Application Note

NextGeneration SONET/SDH Technologies

by Werner Habisreitinger

Introduction

Designed to optimize TDM-based traffic, SONET/SDH is very robust and reliable, containing built-in mechanisms to provide 99.999 percent network availability. However, SONET/SDH rings, which are the primary connection to the metropolitan area network (MAN), are not designed to handle bursty packet data efficiently. Additional constraints on performance are the result of the MAN's overly complex, multiple layers of poorly integrated technologies that limit flexibility. Further compounding these difficulties is the immense quantity of data traffic generated from LANs, DSL-based broadband connections, storage area networks (SANs), and local caching by ISPs. The stress that these applications place on the infrastructure puts carriers at financial risk when they are unable to deliver services or levels of performance demanded by the marketplace.

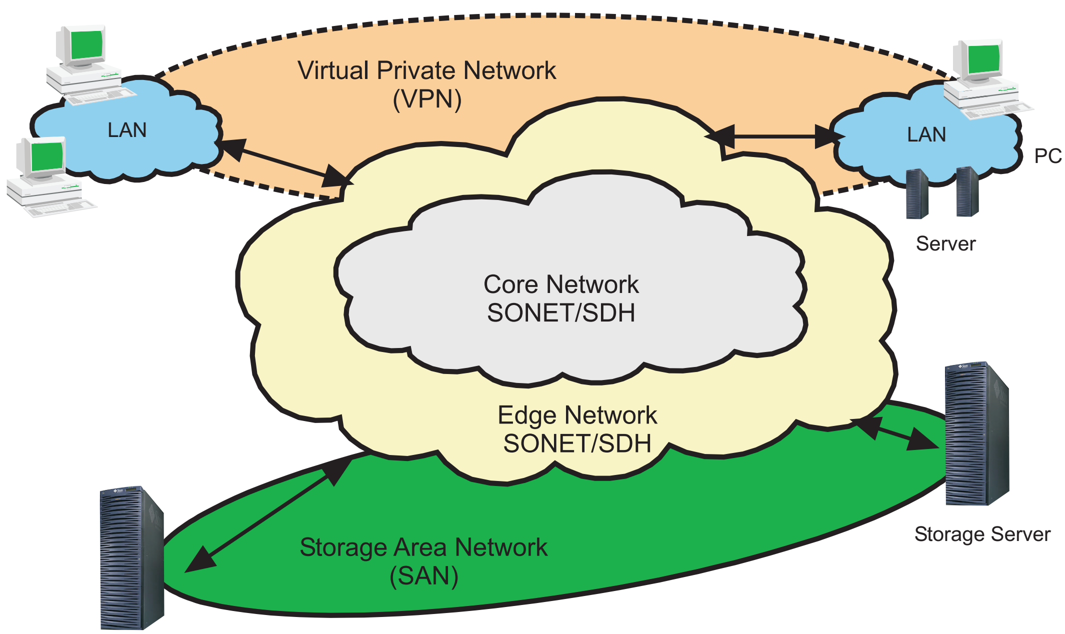

Figure 1: New services put new requirements on legacy SONET/SDH

Without enhancements to the MAN, carriers do not have the flexibility to manage bandwidth or the ability to quickly provision services and ensure network scalability and operational efficiency. However, they also realize that their economic survival depends on being able to optimize the existing SONET-based network's transport technology without spending large amounts of money or decommissioning any of the existing infrastructure.

Next-generation SONET/SDH's advantage over Ethernet

Next-generation SONET/SDH is an umbrella term describing a range of proprietary and standards-based developments that are built on the available SONET/SDH infrastructure. First deployed by long-distance carriers as a way to support new services such as Ethernet, Fiber Channel, ESCON, and DVB, next-generation SONET/SDH enables the delivery of high-speed, high-bandwidth data within very tight budget constraints.

Properties of the data services	Properties of SONET/SDH
Asynchronous transport	Synchronous transport
Dynamic bandwidth	Constant bandwidth
Connectionless	Connection-oriented

Ethernet's proliferation in LANs is largely due to its simplicity and cost-effectiveness. Standard Ethernet line rates are 10/100/1000 Mb/s with 10 Gb/s contending for a significant presence in the MAN. Because Ethernet is based on a best effort principle, meaning the transfer of data is not guaranteed, there is concern that Ethernet cannot fully provide the quality of service, security, redundancy, and restoration capabilities required for both data and voice traffic. The new Ethernet standard, 10 Gigabit Ethernet, will not only be 10 times faster than its predecessor, but it is designed to promote the convergence of networking technologies. However, to send a 10 Gigabit Ethernet signal directly to a legacy SONET ADM, Ethernet line termination equipment must buffer the incoming signal and convert it into a signal supported by SONET.

Although Gigabit Ethernet provides a common frame from the desktop to the backbone, a technology that serves as a transport service for storage, raw data, and audio/video, independent of the protocol, was needed. Fiber Channel (FC) was designed to remove many performance barriers that exist in legacy LANs and channels providing scalable Gigabit technology, control, self-management, and reliability at distances up to 10 km.

	Gigabit Ethernet	Fiber Channel
Applications	Data networks	SAN, audio/ video, data
Line rates	1.25 Gb/s	1.06 Gb/s, 2.12 Gb/s, 10 Gb/s
Frame sizes	Variable, 0 to 1.5 kB	Variable, 0 to 2 kB
Connection oriented	No	Yes

Although TCP corrects for this, delays and reduced bandwidth cause performance problems.

