SYNCHRONIZATION IN SONET NETWORKS

The SONET HOMEPAGE
http://www.sonet.com/

Careful consideration should be given to proper design of the SONET network's synchronization environment. Proper synchronization engineering minimizes timing instabilities, maintains quality transmission network performance, and limits network degradation due to unwanted propagation of synchronization network faults. The synchronization features of the SONET NEs are designed to complement the existing and future synchronization network and allow it not only to make use of network timing but also to take on an active role in facilitating network synchronization.
A number of published sources give generic recommendations on setting up a synchronization network. The SONET NE is designed to operate in a network that complies with recommendations stated in GR-253-CORE and the following documents:

GR-436-CORE, *Digital Synchronization Network Plan*
• GR-378-CORE, *Generic Requirements for Timing Signal Generators (TSG)*
• *ANSI* T1.101, *Synchronization Interface Standards for Digital Networks*
• GR-1244-CORE, *Clocks for the Synchronized Network: Common Generic Criteria*.

Recommendations
The following are some key recommendations from the documents listed before.

1. A node can only receive the synchronization reference signal from another node that contains a clock of equivalent or superior quality (Stratum level).

2. The facilities with the greatest availability (absence of outages) should be selected for synchronization facilities.

3. Where possible, all primary and secondary synchronization facilities should be diverse, and synchronization facilities with the same cable should be minimized.

4. 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.

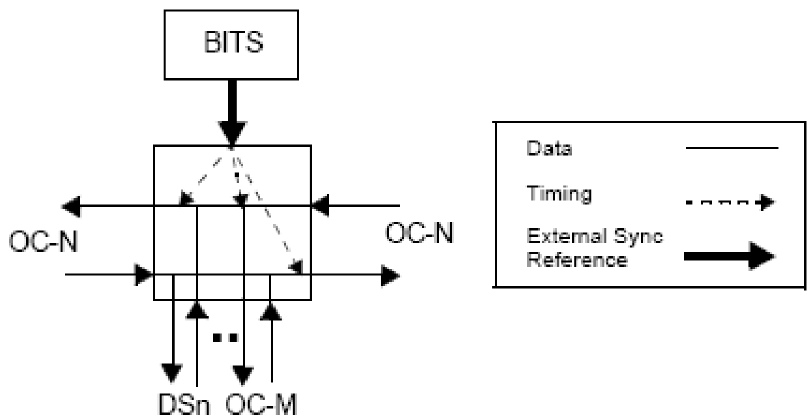
5. No timing loops may be formed in any combination of primary and secondary facilities.

The Stratum 3 Timing Generator
SONET NEs supports a Stratum 3 Timing Generator (TG3). The TG3 can be part of the common shelf equipment or embedded in each high speed optical line unit, OC-12, OC-48, and OC-192 optical interface circuit packs. The TG3 operates with an internal oscillator of ± 4.6 ppm long-term accuracy in the free running mode, while in holdover the accuracy is ± .37 ppm over the full -40 to +65 degree C temperature range. The TG3 should be used according to the recommendations in the documents referenced previously.

Overview
Synchronization is an important part of all SONET products. The SONET NE is designed for high performance and reliable synchronization and can be used in a number of synchronization environments. Each SONET NE can be provisioned to **free run** from an internal oscillator, **line timed** from an incoming optical interface, or get **external timing** from the digital synchronization network via DS1 references.

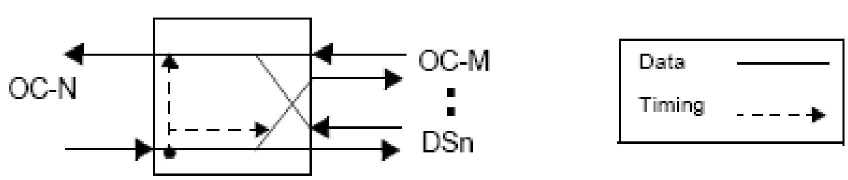
SONET NEs can support multiple synchronization reference configurations:

• **External Timing** from a Stratum 3 or better office clock (typical central office installations should be synchronized with DS1 timing references from a Stratum 1 source).



• **Free Running** from the shelf's internal Stratum 3 Timing Generator (no synchronization inputs).

