync status messages in my sync distribution plan, do I have to worry about timing loops?

**A.** Yes. Source Specific Multicasts (SSMs) are certainly a very useful tool for minimizing the occurrence of timing loops, but in some complex connectivities they are not able to absolutely preclude timing loop conditions. In a site with multiple Synchronous Optical Network (SONET) rings, for example, there are not enough capabilities for communicating all the necessary SSM information between the SONET network elements and the Timing Signal Generator (TSG) to cover the potential timing paths under all fault conditions. Thus, a comprehensive fault analysis is still required when SSMs are deployed to ensure that a timing loop does not develop.

## Q. If ATM is asynchronous by definition, why is synchronization even mentioned in the same sentence?

**A.** The term Asynchronous Transfer Mode applies to layer 2 of the OSI 7-layer model (the data link layer), whereas the term synchronous network applies to layer 1 (the physical layer). Layers 2, 3, and so on, always require a physical layer which, for ATM, is typically SONET or Synchronous Digital Hierarchy (SDH); thus the "asynchronous" ATM system is often associated with a "synchronous" layer 1. In addition, if the ATM network offers circuit emulation service (CES), also referred to as constant bit-rate (CBR), then synchronous operation (that is, traceability to a primary reference source) is required to support the preferred timing transport mechanism, Synchronous Residual Time Stamp (SRTS).

## Q. Most network elements have internal stratum 3 clocks with 4.6ppm accuracy, so why does the network primary clock need to be as accurate as one part in 10^11?

**A.** Although the requirements for a stratum 3 clock specify a free-run accuracy (also pull-in range) of 4.6ppm, a network element (NE) operating in a synchronous environment is never in free-run mode. Under normal conditions, the NE internal clock tracks (and is described as being a traceable to) a Primary Reference Source that meets stratum 1 long-term accuracy of one part in 10^11.

This accuracy was originally chosen because it was available as a national primary reference source from a cesium-beam oscillator, and it ensured adequately low slip-rate at international gateways.

**Note:** If primary reference source (PRS) traceability is lost by the NE, it enters holdover mode. In this mode, the NE clock's tracking phase lock loop (PLL) does not revert to its free-run state, it freezes its control point at the last valid tracking value. The clock accuracy then drifts elegantly away from the desired traceable value, until the fault is repaired and traceability is restored.

## Q. What are the acceptable limits for slip and/or pointer adjustment rates when designing a sync network?

**A.** When designing a network's synchronization distribution sub-system, the targets for sync performance are zero slips and zero pointer adjustments during normal conditions. In a real-world network, there are enough uncontrolled variables that these targets will not be met over any reasonable time, but it is not acceptable practice to design for a given level of degradation (with the exception of multiple timing island operation, when a worst-case slip-rate of no more than one slip in 72 days between islands is considered negligible). The zero-tolerance design for normal conditions is supported by choosing distribution architectures and clocking components that limit slip-rates and pointer adjustment rates to acceptable levels of degradation during failure (usually double-failure) conditions.

## Q. Why is it necessary to spend time and effort on synchronization in telecom networks when the basic requirement is simple, and when computer LANs have never bothered with it?

**A.** The requirement for PRS traceability of all signals in a synchronous network at all times is certainly simple, but it is deceptively simple. The details of how to provide traceability in a geographically distributed matrix of different types of equipment at different signal levels, under normal and multiple-failure conditions, in a dynamically evolving network, are the concerns of every sync coordinator. Given the number of permutations and combinations of all these factors, the behavior of timing signals in a real-world environment must be described and analyzed statistically. Thus, sync distribution network design is based on minimizing the probability of losing traceability while accepting the reality that this probability can never be zero.

## Q. How many stratum 2 and/or stratum 3E TSGs can be chained either in parallel or series from a PRS?

**A.** There are no defined figures in industry standards. The sync network designer must choose sync distribution architecture and the number of PRSs and then the number and quality of TSGs based on cost-performance trade-offs for the particular network and its services.