Next-generation SONET/SDH extends the utility of the existing SONET/SDH network by leveraging existing layer 1 networking and including technologies such as virtual concatenation (VC), generic framing procedure (GFP), the link capacity adjustment scheme (LCAS), and integrates the customer interface into the network elements.

Test applications

Putting into service test of a "Next-generation SONET/SDH" connection

The term "Next-generation" covers an entire conglomerate of different technologies that are built upon each other. The test described here assumes that the physical connection is good, and is only intended to check that the service offered is transmitted correctly. Where this is not the case or where the manufacturer needs to determine whether the solution

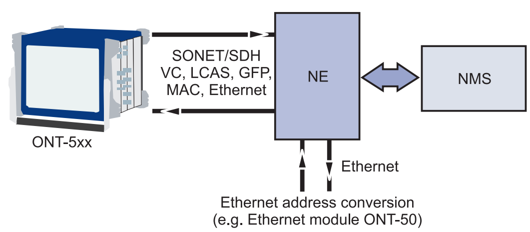

Figure 2 Test setup for putting into service measurement

provided operates in conformity with the applicable standards, the individual layers such as VC, LCAS, GFP or Ethernet should be investigated in more detail. The test applications for this are described in subsequent sections of this application note.

The simplest way to put these new network elements into service is to test the transparency of the payload.

Without doubt, the most common application for next-generation SONET/SDH is Ethernet transmission. However, the composition of next-generation SONET/SDH can vary from one user to another.

The test application described here assumes a maximum capacity configuration, but can be adapted to suit individual requirements.

The test can be done in two different ways. The first method is a full-channel measurement that is performed only at the SONET or SDH interface of a network element. This does however require a loop back at the Ethernet interface. It should be noted that a purely physical loop is not enough. A further test instrument or an ONT-5xx Ethernet test module must be used to convert the address of the packets received at the Ethernet port.

The first step is to match the configurations of the ONT-5xx and the network element. This firstly concerns the physical layer settings (bit rate, SDH or SONET, mapping, number of virtual containers, position and sequence numbers). Then you have to decide whether or not LCAS is to be activated, and to set the frame formats, addresses and Ethernet bandwidth for the GFP and MAC layers. Once these settings have been made, make sure that the link is alarm free and that Ethernet traffic is flowing. You can do this using an ONT-5xx in conjunction with the network management system.

The GFP / MAC status LED page or the Ethernet status page will give you a quick overview of the states of the various layers.

Figure 3: ONT-503/506/512 alarm overview

Depending on the test setup, the test parameters can be evaluated using both the Ethernet test module and the SONET/SDH receiver of the NewGen module of the ONT-5xx.

The test parameters are:

- Ratio of received bandwidth to transmitted bandwidth
- Ratio of the number of frames received to the number of frames transmitted
- Lost frames
- Average transfer delay
- Delay variation
- FCS errors

The ONT-5xx has several display modes that can be used for evaluation:

Figure 4: GFP/MAC traffic generation and analysis

You can vary the generated Ethernet bandwidth and display the dependent utilization of the GFP layer on both the TX and RX sides on this page.

In this figure, you can see that bit errors have occurred, as indicated by the FCS errors that are shown. Also, a loss of frame delineation (LFD) has occurred, which results in a LPAC. The cause cannot be determined directly, so a further analysis of the SONET/SDH layer is needed.

Figure 5: MAC error insertion and analysis

Virtual concatenation group test (without LCAS)

Virtual concatenation is a method that allows network operators to match the capacity of their SONET/SDH networks very efficiently to the transmission of new data services, such as Ethernet, or to a bandwidth demanded by a particular user. Several containers are virtually linked together in order to match the bandwidth required by the service being transmitted. Together, these groups of concatenated containers form a common payload, known as the virtual concatenation group or VCG. The tests described below check that setting up, expansion and reduction of a VCG has been accomplished without errors.

Example signal structure of device under test (DUT): STM-16 with 4 × VC-4 or OC-48 with 4 × STS-3c

The ONT-503/506/512 is configured with a VCG composed of a group of four VC-4 or four STS-3c. In this example, the group comprises VC-4/STS-3c numbers 1, 2, 3 and 4. The sequence number is determined according to the setting of the DUT, but can generally be selected at will, just like the channel number described above. The receiver will indicate a GP-LOM alarm or a payload mismatch if the selected channels and sequence numbers do not match up. Error-free transmission of the payload can then be checked using an Ethernet payload. HEC errors must not occur and the FCS must be received correctly.

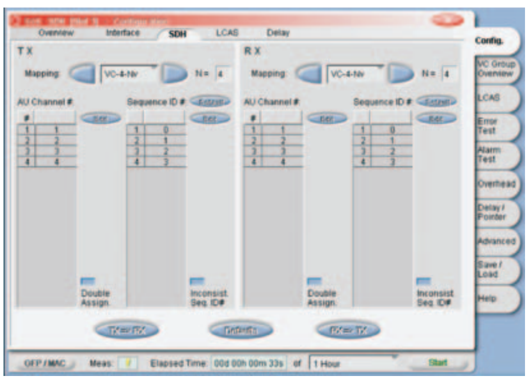

Figure 6: Configuration of VCGs

Function test: Increase bandwidth = expand VCG

The bandwidth of a transmission channel is matched to user requirements by adding or removing virtual containers. This is a basic function of virtual concatenation. The test described below verifies the reaction of the DUT to an additional or a missing member of a VCG.