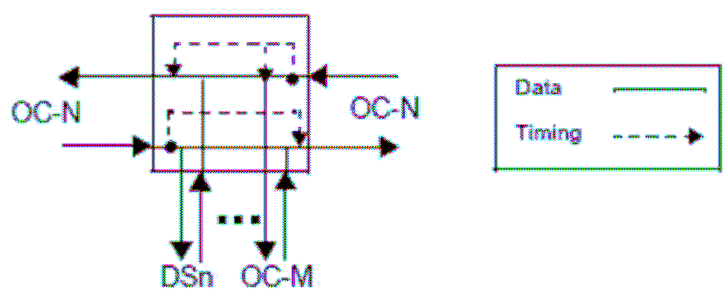
• **Line/Loop Timing** from incoming high speed OC-12, OC-48, or OC-192 optical line signals (for small central offices or remote sites).



These timing modes are supported by the embedded Stratum 3 Timing Generator. The three basic timing modes can be combined into various network configurations.

Through Timing
Through-timing is not a recommended timing mode for SONET NEs that contain LTE (e.g., ADMs). For such NEs, the through-timing mode can be a very complex timing scheme. For example, the user may find it unclear what the timing source is for a low-speed "interface", or for the protection line at an NE that supports line APS (particularly if a 1:n APS architecture is being used). However, through-timing is the required timing mode for

regenerators (see TR-NWT-000917), and is supported by some other types of deployed SONET NEs.



Internal timing distribution
In support of evolution toward SONET-based timing distribution, SONET NEs can derive an optional DS1 timing output from the incoming OC-12, OC-48, and OC-192 optical line interfaces.
With this capability, the SONET NEs network can distribute high quality synchronization among its sites. For example, the building integrated timing supply (BITS) clock in each office can be synchronized using SONET facilities by using the DS1 timing output from SONET NEs in each office**.** Internal timing functions are provided by the Stratum 3 Timing Generator (TG3). The TG3 distributes clock and frame signals, derived from the selected reference source, to the transmission packs.

External timing mode
In external timing mode, the TG3 accepts two DS1 references from an external Stratum 3 or better clock. This Stratum 3 (or better) clock would typically be traceable to a primary reference source (PRS). The DS1 references from the clock synchronize the local SONET NEs with other network equipment operating under the same primary clock source. A high-stability digital phase-locked loop (DPLL) removes transient impairments on the DS1 references for improved jitter performance. The PRS is equipment that provides a timing signal whose long-term accuracy is maintained at 10^ -11 or better with verification to universal coordinated time, and whose timing signal is used as the basis of reference for the control of other clocks in the network. Universal coordinated time is a time and frequency standard maintained by the US National Institute of Standards and Technology. The DS1 reference inputs are monitored for error-free operation. If the selected reference becomes corrupted or unavailable, the TG3 will switch to the protection reference without causing service degradations. A switch to the protection reference is revertive or non-revertive depending upon provisioning. If both DS1 inputs are corrupted, the DPLL circuit holds the on-board oscillator frequency at the last good reference sample (holdover). The TG3 will switch back to the external timing mode when a reference is no longer corrupted, but it can be provisioned to require a manual switch from holdover. Switching between the two DS1 reference inputs can also typically be done using a manual command.

Line timing mode
In line timing mode, the TG3 derives local shelf timing from the incoming service OC-12, OC-48, or OC-192 high-speed optical line signal. The DPLL serves to remove any timing transients for improved network jitter performance. When provisioned for automatic protection switching, if one of the OC-n references is corrupted or unavailable, the TG3 will make a protection switch to the other reference without causing timing degradations. If all OC-n timing signals are lost, the TG3 will switch to holdover mode. The TG3 will normally switch back to the line timing mode when a reference is no longer corrupted, but it

can be provisioned to require a manual switch. Switching between the two Main OC-n reference inputs can also be done using a manual command.

Free running mode
In free running mode, no mode switching is performed. The TG3 derives timing from a high stability temperature-compensated, voltage controlled crystal oscillator that has an end of life performance of ± 4.6 ppm, which is Stratum 3 accuracy. Only one SONET NE in a sub-network should be provisioned in the free running mode. All other SONET NEs in the sub-network should be line timed to this free running system to avoid pointer adjustments . A DS1 timing output can also be derived from the OC-n line rate, so it is not subjected to multiplexing or pointer processing effects. The result is a DS1 traceable to the far-end source with extremely low jitter and wander. The timing output can be locked to an OC-n line or the OC-n source can be automatically selected using synchronization messages. In either case threshold AIS may be enabled to insert AIS if the synchronization message of the OC-n source is poorer than a provisioned threshold.The frame format on the DS1 output is provisionable. Provisioning options are superframe format (SF) or extended SF (ESF). The DS1 is a framed all-ones signal under normal conditions or an AIS signal under failure conditions.

