SONET Synchronization: What's Happening

Robert W. Cubbage
Alcatel Network Systems, Inc.
Richardson, Texas

Abstract

Almost everyone that has heard of SONET knows that the acronym stands for Synchronous Optical NETwork. There has been a host of magazine articles on SONET rings, SONET features, even SONET compatibility with digital radio. What has not been highly publicized is the critical relationship between SONET, network synchronization, and payload jitter. This paper will address this topic.

Introduction

Almost everyone that has heard of SONET knows that the acronym stands for Synchronous Optical NETwork. There has been a host of magazine articles on SONET rings, SONET features, even SONET compatibility with digital radio. What has not been highly publicized is the critical relationship between SONET, network synchronization, and payload jitter. This topic has been jointly studied by T1X1.3 and T1X1.6 Working Groups. Recently, these two groups have been combined into one group which is called T1X1.3 Synchronization and Tributary Analysis Working Group.

Still No Jitter Specification

The work T1X1.3 is currently doing in SONET payload jitter is extremely important to the successful deployment of SONET equipment in the network. If the badly needed DS3 payload jitter specifications are not specified by ANSI soon, manufacturers will be free to output levels of jitter in their equipment that may cause unacceptable service in the network. In addition, these problems can be extremely difficult to trace. Some people may be surprised to learn that standardization of SONET began in 1985, and it is now 1992 and there still is no SONET payload jitter specification from ANSI. The industry is getting close and is expected to release these badly needed jitter specifications for letter ballot in March of 1993. This paper explains the relationship between synchronization and payload jitter in SONET systems and how important these specifications are.

Asynchronous vs. Synchronous Multiplexing

In the past, network synchronization quality did not have an adverse effect on payload transport systems because these transport systems operated asynchronously. In other words, the transport system did not require external synchronization to properly operate. They used a free running oscillator in each terminal to drive the output frequency such as a 1.2 Gb/s fiber optic terminal (e.g. Alcatel's LTS-21130). But SONET has changed all this. The "S" in SONET stands for synchronization and now the SONET transport system requires synchronization engineering (except in some simple point-to-point cases).

SONET uses synchronous multiplexing to go from lower rate signal (e.g. STS-1 or OC-3) to higher rate signals (such as OC-12). This allows efficient Add Drop Multiplexers (ADM) to be built. Because the synchronization network has frequency and time phase variations, SONET uses an STS-1 pointer processor to synchronously multiplex "N" STS-1s to an OC-N signal in a slipless manner. A pointer processor uses positive/zero/negative pulse stuffing to accommodate differences in STS-1 frequencies when synchronously multiplexing them together to form the high speed output.

Figure 1 shows an OC-3 terminal with three STS-1 inputs and one OC-3 output. The three STS-1s go through a pointer processor to frequency synchronize them so that they may be multiplexed in a synchronous manner to form the OC-3 output signal. One of the drawbacks of this technique is that jitter is encoded into the signal that is being transported when an STS-1 pointer adjustment occurs. This is similar to jitter caused in an M13 except it is more severe.

This jitter, being much more severe than the jitter caused in an M13, can cause service degradation. Simply put, time phase noise on the synchronization network can cause STS-1 pointer adjustments in SONET systems. These pointer adjustment cause 8 unit interval of phase discontinuity (or jitter) to be encoded in the payload signal being transported (e.g. DS3). This jitter, if not properly bounded, will cause severely errored seconds (bit errors or mis-frames) to occur on payload being carried. Thus, giving the end customer poor quality of service. This has been one of the major issues T1X1.3 has been addressing (i.e. how synchronization performance affects service quality in a hybrid network).

Service Affecting Jitter Across SONET Islands

Figure 2 shows an example of a hybrid network which is a network with mixed asynchronous and SONET transport equipment. In a hybrid network, a DS3 is transported by traditional asynchronous transport equipment (e.g. 565 Mb/s lightwave system) and SONET islands. A SONET island is a collection of SONET equipment interconnected at the OC-N or STS-1 interface. This can be as small as a point to point SONET transport system or as large as ten to a hundred SONET network elements interconnected. Jitter accumulation of a DS3 signal across multiple SONET islands must be bounded, or the current network jitter specifications will be exceeded. This may cause the service being transported to degrade to a point were it is unreliable. There are many complex variables which can have an influence on jitter accumulation in a hybrid network, and two primary factors are the quality of the synchronization input and the payload jitter produced per single pointer adjustment. Before going into any detail, it is important to understand how synchronization is distributed in the network today.

Typically, synchronization timing is distributed from one Central Office (CO) to another Central Office via traffic carrying DS1 facilities. When synchronization timing signals are distributed using traditional transport equipment (fiber terminals, multiplexers, digital cross-connects, etc.), phase noise is added to the signal. This phase noise is caused by various sources which include waiting time jitter cause by multiplex pulse stuffing, thermal noise, etc.