Starting from the configuration described previously, the existing VCG is expanded by adding a further container. To do this, the number of containers in the ONT-5xx is increased from N = 4 to N = 5. Since this change has not yet been followed by the DUT, it reacts with LFD (Loss of Frame Delineation – GFP) alarms and the collapse of the Ethernet bandwidth to zero.

The new size of the VCG is now taken up by the DUT. The connection is once again error-free. The Ethernet bandwidth can now be increased in the ONT-5xx and can be read off in the GFP/MAC generator window.

Function test: Changing the sequence of VCs within a VCG

In the following test, the composition of the VCG is altered. VC-4/STS-3c container #3 is replaced by container #10. The change is made in the ONT-5xx using the window shown above.

The reaction of the DUT to a change in sequence number is also tested. To do this, the relevant channel is selected and the sequence number changed. For example: ONT-5xx TX: VC-4/STS-3c #1, SQ#0 -> SQ#1 and VC-4/STS3c #2, SQ#1 -> SQ#0. As long as these changes are made only in the ONT-5xx on the one side and not in the network element, the network element will register a GP-SQM alarm. All alarms should clear as soon as the settings are also made in the network element.

Error case: How does the DUT react to the loss of a VC?

The loss of a VC caused by an interruption or by the failure of a network element is a possible scenario in everyday operation. Because the members of a VCG can be transmitted over different paths within a SONET/SDH network, failure of one path leads to loss of a part of the VCG. In such cases, even the correctly received part of the VCG must also be rejected, since the transmitted service cannot be reassembled due to the missing part of the payload.

This scenario is generated by inserting an AU-AIS (SONET: AIS-L) alarm. The device under test must then reject the entire VCG as described above. The ONT-5xx detects a HP-RDI (SONET: RDI-P) alarm.

The test configuration shown in figure 7 can be used to check the reaction on the Ethernet side. The expectation is for the received Ethernet bandwidth to drop to zero.

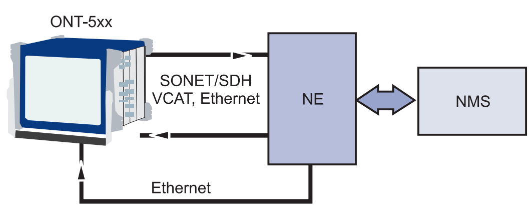

Figure 7: Interworking test

The case described above concerns a network element where LCAS is not employed. The reaction of a network element with LCAS is described in a later section.

Differential delay generation and analysis

When the network supports virtual concatenation, the payload is split and sent via different paths through a long-haul network. Because these two or more paths are not the same length and contain a different number of network elements, the VCG members do not reach the termination point at the same time. The terminating equipment must compensate for this differential delay to reassemble the payload. Naturally, this compensation must operate without errors even under the most difficult circumstances. Differential delay is caused by various factors. One of these is the difference in the lengths of the paths used by the VCG. This differential delay is relatively constant. Variable delay can be caused by the normal pointer actions in SONET/SDH networks or by switching to a back-up circuit.

Generation of differential delay

The maximum permissible differential delay is limited to 256 ms as a result of the ITU-T standardization of the multi frame indicator (MFI) parameter. This value is given by the number of bits that are available. This is, however, a purely theoretical limit, which is never likely to be fully utilized even under the worst conditions imaginable. For this reason, manufacturers are left to decide how much differential delay can be compensated for by their network elements. The ONT-5xx is capable of generating three different kinds of differential delay, making it possible to determine the performance of the device under test even for worst-case scenarios.

- **Direct mode**
  Direct mode allows you to set a defined propagation delay for the individual group members. The differential delay results from these delays. This mode can simulate a constant delay caused by length differences as well as a sudden change in delay caused by an APS switchover. The number of frames and pointers determines the magnitude of the delay. This interrupts the service briefly. Alarms occur in various different layers. The device under test should generally recover from this stimulus within a short period of time.

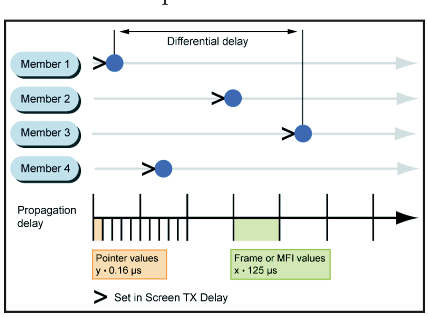

Figure 8: Differential delay – direct mode

Example:

- Set member 1 to n to 0 ms (one after another) and all others to maximum delay
- Set member 1 to maximum delay and all others to 0 ms

- **Pointer mode**
  A gradual change in differential delay occurs in this mode. Depending on the value set, you can simulate the normal behavior of SONET/SDH networks as well as extreme pointer adjustments caused by synchronization problems or wander.

  In all of this, the service must not be degraded in any way by errors or alarms.
  The pointer actions that occur are, however, registered by the network elements or test

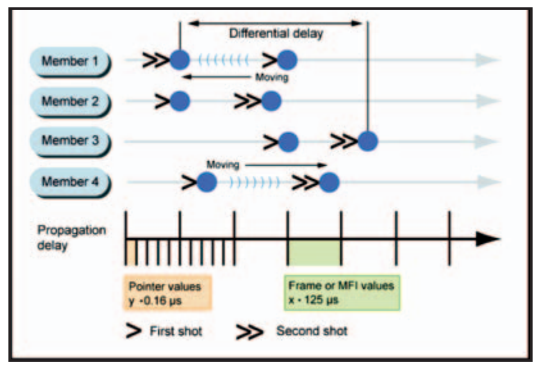

Figure 9: Differential delay – pointer mode

Example:

- Set members 1 to 4 to maximum delay and all others to 0 ms

- **Stress mode**
  In this mode, the device under test has to cope with a sequence comprising a mixture of phases with changing values and phases with constant values. Users can adapt this sequence individually to suit the test requirements. The aim is to simulate a combination of realistic worst-case scenarios for the network and to find out how the device under test reacts.
  As with pointer mode, service interruptions must not occur.