Holdover Mode
In case of unprotected synchronization reference failure, the TG3 will switch to "holdover mode" and continue to provide system timing, using the internal oscillator to maintain the last known good reference frequency. If the DS1 timing output is enabled for network synchronization, DS1 AIS is inserted on detection of unprotected optical reference failure.

Network Timing Distribution
DS1 signals have long been used to pass timing information through the network synchronization hierarchy. These DS1 timing references should be transmitted between master and slave clock sources over the most reliable facilities available. In some cases, these DS1 signals also carry traffic. The facility of choice has evolved from T-carrier through asynchronous lightwave systems to SONET lightwave systems. As these systems are upgraded to SONET systems, timing distribution plans should be revisited to ensure the quality of the timing signals are not degraded. With proper planning, SONET can be used to improve the overall quality of the network timing.

Interoffice Timing Distribution
One way SONET can be used to improve the quality of interoffice network timing is through the use of OC-n timing distribution. SONET NEs support the evolution to interoffice OC-n timing distribution by providing a DS1 timing output derived from the incoming OC-n signal. TheDS1 timing output is traceable to the clock source that times the SONET sub-network and has extremely low jitter and wander. This is true regardless of the number of SONET NEs connected in the network. This DS1 can be fed to the local BITS clock which subsequently times the local SONET NEs and the other equipment in the office. If a BITS clock is not available in the office, the DS1 timing output can be used to time other equipment directly. SONET NEs can provide DS1 timing outputs in all supported topologies (for example, linear add/drop and ring). With OC-n timing distribution, the OC-n line signal, rather than a DS1 multiplexed into the SONET payload, will provide a timing transport mechanism better suited to a complex, heavily interconnected SONET network. SONET NEs can also provide timing to sub-tending Network Element (NEs).

Potential Advantages

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 CO architecture evolves to replace DSX interconnects with SONET STSX-1 interconnects and direct OC-n interfaces, OC-n distribution becomes more efficient than multiplexing DS1 references into an access facility in the CO.

A previous drawback to using OC-n timing distribution was that the network timing failures could not be communicated to downstream clocks via DS1 AIS, because the DS1 signal does not pass over the OCn interface. A standard SONET synchronization messaging scheme to convey synchronization status performs this function. All next gen SONET NEs support this synchronization messaging scheme. With this option, clock Stratum levels and usability can be passed from NE to NE, allowing downstream clocks to switch timing references without creating timing loops, if a network synchronization distribution failure occurs. If a quality timing reference is no longer available, the SONET NE sends AIS over the DS1 interface.

Access Network Timing Distribution

OC-n timing distribution can also be used in access networks or to small COs. In this configuration, a DS1 reference from the CO BITS clock times the OC-n transmitted to the remote site. The line timing capability of the SONET NE provides the ability to recover OC-n timing. The DS1 timing output feature can be used to also extend timing to customer networks or remote sites. In this case, the DS1 timing output may be used to time remote switches, SONET NE shelves, or other local equipment directly. In this configuration, it is important that the DS1 reference to the SONET NE in the CO be traceable to the same clock used to source the DS1s being carried to the customer site or small CO. If it is not, slips may occur.

Alternate Timing Sources

Although an ideal source of timing, OC-n timing distribution, via 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. This is not recommended, see timing FAQ for details. 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 master clock via line timing.
In this environment, the high-performance desynchronizer design of a SONET NE allows a DS1 timing reference to be carried as a multiplexed DS1 payload. Multiplexed DS1 reference transport is also consistent with current planning and administration methods.
Applications include passing synchronization from the public switched network to a PBX-based private network and synchronizing an end-office remote switch to a larger office's host switch.

Synchronous operation via line timing eliminates the generation of 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. While the design of a SONET NE maintains jitter/wander within standard DS1 interface requirements, even in the presence of VT pointer adjustments, and while the DS1 is likely to be stable enough for most equipment to use as a timing reference, some equipment may have more stringent stability requirements for its timing references.