Historically, the phase noise on synchronization sources did not cause serious service degradation on digital switching systems because they used large slip buffers. Most NE's which require slip buffers, have 1 or 2 DS1 frame storage buffers. This large amount of buffering can easily accommodate the short-term phase noise introduced in the network. Now, because of the way that SONET systems handle short-term phase noise variations, there is a need to specify and limit the short-term phase noise on a signal used to synchronize a SONET NE. The phase noise of most interest to SONET network is in the observation range of 0.1 to 1000 seconds. Specifications for this range have recently been adopted and are currently being letter balloted at the T1 level. High levels of short-term phase noise, on either the synchronization input or the OC-N input to a SONET NE, can cause excessive pointer movements to occur in STS-1 or VT pointer processors, which in turn can cause excessive jitter in the payload signal. This jitter can cause degradation to or loss of customer service altogether. As a result, SONET is sensitive to this phase noise which the existing network can tolerate.

Phase Noise, Jitter, and Wander

Network phase noise which has high speed frequency components (> 10 Hz) is called jitter. Slower speed phase noise is called wander. Both jitter and wander routinely exist in the network and can cause data impairments to occur. In today's network, excessive jitter can cause bit errors or signal frame loss whereas wander can cause buffer spills or slips to occur. Although SONET is no more sensitive to jitter than any other network element, it does react to low speed wander. SONET, in effect, translates low speed wander on the synchronization input to high speed jitter on the payload being transported. The jitter shows up on DS1s and DS3s which traverse a SONET system. The mechanism in SONET which does this translation is the STS-1 or VT pointer processors.

One of the benefits of the STS-1 (or VT) payload pointer is to provide the ability for SONET NE's to operate properly in a plesiochronous environment without the need for slip buffers. This avoids the delays and data impairments that can be caused by frame slip buffers. This is accomplished in a similar manner as an M12 (a DS1 to DS2 multiplexer). An M12 can account for differences in DS1 and DS2 frequencies by using positive pulse stuffing technique. But one of the major differences between the STS-1 payload pointer and an M12 multiplexer is that the STS-1 payload pointer operates on the highest theoretical jitter peak with positive/zero/negative stuffing. To further compound this, SONET uses byte stuffing rather than bit stuffing. This causes the waiting time jitter to be an order of magnitude higher than single bit stuffing. As a result, severe jitter can appear in the payload signal. SONET requires sophisticated desynchronizers which can attenuate the 8 bits of phase discontinuity (or jitter) caused by STS-1 (or VT) pointer adjustments.

Important Role of T1X1 Committee

T1X1 has been studying the relationship of synchronization quality, STS-1 pointer adjustment, DS3 payload jitter, and service performance in a hybrid network that will occur while transitioning the network to SONET. It has been through industry cooperation and participation that has help T1X1 solve this complex problem. First, network synchronization measurements needed to be taken in the actual network. Important data on synchronization quality (short-term stability) was not available. Several network providers spent months collecting needed data to help specify synchronization network performance. T1X1 contracted the services of NIST (National Institute of Standards and Technology) to help analyze the data, and NIST provided T1X1 with a new metric on how to specify synchronization quality in the region of interest. This new metric is called Time Variance (TVAR), and is currently being used to specify synchronization performance levels for SONET. In addition, a clock noise model was developed which was based on the characteristics of the synchronization network data. This clock noise model was used to simulate the jitter performance of a DS3 being transported in a hybrid network similar to that shown in Figure 2.

Results of Two Years Work

After collecting synchronization network data and extensive network simulation, it is recommended that the best manner to control DS3 payload jitter accumulation in a hybrid network is to limit the jitter at the source. That is minimize the jitter caused by a single STS-1 pointer adjustment. This would allow network providers to use their existing synchronization network without requiring costly replacement for SONET deployment. In other words, SONET equipment could be deployed and synchronized with current synchronization network if the proposed tighter DS3 payload jitter specifications are adopted..

The current proposed DS3 payload jitter specification for a single pointer movement is 0.25 unit interval peak-to-peak. This specification is expected to begin the T1X1 letter ballot process by March 1993 and is tighter than the previous proposed 1.5 unit interval SONET payload output jitter specification. But recent analysis has shown that the tight specifications are needed for achieving satisfactory network performance and will most likely be adopted as ANSI standards later next year. The new tighter jitter specification affects the point were DS3s are extracted from a SONET transport system (i.e. at the DS3 input/output conditioning circuits). To avoid and minimize possible network problems caused by excessive jitter, it is important equipment be checked to see if it complies with the new anticipated jitter specification.

Summary

SONET has not only gained national acceptance, but world wide acceptance. The industry understands the benefits that SONET promises to offer with efficient ADM, transport of new broadband services, extensive performance monitoring and fault location capability. But one very important specification overlooked is the DS3 payload jitter specification for SONET. This can have a major impact on quality of service as SONET is deployed in network. Network jitter problems caused by STS-1 pointer adjustment can be extremely difficult to pinpoint. Tighter jitter specification can give the network the margin needed to guarantee grade of services customers are demanding. Network operators need to consider supporting and adopting the 0.25 unit interval single pointer adjustment proposed specification in T1X1 because it will help ensure that proper network performance is maintained as the network migrates towards an all SONET network.