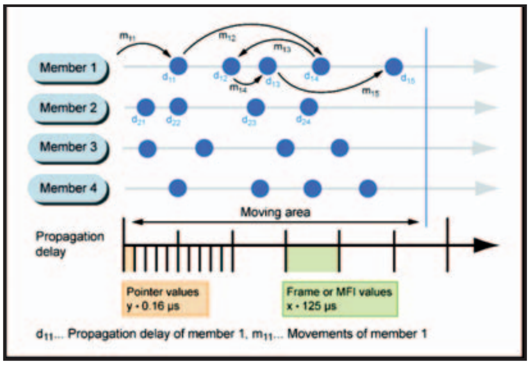

Figure 10: Differential delay – stress mode

Example:

Set maximum pointer speed (AU = 500/s). Set max. TX delay to the maximum allowed system value. Perform the test for 1 hour. Expected result: No errors/alarms.

Figure 11: Setting differential delay on the ONT-5xx

Differential delay analysis

Analysis of differential delay is particularly important during the installation of network elements. Theoretically, the differential delay between two paths can be calculated from available network topology data and the specifications quoted by systems manufacturers. Based on the maximum tolerable differential delay specified by the manufacturer and the calculated values, an estimate can be made which will be sufficient in most cases, particularly for mid-range distances. Differential delay analysis is, however, highly recommended for transatlantic links or links that utilize satellite paths or the networks of other providers. In such cases, measurement quickly and simply provides a clear statement.

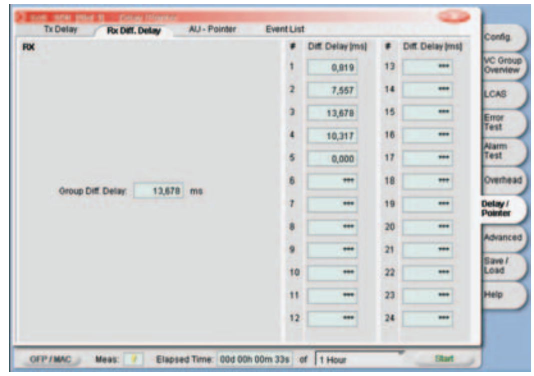

Figure 12: Differential delay analysis with the ONT-5xx

Testing the interaction of LCAS and VC

LCAS extends the range of functions already described for virtual concatenation. Using LCAS allows dynamic adaptation of the bandwidth to user demands. One major advantage of using LCAS is that there is no interruption in service when the bandwidth is adjusted. In other words, a user can for example be assigned more bandwidth without having to lose the use of an existing link for a certain period of time. There is a further advantage to both user and provider alike when a path failure occurs. Let us assume that a VCG consists of four VC-4, with two VC-4 in each case being transmitted via different paths through an SDH network. One of these paths is completely interrupted. This failure is signaled to the LCAS source by the LCAS sink. At this point, the LCAS source removes the two interrupted VC-4 from the transmission bandwidth and carries on using just the remaining two VC-4. Although this halves the bandwidth, the link is reestablished. As soon as the fault is repaired, the reinstated VC-4 are again used for transmitting the service. This increase in bandwidth takes place without interrupting the transmission that is in progress.

Figure 13: LCAS summary of sink and source

There are two primary aspects to testing LCAS: Firstly, to ensure that the bandwidth adaptation works to its full extent, i.e. exactly the desired bandwidth is available on completion of adaptation, and secondly to make sure that no interruptions in payload transmission and no bit errors occur during the adaptation process. The protocol sequence and LCAS state diagram will need to be subjected to further tests if these basic tests are not successful.

The network management system plays a decisive role in LCAS testing, as it triggers bandwidth adaptation in the network elements and also passes on status messages to the management system.

Transparency

First of all, you need to make sure that the static transmission between the device under test and the ONT-5xx is free of errors. This assumes that the SONET/SDH signal structure as well as the VCG settings described previously are matched.

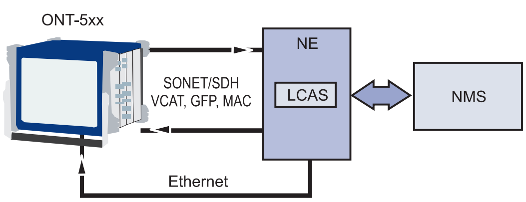

Figure 14: Testing the interaction of LCAS and VC

The LCAS protocol can subsequently be activated in both the DUT and the ONT-5xx. The transmission must still be error free after this step is taken. In the ONT-5xx, the FCS field in the MAC frame or the MAC lost frame counter = 0 serves as an indication of error free payload transmission just as with the test applications described previously.

Changing the bandwidth – normal life cycle

The LCAS protocol has been standardized by international bodies such as ITU-T and ANSI to guarantee compatibility between the system solutions provided by different manufacturers. These standards describe in detail the processes for adding and subtracting virtual containers. An important part of this standardization includes state machines for the LCAS source and LCAS sink and, finally, communication between the two sides. Since the forward and return paths of an LCAS link are configured independently, the generator and receiver of the device under test must be investigated separately.