## Q. Is synchronization required for non-traditional services such as voice-over-IP?

**A.** The answer to this topical question depends on the performance required (or promised) for the service. Usually, Voice-over-IP is accepted to have a low quality reflecting its low cost (both relative to traditional PSTN voice service). If a high slip-rate and interruptions can be accepted, then the voice terminal clocks could well be free-running. If, however, a high voice quality is the objective (especially if voice-band modems including Fax are to be accommodated) then you must control slip occurrence to a low probability by synchronization to industry standards. You must analyze any new service or delivery method for acceptable performance relative to the expectations of the end-user before you can determine the need for synchronization.

## Q. Why is a timing loop so bad, and why is it so difficult to fix?

**A.** Timing loops are inherently unacceptable because they preclude having the affected NEs synchronized to the PRS. The clock frequencies are traceable to an unpredictable unknown quantity; that is, the hold-in frequency limit of one of the affected NE clocks. By design, this is bound to be well outside the expected accuracy of the clock after several days in holdover, so performance is guaranteed to become severely degraded.

The difficulty in isolating the instigator of a timing loop condition is a function of two factors: first, the cause is unintentional (a lack of diligence in analyzing all fault conditions, or an error in provisioning, for example) so no obvious evidence exists in the network's documentation. Secondly, there are no sync-specific alarms, since each affected NE accepts the situation as normal. Consequently, you must carry out trouble isolation without the usual maintenance tools, relying on a knowledge of the sync distribution topology and on an analysis of data on slip counts and pointer counts that is not usually automatically correlated.

## Q. What is the difference between SONET and SDH?

**A.** There is no STS-1. The first level in the SDH hierarchy is STM-1 (Synchronous Transport Mode 1) has a line rate of 155.52 Mb/s. This is equivalent to SONET's STS-3c. Then comes STM-4 at 622.08 Mb/s and STM-16 at 2488.32 Mb/s. The other difference is in the overhead bytes which are defined slightly differently for SDH. A common misconception is that STM-Ns are formed by multiplexing STM-1s. STM-1s, STM-4s and STM-16s that terminate on a network node are broken down to recover the virtual circuits (VCs) they contain. The outbound STM-Ns are then reconstructed with new overheads.

## Q. What is hair pinning, and why would I want to use it?

**A.** Hair pinning is bringing traffic in on a tributary and instead of putting it on the high speed OC-N line you direct it out another low speed tributary port. You might want to do this if you have interfaces to two interexchange carriers (IXCs) on different nodes. If one of your IXCs goes down, you can hair pin the other to pick the traffic, assuming the spare capacity exists on the tributary. Hairpin cross-connections allow local drop of signals, ring extensions supported by a ring host node, and allow passing traffic between two ring interfaces on a single host node. In this case, no high speed channel is involved and the cross-connections are entirely within the interfaces.

## Q. Doesn't a two fiber bi-directional line switched ring (BDLSR) waste half of the line rate bandwidth?

**A.** No. It can be shown that in all cases the aggregate bandwidth on a two fiber BDLSR is no less than the aggregate bandwidth on a path switched ring. In some cases that exemplify an inter-office transport ring, it can actually be shown that the aggregate bandwidth of a two fiber BDLSR can be larger than that of a path switched ring.

## Q. What is the difference between TSA and TSI?

**A.** Time Slot Assignment (TSA) allows for flexible assignment for add-dropped signals but not for through path signals. Once a signal is multiplexed onto a time slot it stays in that time slot until it is dropped. Time Slot Interchange (TSI) is more flexible in that it allows a signal passing through a node to be placed in another time slot if desired. Equipment that provides neither TSA or TSI is said to be hard wired. This pass-through grooming, which is not supported by systems limited to TSA, allows in-transit bandwidth rearrangements for maximum facility utilization. This grooming is most useful for networks with intersite routing (for example, interoffice or private networks) and networks with significant churn (service removal as well as new service installation).

## Q. What are some timing rules of thumb?

**A.** Here are some basic points:

- A node can only receive the synchronization reference signal from another node that contains a clock of equivalent or superior quality (stratum level).
- The facilities with the greatest availability (absence of outages) should be selected for synchronization facilities.
- Where possible, all primary and secondary synchronization facilities should be diverse, and synchronization facilities within the same cable should be minimized.
- The total number of nodes in series from the stratum 1 source should be minimized. For example, the primary synchronization network would ideally look like a star configuration with the stratum 1 source at the center. The nodes connected to the star would branch out in decreasing stratum level from the center.
- No timing loops may be formed in any combination of primary.