Overview Synchronization Messaging

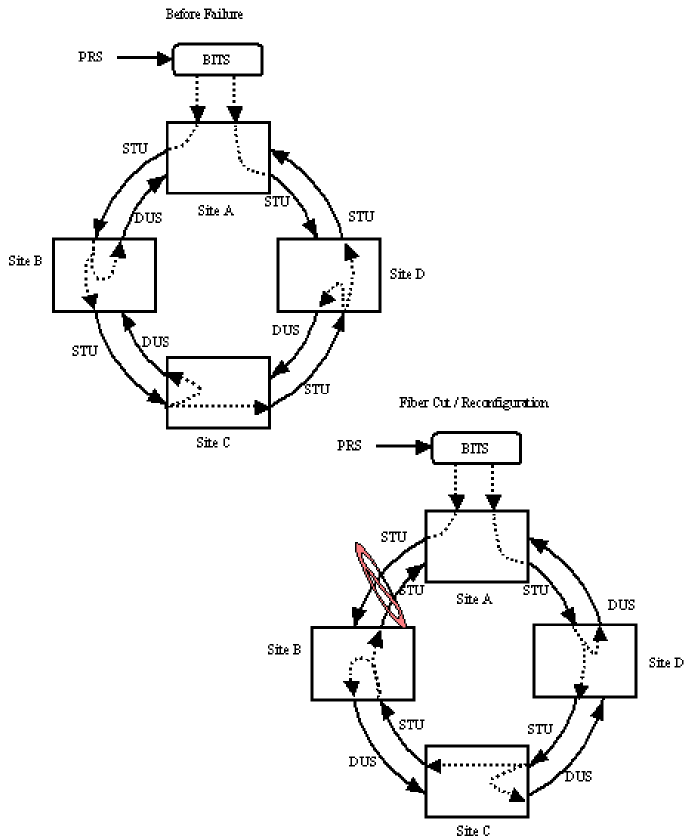
SONET NE provides a standardized synchronization messaging feature to ensure the integrity of network synchronization during both normal and abnormal conditions. Through the use of synchronization messaging, the current quality and usability of the timing source can be conveyed from one SONET NE to the next. This capability allows line-timed SONET NEsshelves to automatically change their timing

reference in order to always maintain the highest quality timing available and avoid loops. The capability also allows SONET NEs to inform a local BITS clock when the DS1 timing output has been degraded and should no longer be used as a reference.
This synchronization messaging feature is based on the scheme developed in the *ANSI* T1X1 standards committee. The applications that are currently supported with the synchronization messaging feature can be divided into the following categories: DS1 timing output integrity and automatic synchronization reconfiguration.

The derived DS1 timing outputs are typically used as a synchronization reference to a BITS clock which provides the timing reference to an externally-timed SONET NE shelf. The synchronization reference is derived from the SONET transmission facility which is synchronized from an upstream timing reference. In this way, the timing from the BITS clock in one office (master) is distributed to the next office (slave) using the SONET transmission facilities between them as the synchronization vehicle. The BITS are typically capable of synchronizing to a Stratum 3 or better accuracy. SONET NEs are equipped with the embedded TG3 is capable of synchronizing to a 4.6 ppm clock (Stratum 3) or better. The Stratum timing hierarchy requires that clocks of equal or better Stratum level be used to synchronize other clocks.
In this way, the Stratum timing hierarchy is preserved under all failure conditions. Under non-failure conditions SONET NEs do not introduce their own internal timing source onto the SONET facility, but merely transfers the quality of its timing reference. A failure of all derived DS1 timing references to the BITS at the master office will cause the BITS to enter holdover mode, whose minimum accuracy is dependent on its internal clock. Since the BITS internal clock is of equal or better Stratum level than SONET NE the externally-timed SONET NE shelf will use this reference to synchronize all outgoing SONET transmission facilities. This preserves the required hierarchical structure of the timing network which must be maintained at all times. Detailed examples of sync messaging are shown later.

Automatic synchronization reconfiguration
SONET was designed to operate optimally in a synchronous environment. Although plesiochronous and asynchronous operation can be supported through the use of pointer adjustments, transmission quality is affected by the generation of additional jitter and wander due to pointer adjustments. Because of this, it is desirable to maintain synchronous operation whenever possible through the use of synchronization messages, the quality of the different timing references can be made available at each SONET NE.
The SONET NE shelf can be optioned to determine the best timing reference available and switch to that reference. Through this mechanism, the synchronous operation of the sub-network can be maintained. The switching of timing references is hitless, and the synchronization messages also allow it to be done without creating timing loops in the process

Ring Network Example
Under normal operation, the access ring network shown in the following figure has one SONET NEsshelf externally timed and the others line timed. If a fiber failure occurs between the first two SONET NEsshelves, the synchronization auto reconfiguration feature causes SONET NE shelves to change their line timing directions to the opposite direction. The result is that the ring is again operating synchronously. The ring already provides self-healing of the traffic, so it is especially important to maintain synchronous operation during this type of failure to prevent service degradation due to increased jitter and wander.