ONT-503/506/512 TX -> DUT RX

The ONT-5xx allows you to emulate the LCAS protocol and thus to check that a device under test is operating according to the standard under realistic conditions.

The transmit status of the individual group members is shown along with the receiver confirmation (received MST control) as depicted in figure 15 below. This display gives users a very good overview of any changes initiated and the corresponding reactions of the device under test.

GFP/MAC is also used as the test payload in this test application. When configuring the device under test, you must pay particular attention to ensuring that the MAC packets get back to the ONT-5xx again.

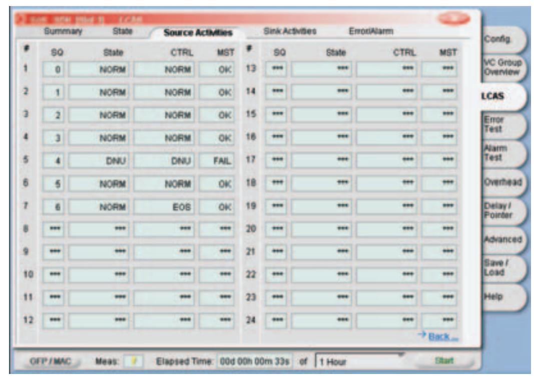

Figure 15: LCAS generator settings and status

Example: There is an LCAS link from the ONT-5xx to the DUT consisting of two VC-4 containers (VC-4-2v) and also an LCAS link from the DUT to the ONT-5xx consisting of one VC-4. The return path is needed for LCAS; otherwise the return responses cannot be transmitted from the sink to the source (see figure 16).

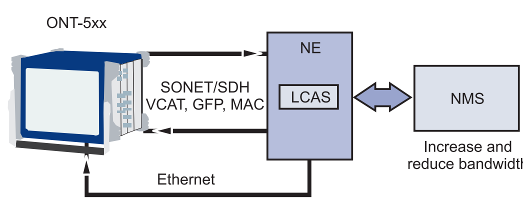

Figure 16: Starting point for the LCAS test

The container status for VC4 #1 = NORM and VC4 #2 = EOS. Select any container to add a further container to the VCG. The container now has IDLE status. The container is activated using the "Add" button, thus contributing to an increase in the bandwidth. This action is also reflected in the graphical overview. After the action, the selected container has the status VC-4 #3 = EOS. The status of VC-4 #2 changes to VC4 #2 = NORM. This action should be confirmed with MST = OK and RS-Ack inverted by the DUT acting as LCAS sink.

No transmission errors should be detectable in the payload as LCAS is provided for interrupt-free bandwidth expansion. This is best checked in the "GFP/MAC Analyzer - MAC details" window. No frame losses should be indicated there.

At the same time, a successful increase in bandwidth can also be recognized by a corresponding change in the GFP/MAC bandwidth. To do this, manually increase the Ethernet bandwidth of the generator in the ONT-5xx and check the result display of the analyzer.

Frame size	MAC bandwidth	GFP bandwidth with GFP FCS	GFP Bandwidth without GFP FCS
64 bytes	10 Mb/s	11.874 Mb/s	11.249 Mb/s
256 bytes	10 Mb/s	10.469 Mb/s	10.313 Mb/s
1518 bytes	10 Mb/s	10.080 Mb/s	10.052 Mb/s

Expected measurement results – Ethernet frame format 802.3

A more stringent version of this test is represented by virtually simultaneous addition of all the containers of a VCG. This can be realized without any problems by using the ONT-5xx.

This test should also be performed for reducing the bandwidth by individual containers in a similar manner. Here, too, transmission errors in the payload should not occur.

Along with the IDLE and OK states, the state machine of the LCAS sink includes a further state: FAIL. This message indicates to network management that the affected container of the VCG is not being received any more. Network management can derive actions from this, such as switching the affected container via a back up path.

A message is also returned to the LCAS source at the same time.

The ONT-5xx allows you to generate a lost container by means of AIS insertion. The status of this container is set to FAIL. This network element reaction can be traced with the help of the management system. At the same time, a message is sent to the LCAS source using MST. This results in the status of the affected container being set to DNU. The LCAS source will no longer pass on the contents of this container.

DUT TX -> ONT-503/506/512 RX

The test scenario described so far primarily concerns testing of the LCAS link from the ONT-5xx to the DUT. Bandwidth adaptations in the reverse direction are based on changes in the state machine for the LCAS source in the network element. These can only be initiated by the management system. The reaction on the LCAS layer is monitored by the ONT-5xx. In this way, you can determine whether LCAS is operating properly and is correctly linked in to the management system.