Definitions

Phase Noise -	Perturbations of a digital signal's "1s" and "0s" as compared to an ideal source.
Jitter -	The short term phase variations of the significant instants (e.g. zero level crossings) of a digital signal from their ideal position in time. Here short term implies phase oscillations of frequency greater that or equal to 10 Hz. Jitter is a potential source of bit errors and mis-frames in a digital network.
Wander -	The long term phase variations of the significant instants (e.g. zero level crossings) of a digital signal from their ideal position in time. Here long term implies phase oscillations of frequency less than 10 Hz. Wander is a potential source of slips in a digital network.
Pointer Adjustment -	Technique for accommodating timing differences within SONET.
Pointer Processor -	A device which performs pointer adjustment to frequency synchronize an STS-1 input to an OC-N output rate.
Plesiochronous -	Two signals are plesiochronous if their corresponding significant instants occur at nominally the same rate, any variation in rate being constrained within specified limits. In other words, two signals whose frequency is almost synchronous.
Bit/Byte stuffing -	a technique used to frequency synchronize a signal's rate to some other rate. An M13 uses bit stuffing when multiplexing 28 DS1s to one DS3. A SONET STS-1 pointer processor uses byte stuffing (eight bits at a time) when multiplexing an STS-1 to OC-N output. Both of these techniques cause phase noise in the signal, except byte stuffing is eight times worse.

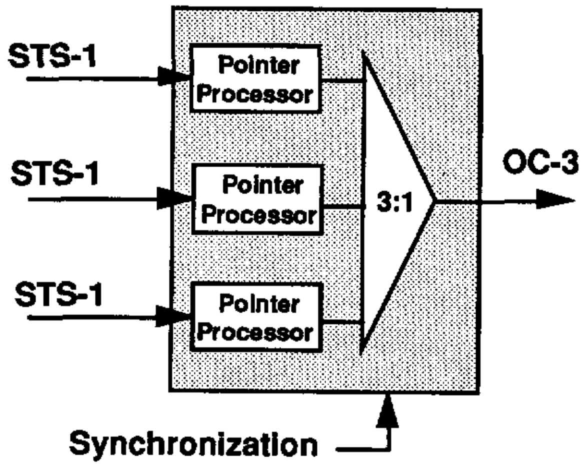

Figure 1: SONET synchronous multiplexing with STS-1 pointer processors

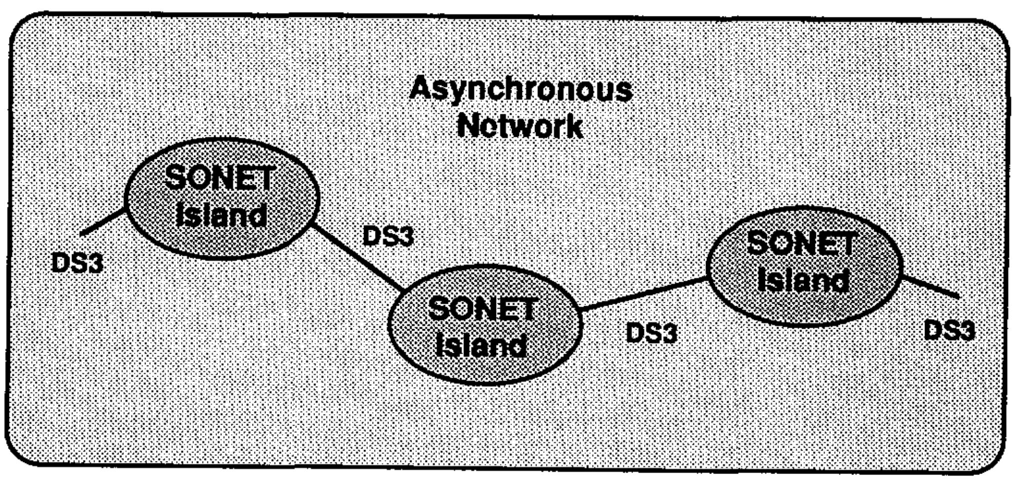

Figure 2: Hybrid Network used to study network DS3 jitter accumulation

QUESTIONS AND ANSWERS

K. Martin, Bonneville Power Administration: I am curious with the SONET why they do that stuffing like that, it seems like it throws all your timing off.

R. Cubbage, Alcatel Network System Inc.: Yes, some hind sight there. we would rather have had bit pointers but if you look at why we do that type of stuffing and SONET. Since we are using synchronous transport systems and synchronous multiplexing, we have to be able to account differences in frequency or phase between an input signal we are multiplexing and the output signal. The way we do in today's switch network is a slip buffer. The only other alternative of using pointer processors is to use a slip buffer. A slip buffer at the SONET rate leads to the DS1 rate. It is only a 193 bits at the DS1 rate. At the SONET rate since it's 51.84 megabits it would be 6,480 bits. So a slip buffer would be over 6000 bits in length and at every transport multiplexing circuit you would have at least 125 microseconds of delay. When you look at the number of elements you would go through in a network, that delay would be unacceptable. So pointer processors, a fraction of a size, minimizes the delay and reduces the buffer storage.