As mentioned previously, SONET sync messaging is used to communicate the quality of the subnetwork timing throughout the subnetwork. This is done using bits 5-8 of the S1 byte in the SONET overhead. If a SONET NEs shelf is deriving timing from a given OC-n interface, and sync messaging is enabled on that interface, the system interprets the received message to determine the system's timing status. The system also determines the state of the DS1 output, if the DS1 output is enabled, by forcing a DS1 AIS on the DS1 sync outputs if the timing status received on the OC-n interface is below a provisioned quality threshold. SONET NEsalso transmits over the particular OC-n interface, and all other OC-n interfaces that are enabled for sync messaging, the appropriate message indicating the quality of its timing and its usability.

Sync Messages Using S1 Byte

The following tables list the associated internal timing status and DS1 output states that are associated with sync messages (using the S1 byte) received from the OC-n interface when sync messaging is enabled. The smaller the quality number the better the quality of the source.

Generation 1 SSM

SONET Synchronization Quality Level Description	Quality Level	S1 Bits (b5-b8)
Synchronized - Traceability Unknown	2	0000
Stratum 1 Traceable	1	0001
Stratum 2 Traceable	3	0111
Stratum 3 Traceable	4	1010
SONET Minimum Clock Traceable	5	1100
Reserved for Network Synchronization	User Assignable	1110
Don't Use for Synchronization	7	1111
NOTES 1 The leftmost bit is transmitted first. 2 Quality level 6 (Stratum 4 Traceable) is not used by SONET.		

SSM1 DS1 Code Words

DS1 Synchronization Quality Level Description	Quality Level	ESF Data-Link Codeword
Synchronized - Traceability Unknown	2	00001000 11111111
Stratum 1 Traceable	1	00000100 11111111
Stratum 2 Traceable	3	00001100 11111111
Stratum 3 Traceable	4	00010000 11111111
SONET Minimum Clock Traceable	5	00100010 11111111
Stratum 4/4E Traceable	6	00101000 11111111
Don't Use for Synchronization	7	00110000 11111111
Reserved for Network Synchronization	User Assignable	01000000 11111111
NOTE - The rightmost bit is transmitted first.		

Generation 2 SSM

SONET Synchronization Quality Level Description	Quality Level	S1 Bits (b5-b8)
Synchronized - Traceability Unknown	2	0000
Stratum 1 Traceable	1	0001
Stratum 2 Traceable	3	0111
Transit Node Clock Traceable	4	0100
Stratum 3E Traceable	5	1101
Stratum 3 Traceable	6	1010
SONET Minimum Clock Traceable	7	1100
Provisionable by the Network Operator (see note 3)	User Assignable	1110
Don't Use for Synchronization	9	1111

NOTES

1 The leftmost bit is transmitted first.

2 Quality level 8 (Stratum 4 Traceable) is not used by SONET.

3 The "Provisionable by the Network Operator" has been renamed from "Reserved for Network Synchronization" (see table 3)

SSM2 DS1 Code Words

DS1 Synchronization Quality Level Description	Quality Level	ESF Data-Link Codeword
Synchronized - Traceability Unknown	2	00001000 11111111
Stratum 1 Traceable	1	00000100 11111111
Stratum 2 Traceable	3	00001100 11111111
TNC Traceable	4	01111000 11111111
Stratum 3E Traceable	5	01111100 11111111
Stratum 3 Traceable	6	00010000 11111111
SONET Minimum Clock Traceable	7	00100010 11111111
Stratum 4/4E Traceable	8	00101000 11111111
Provisionable by the Network Operator (see note 2)	User Assignable	01000000 11111111
Don't Use for Synchronization	9	00110000 11111111

NOTES

1 The rightmost bit is transmitted first.

2 The "Provisionable by the Network Operator" has been renamed from "Reserved for Network Synchronization" (see table 2)

Disabling sync messaging

Sync messaging using the SONET S1 byte can be disabled on a per OC-n interface basis. **A DON'T USE** message is transmitted on bits 5-8 of the S1 byte if this is done. The DON'T USE message is sent to indicate that its timing is not suitable for synchronization (for example, back towards the line timing source).

External Timing With SYNC OUT

When SONET NEs are configured for external timing and its DS1 output port is provisioned for the SYNC OUT mode, the DON'T USE is sent on the OC-n interface towards the NE from which the DS1 timing output is being derived.

The Synchronized - Traceability Unknown **(STU)** message is sent on all other OC-n interfaces where sync messaging is provisioned. If the DS1 output is generating AIS while the system is configured in this way, the message STU is transmitted on all OC-n interfaces.