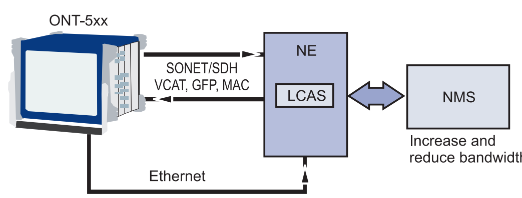

Figure 18: Testing the LCAS source in a network element

GFP and MAC test

The GFP and MAC test is based on the assumption that the

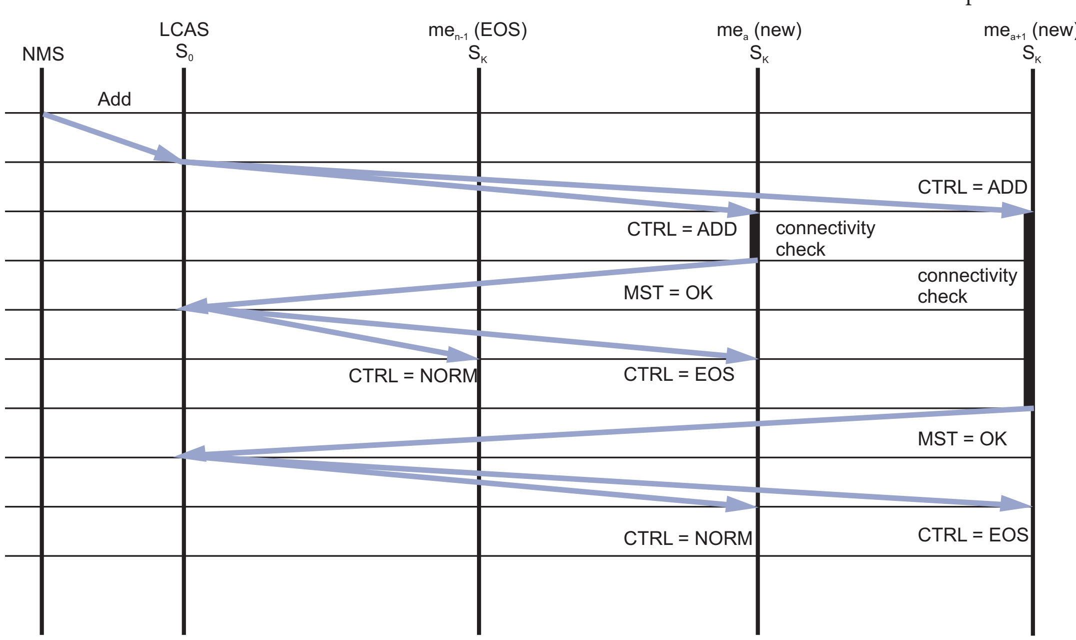

Figure 17: ITU-T G.7042 Handshake diagram for adding multiple containers

subordinate layers such as SONET and SDH function without errors in possible combination with VC and LCAS.

The following functions should be tested for GFP:

- GFP header generation and analysis, e.g. correctable or uncorrectable errors
- Bandwidth adaptation: does GFP adapt to VC bandwidth changes without errors?
- Payload mapping and demapping
- Generation of GFP management frames

GFP overhead generation and analysis

GFP handles the adaptation to the transport layer of widely differing clients such as Ethernet, FICON, ESCON and others. As a result, the GFP frame must have formats and contents that match the payload type. Next-generation network elements can be configured individually for the various services.

The ONT-5xx is used to check whether the frame contents have been implemented to conform to the standards.

Plain text selection is used in the ONT-5xx to set the format and content of the GFP header. Network management can then be used to check that these contents are correspondingly recognized by the network element.

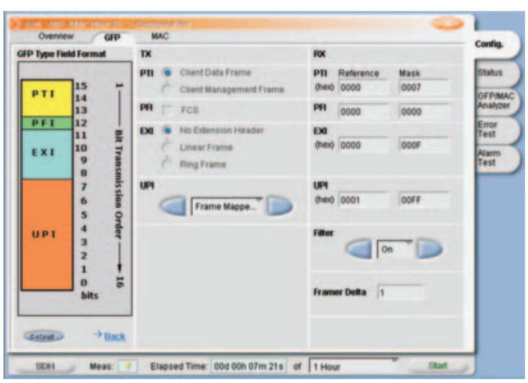

Figure 19: Setting the GFP payload header

In most cases analysis of the GFP overhead requires the use of a filter. In practice, this filter allows you to extract the relevant test channel from the large number of different GFP channels.

GFP error insertion and analysis

The GFP core header includes an header error control (HEC) field. This 16-bit wide field contains a CRC-16, which makes it possible to correct single bit errors and to detect multiple bit errors in the header. In this way, the length indicator (PLI) contained in the core header next to the CRC field is protected against transmission errors that may occur. An incorrect length indication for the GFP frame will always result in loss of synchronization on the receiver side. For this reason, it is important that this function is tested.

Fiure 20: GFP error insertion and evaluation

Figure 20 shows the possible insertions that can be made with the ONT-5xx as well as the result displays. You can insert single or multiple errors. These errors should be detectable in the network element with the aid of the network management system. The network element should go out of step briefly when several errors are inserted. This is indicated by a loss of frame delineation (LFD) alarm. Frame synchronization must, however, be reestablished by the network element.

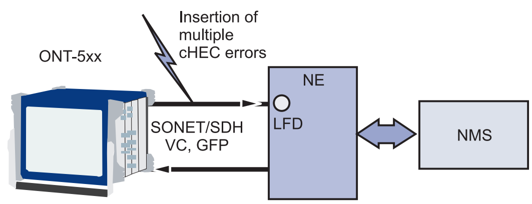

Figure 21: Insertion of cHEC errors

MAC frame generation and analysis

The media access control (MAC) frame primarily contains the address information for transmission of the Ethernet frame. Further parameters depending on the encapsulated type of Ethernet frame are also present. These are the settings that need to be made before a test is performed. The ONT-5xx employs a user-friendly selection list for setting the frame type.