## Q. What are some advantages of timing from an OC-N line?

**A.** OC-N timing distribution has several potential advantages. It preserves transport bandwidth for customer services and guarantees a high-quality timing signal. Also, as the network architecture evolves to replace Digital Signal Cross Connect (DSX) interconnects with SONET interconnects and direct OC-N interfaces, OC-N distribution becomes more efficient than multiplexing DS1 references into an access facility. A previous drawback to using OC-N timing distribution was that network timing failures could not be communicated to downstream clocks via DS1 Alarm Indication Signal (AIS), since the DS1 signal does not pass over the OC-N interface. A standard SONET synchronization messaging scheme to convey synchronization failures is in place. With this option, clock stratum levels can be passed from NE to NE, allowing downstream clocks to switch timing references without creating timing loops, if a network synchronization failure occurs. If a quality timing reference is no longer available, the NE sends AIS over the DS1 interface. If the local OC-N lines fail, the NE outputs AIS on the DS1 output or an upstream NE enters holdover. Although an ideal source of timing, OC-N timing distribution, through a DS1 timing output, cannot be used to provide timing in all applications. In cases where the local equipment is not provided with an external timing reference input, or in some private networks where the timing is to be distributed from another private network location, timing may be distributed via traffic-carrying DS1s. In these applications, a stable DS1 timing source can be achieved by ensuring that all elements in the SONET network are directly traceable to a single primary clock via line timing.

**Note:** Synchronous operation via line timing eliminates the generation of virtual terminal (VT) pointer adjustments, thus maintaining the phase stability needed for a high-quality DS1 timing reference. Cross-connecting at the STS-1 level also eliminates the VT pointer adjustments. It is recommended that, where possible, the DS1 sources (switch, private branch exchange [PBX], or other equipment) be traceable to the same timing source used to time the SONET NE. Multiplexed DS1 reference transport is also consistent with current planning and administration methods (but you better know exactly what is happening to that multiplexed DS1).

## Q. What is the advantage of using the DS1 timing output instead of a multiplexed DS1 as the timing reference?

**A.** The DS1 timing output is derived from the optical line rate and is superior because the DS1 is virtually jitter-free. Synchronization messages guarantee the traceability of the timing. Administration of traffic DS1s for timing is eliminated

## Q. Can a DS1 carried over SONET ever be used as a timing reference?

**A.** Yes. In many applications there is no other choice. Most switch remotes, for instance, obtain their timing from a specific DS1 signal generated by their host switch; so these remotes must line or loop time from the DS1 signal. In addition, digital loop carrier (DLC) equipment, channel banks, and PBXs are not likely to have external references and may be allowed to line or loop time from a DS1 carried over SONET. Five years ago all the literature however answered no to this question. See the next question for more information.

## Q. Are there any specific concerns when using a DS1 carried over SONET to time equipment such as a switch remote or DLC?

**A.** Yes. The major concern is to make sure all the equipment is synchronous to each other to prevent pointer adjustments. For example should you have an OC-N that goes through multiple carries, a LAN Emulation Client (LEC) and interexchange carrier (IXC) for example, and one of clock is a stratum 1 while the other is being timed from some stratum 3 holdover source, you will have pointer adjustments that will translate into DS1 timing jitter.

## Q. How many SONET NEs can I chain together in an add or drop configuration before the timing becomes degraded?

**A.** The stratum level traceability of the nth node in an add or drop chain is the same as that in the first node. Also, while timing jitter theoretically increases as the number of nodes is increased, the high quality timing recovery and filtering should allows add or drop chains to be extended to any practical network limit without detectable increases in jitter levels. In practice, the only effects on timing at the nth node will occur whenever high-speed protection switches occur in any of the previous n-1 nodes.

## Q. Why are there more issues related to timing with SONET equipment than there is with asynchronous equipment?

**A.** SONET equipment was designed to work ideally in a synchronous network. When the network is not synchronous, mechanisms such as pointer processing and bit-stuffing must be used and jitter or wander increases.

## Related Information

- **Technical Support - Cisco Systems**