TG3 With Free Running Or Holdover
When using the embedded TG3, if SONET NE is configured for free running or is in holdover mode, the Traceable Stratum 3 message is sent on all OC-n interfaces for which sync messaging is enabled.

Line Timing
When SONET NEsis configured for line timing, the DON'T USE message is sent on the OC-n interfaces towards the NE from which the timing is being derived. The message received on the OC-n interface is sent on all other OC-n interfaces where sync messaging is enabled.

Automatic Synchronization Reconfiguration
With automatic synchronization reconfiguration, the SONET NEsshelves receive and compare the incoming sync messages on the OC-n interfaces available for line timing to select the highest quality synchronization reference available. If the received quality levels are the same on the references available for timing, the active line timing reference takes precedence. This feature guarantees the non-revertive operation of reconfiguration. The existence of automatic synchronization reconfiguration does not affect OC-n line protection switching.

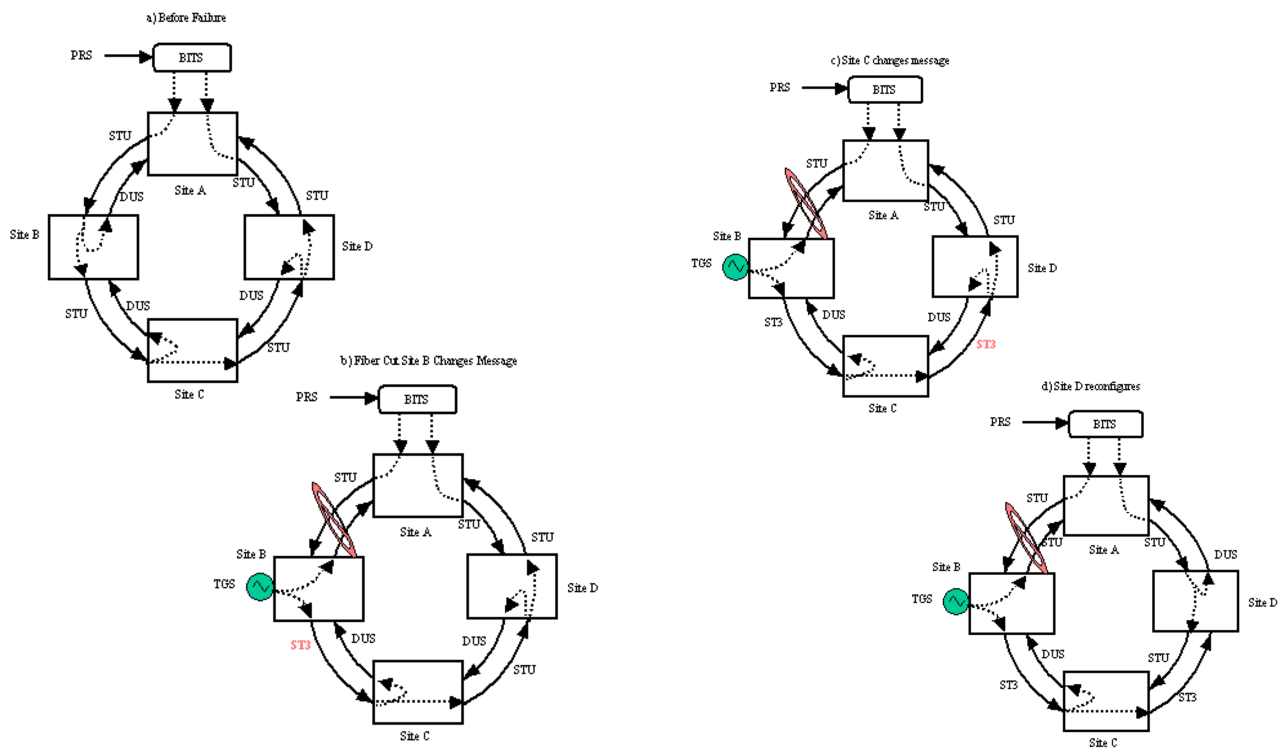
Examples
In this section, some detailed examples are given to show specifically how the sync messages propagate through network and assist in the recovery from a fiber failure. Through these examples, one can extend the same concept to any other network that may include different topologies, number of sites, failure locations, and number of BITS clocks. Some examples are depicted in a linear configuration because the particular sync messaging concept is more easily conveyed in linear terms. Those concepts can be applied to SONET ring networks.