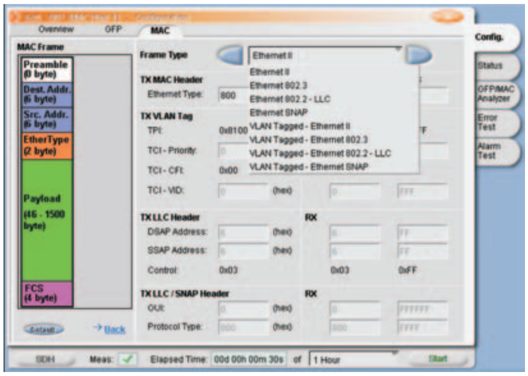

Figure 22: Setting the MAC frame

You must make sure that the corresponding Ethernet packets are filtered out from the large number of packets on the receive side.

MAC error insertion and analysis

Insertion and analysis of errors depends on the selected type of Ethernet frame. Service transparency can be determined using the “Errored” and “Lost Packets” parameters.

Please note that very low error rates can only be determined with correspondingly very long measurement times. The error types are described in the theory section of this application note.

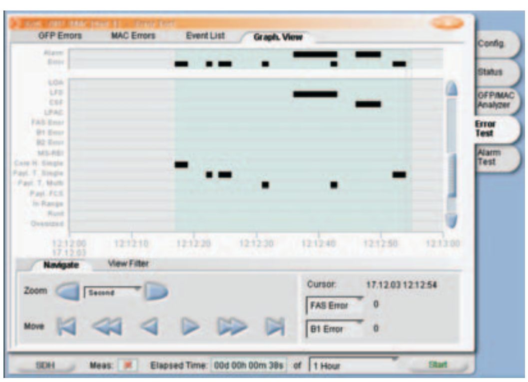

Figure 23: Graphical error analysis

Components of next-generation SONET/SDH – technical background

Virtual concatenation

The traditional method of concatenation, as defined in standards such as ITU-T G.707, is termed “contiguous.” This means that adjacent containers are combined and transported across the SONET/SDH network as one container. Contiguous concatenation’s limitations included the necessity that all network nodes that are part of the transmission path must be able to recognize and process the concatenated container and the lack of bandwidth granularity, which makes transporting many data signals inefficient.

Virtual concatenation, as recently defined by the ITU-T & ANSI, addresses the drawbacks associated with the contiguous method. Virtual concatenation maps individual containers into a virtually concatenated link. Any number of containers can be grouped together, which provides better bandwidth granularity than attained using traditional tech-niques. In addition, it enables network operators to adjust the transport capacity to the required customer service for greater efficiency. Because the intermediate network nodes treat each container in the link as a standard, non-concatenated container, only the path originating and path terminating equipment need to recognize and process the virtually concatenated signal structure. This means that each link can take its own path through the network, which can lead to phase differences between containers arriving at the path terminating equipment, requiring the equipment to buffer delays.

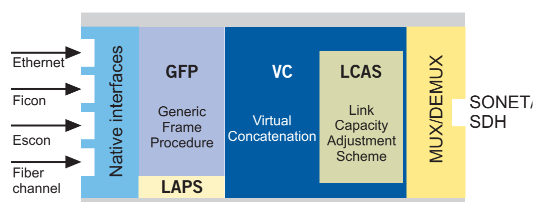

Figure 24: Overview of next-generation SONET/SDH

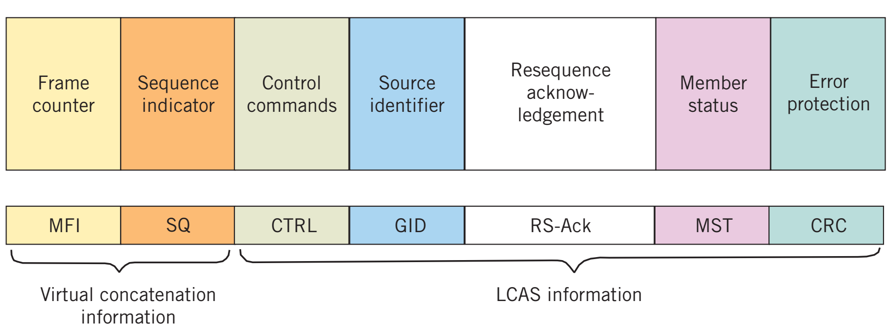

Figure 25: VC/LCAS control packet

Today's transport granularities are defined by the standard line rates STM-0/1/4/16 and STM-64 (OC-1/3/12/48 and OC-192). For example, a 1 G service is currently transported via an STM-16 channel. In this case, the actual transport capacity efficiency is about 42 percent. The group VC-4-7v is a virtual concatenated group (VCG), where VC-4 defines the basic granularity and 7v defines the number of members in the group, for nearly an 85 percent gain in efficiency.

Service	Transport capacity efficiency without VC	Transport capacity efficiency with VC
Ethernet (10 Mb)	VC-3 --> 20%	VC-12-5v --> 92%
Fast Ethernet (100 Mb)	VC-4 --> 67%	VC-12-47v --> 100%
ESCON (200 Mb)	VC-4-4c --> 33%	VC-3-4v --> 100%
Fiber Channel (1 Gb)	VC-4-16c --> 33%	VC-4-6v --> 89%
Gigabit Ethernet (1000 Mb)	VC-4-16c --> 42%	VC-4-7v --> 85%

The information required for virtual concatenation is transported in the path overhead of the individual containers.