Synchronization Reconfiguration In An Access Ring Showing The Intermediate Sync Messaging And Reconfiguration Steps.
Figure **"a"** illustrates an access ring operating in its normal configuration. The SONET NE shelf at the CO is externally timed, and each of the other SONET NE shelves are line timed in a counterclockwise direction. The STU message is sent to indicate where timing is traceable to an external BITS and where it is valid to be used. The DON'T USE message is sent on the interface that is being used as the line timing reference and, thus, where using that timing would create a timing loop. Sync messaging and automatic synchronization have both been enabled for this network. In Figure **"b"**, a fiber has been cut between sites A and B. Immediately, the SONET NE shelf at site B enters holdover and sends out the Stratum 3 message to site C. The SONET NE shelf at site B cannot switch to line time from site C because it is receiving the DON'T USE message on that interface.

In Figure **"c"**, the SONET NE shelf at site C detects the incoming Traceable Stratum 3 message and sends the message to site D. The SONET NEsshelf at site C cannot switch to line timing from the other rotation because it is receiving the DON'T USE message on that interface.

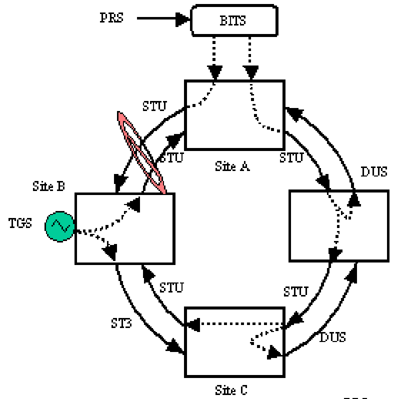
In Figure **"d"**, the SONET NE shelf at site D detects the incoming Traceable Stratum 3 message.

The STU message is a better quality message than the Traceable Stratum 3 message, so the SONET NE shelf at site D switches to line timing from site A. After the switch occurs, the DON'T USE message is sent back to site A, and the STU message is retransmitted to site C.

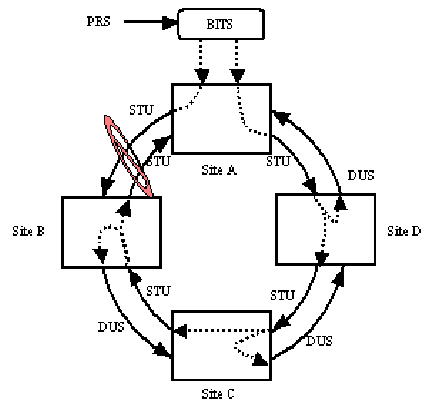


In Figure **"e"**, the SONET NE shelf at site C detects the incoming STU message from site D. The STU message is a better quality message than the Traceable Stratum 3 message being received from site B, so the SONET NEsshelf at site C switches to line time from site D.
After the switch occurs, the DON'T USE message is sent back to site D, and the STU message is retransmitted to site B. In Figure **"f"**, the SONET NEsshelf at site B detects the incoming STU message from site C. The STU message is a better quality message than the internal holdover capability, so the SONET NEsshelf at site B switches to line time from site C.
After the switch occurs, the DON'T USE message is sent back to site C, and the STU message is forwarded to site A. When the failure clears, the synchronization remains in the new configuration unless it is manually switched back.

e) Site C reconfigures



f) Site B reconfigures



TIMING FAQ

***Q**. How do I time SONET NEsshelves in a central office environment?*
A. Each SONET NEsshelf should be externally referenced to the BITS clock in the office. If a BITS clock is not available in the office, a traffic-carrying DS1 from the local switch may be bridged (for example, using a bridging repeater) as the reference to the SONET NEsshelf. Line timing may also be used, but at least one SONET NE shelf in the network must be externally timed.

***Q.** Where do I use the DS1 timing output feature?*
A. The primary application is for supplying a timing reference to the office BITS clock. This allows the BITS clock to be slaved to a BITS clock in another office that is, in turn, traceable to the primary reference source (PRS). Typically, the SONET NE supplying the DS1 timing output will, in turn, be externally timed by the BITS clock. If there is no BITS clock, the DS1 timing output can be used to time a switch or switch remote (if the switch remote is equipped for that option) directly or even another SONET NE Multiplexer.