	SDH	SONET
High order path	H4	H4
Low order path	K4	Z7

The parameters required for virtual concatenation are the frame counter (MFI) and the sequence number (SQ).

Because members of a VCG can travel through the network via different paths, they do not all arrive at the destination port at the same time. To eliminate differential delay and guarantee the integrity of all the members in a group, a sequence number (SQ) is assigned to each member.

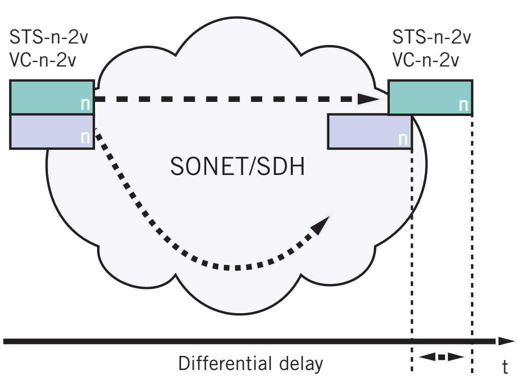

Figure 26: Differential delay

The MFI can detect differential delays between VCG members and compensate for them up to 512 ms. The parameters describing the frame counter and sequence number are summarized in the following table.

Path	Number of frames	Sequence number
High order path	0 – 4095	0 – 255
Low order path	0 – 4095	0 – 63

LCAS

A more recent standard development is the LCAS protocol, which runs between two NEs that are connected at the customer interface to the traditional SONET/SDH network. Each H4/K4 byte transports a control packet, which consists of information regarding virtual concatenation and parameters of the LCAS protocol.

By determining which members of a VCG are activated and how they are used, LCAS enables the originating equipment to dynamically change the number of containers in a concatenated group in response to a real-time change in bandwidth requirement. This increase or decrease in the transport bandwidth can be accomplished without negatively influencing the service. For example, a company that is supported by a 500 Mb/s link between branches during normal business hours needs a higher bandwidth to perform updates during off hours. With LCAS, 1 Gig of additional bandwidth is automatically provisioned without any adverse impact to service.

The following parameters in the control packet are relevant for the LCAS protocol:

- Control commands (CTRL) synchronize the source and receiver and transport information regarding the status of the individual members of a VCG
- Source identifier (GIP) tells the receiver which VCG a particular member belongs
- Resequence acknowledgement (RS-Ack) notifies the source that the receiver received initiated changes
- Member status (MST) transfers the status of the link from the sink to the source for each individual member of the VCG (OK=0, FAIL=1)
- Error protection (CRC) detects errors and discards errored control packets for individual members of the VCG

Generic framing procedure

Encapsulation techniques such as the generic framing procedure (GFP) must be applied to adapt asynchronous, bursty traffic and variable frame sizes before data service traffic such as IP/PPP, Ethernet MAC, Fiber Channel, ESCON, and FICON is transported over SONET/SDH networks. GFP adapts a frame-based data stream to a byte-oriented data stream by mapping the diverse services into a general-purpose frame, which is then mapped into the well-known SONET/SDH frames. This framing structure is better at detecting and correcting errors and provides greater bandwidth efficiency than traditional encapsulation procedures.

- The four parts comprising the GFP frame are the core header, payload header, actual payload area, and optional error detection field.
- Core header defines the GFP frame length and detects CRC errors
- Payload header defines the type of information transported, either management frames or client frames as well as the content of the payload
- Client payload information defines the actual transport payload
- Optional FCS detects errors
- There are currently two modes of client signal adaptation defined for GFP:
  GFP framed (GFP-F), where one data signal frame is mapped in its entirety into one GFP frame

GFP transparent (GFP-T), where data signal block codes are mapped into periodic GFP frames

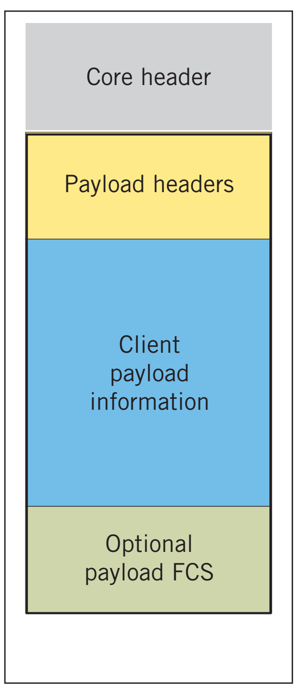

Figure 27: GFP frame

The mode used is dependent on the service being transported; however, to date, Ethernet is the data client signal defined for GFP-F, with Fiber Channel soon to follow. GFP-T maps any data client signal including Ethernet, Fiber Channel, and ESCON. The services mapped via GFP-F consume the least amount of overhead to guarantee the greatest bandwidth efficiency, whereas the priority of those mapped via GFP-T is the fast, efficient transport of data.

In addition to GFP as an adaptation mechanism, there are other methods. Of these, the link access protocol (LAPS) and the high-level data link control (HDLC) are the two predominant framing mechanisms. However, GFP supports multiple services, and it has higher flexibility so that it can be used in combination with OTN and higher stability, which offers the possibility of introducing GFP multiplexing structures.

Mode	Description	Application
GFP-F	Service is mapped frame-by-frame into the GFP frame Minimal overhead Variable GFP frame length	Fast Ethernet, Gig Ethernet, IP, etc.
GFP-T	Service is mapped byte-by-byte into the GFP frame Optimized transfer delay Constant GFP frame length	Fiber Channel, FICON, ESCON, Ethernet, DVB, etc.