Q. *How do I prevent my BITS clock from using a DS1 timing output when a failure in the network results in this DS1 being timed from a SONET NE in holdover?*
A. SONET sync messaging informs the local SONET NE of this condition, and AIS is inserted on the DS1 timing output.
Q. *What is the advantage of using the DS1 timing output instead of a multiplexed DS1 as the timing reference?*

The DS1 timing output is derived from the optical line rate and is superior because:

- The DS1 is virtually jitter-free
- Sync messages guarantee the traceability of the timing
- Administration of traffic DS1s for timing is eliminated.

Q. *Can I ever use the SONET NE in the free running timing mode?*
A. If a PRS traceable external reference is available, it is the recommended timing mode for any/all CO applications. The free running timing mode can be used but a slight increase in jitter will result. If one SONET NE is provisioned for free running, all other SONET NEs in the network must be line timed and SONET interfaces to other equipment are not allowed. The DS1 timing output should not be enabled with a free running network.

Q. *How do I provide timing to a central office host switch that does not have the option for an external reference?*
A. DS1 carried over SONET may contain significant jitter/wander and be unacceptable to the switch as a timing reference. If the central office has a BITS clock, the recommendation is to use the output from the BITS clock into an unused DS1 traffic port on the switch. If the central office does not have a BITS clock, the recommendation is to use the DS1 timing output from the SONET NE as the line timing reference into an unused DS1 traffic port on the switch.

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 time from the DS1 signal. In addition, DLC equipment, channel banks, and PBXs will not likely have external references and may be allowed to line time from a DS1 carried over SONET.

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. The SONET NEs should be synchronous to each other to prevent pointer adjustments. This can be accomplished by having one source SONET that is externally timed. The other SONET NEs in the network should be line timed, or they should be externally timed to a clock to which they provide a DS1 timing output. The SONET NEs should also be synchronous to the switch to prevent excessive mapping jitter. This can be done by synchronizing the host switch to the BITS clock used to reference the SONET .

Q. *Will I have any problems providing timing to a customer that has a high quality PBX or switch?*
A. If the network is completely synchronous, as described in the previous answer, there should be no problems. If the PBX is sensitive to the jitter produced, even under the synchronous conditions, the DS1 timing output of SONET may be required to be used as a timing reference to this equipment.

Q. *Why does Bellcore say that DS1s carried over SONET should not be used for timing?*

A. Bellcore has provided this recommendation because there are several limitations. Bellcore says that DS1s carried over SONET must be used in applications such as switch remotes and will be acceptable, provided pointer adjustments are not created.

Q. *Can pointer adjustments be prevented?*
A. Neither random nor periodic pointer adjustments will occur if the SONET shelf is provisioned for line timing.
Q. *How do I time SONET at a remote site?*
A. Line time.

Q. *How many SONET NEs can I chain together in an add/drop configuration before the timing becomes degraded?*
A. The Stratum level traceability of the nth node in an add/drop chain is the same as that in the first node. Also, while timing jitter will theoretically increase as the number of nodes is increased, the high quality timing recovery and filtering on the SONET allows add/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 ***n***th node will occur whenever high-speed protection switches occur in any of the previous n-1 nodes. These effects should be rare.

Q. *How do I time a SONET ring network?*
A. An interoffice ring should have each node externally timed if BITS clocks are available. All other rings should have one node externally timed (two in some dual homing architectures) and the rest of the nodes line timed. Synchronization reconfiguration is automatic.

Q. *Why are there more issues related to timing with SONET equipment than there are 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/wander increases.

Q. *Can DS3 signals be used to carry DS1 timing signals without the worry of having the network synchronous?*
A. Yes, although this option is more expensive.

Q. *What are the limitations on automatic synchronization reconfiguration?*
A. Automatic synchronization reconfiguration is only available when the SONET is provisioned for line timing mode. This allows the timing direction of an OC-n (OC-12, OC-48, or OC-192) ring network to change automatically in response to a failure. When the SONET is provisioned for external timing, automatic synchronization reconfiguration is not available. When an OC-n fault is detected in the timing direction, AIS is inserted on the derived DS1s which forces the BITS to switch to another good timing source or into holdover preventing timing loops.

Q. *How do I synchronize a BITS clock and maintain automatic synchronization reconfiguration on a SONET ring?*
A. Provision all but the host node (node with co-located PRS) for line timing. Provide each non-host BITS clock with a pair of derived DS1s. The SONET will detect faults and provide the BITS clocks with good inputs if available. Timing loops will be prevented. The host node should be set for external timing and get its timing from an externally timed BITS clock. To prevent a timing loop, the host BITS clock should get

its timing from a PRS traceable source. The non-host nodes should not be timed from the co-located BITS clock since this would disable the automatic synchronization reconfiguration feature.

www.sonet.com