SONET INFORMATION GUIDE

SONET ACRONYM DECODES

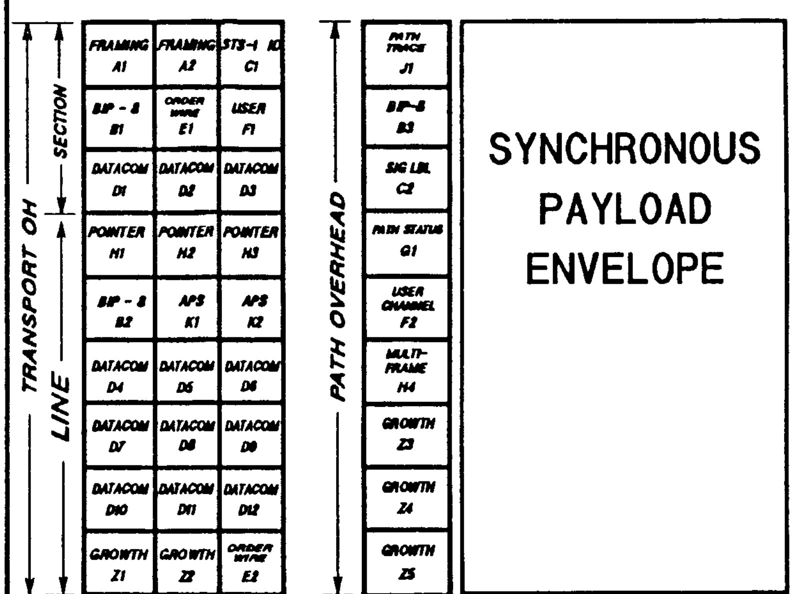
AIS - ALARM INDICATION SIGNAL
ADM - ADD-DROP MUX
APS - AUTO PROTECT SWITCH
ATM - ASYNC TRANSFER MODE
BIP - BIT INTERLEAVED PARITY
BISDN - BROADBAND ISDN
CBO - CONT BIT STREAM ORIENTED
COA - CRAFT, ORDERWIRE, ALARM
CV - CODE VIOLATION
DCC - DATACOM CHANNEL
DCS - DIG CROSS-CONNECT SYSTEM
DLC - DIGITAL LOOP CARRIER
EOC - EMBEDDED OVER-HEAD CHAN
ESS - ELECT SWITCH SYSTEM
FEBE - FAR END BLOCK ERROR
FERF - FAR END RECEIVE FAIL
INA - INTEGRATED NETWORK ACCESS
IOC - INTEROFFICE CHANNEL
IU - INTERFACE UNIT
LEN - LOCAL EXCHANGE NODE
LOF - LOSS OF FRAME
LOP - LOSS OF POINTER
LOS - LOSS OF SIGNAL
MIS - MANAGEMENT INFO SYSTEM
NDF - NEW DATA FLAG
NE - NETWORK ELEMENT
NNI - NETWORK NODE INTERFACE
NT - NETWORK TERMINATION
OC - OPTICAL CARRIER
OH - OVERHEAD
OOF - OUT-OF-FRAME
OSS - OPERATION & SUPPORT SYSTEM
PIC - PHOTONIC IC
PM - PERFORMANCE MONITORING
POH - PATH OVERHEAD
PVC - PERMANENT VIRTUAL CONNECTION
RMN - REMOTE MULTIPLEXER NODE
RT - REMOTE TERMINAL
RTU - REMOTE TEST UNIT
SDH - SYNC DIGITAL HIERARCHY
SMF - SINGLE MODE FIBER
SNI - SUBSCRIBER NETWORK INTERFACE
SOH - SECTION OVERHEAD
SPE - SYNCHRONOUS PAYLOAD ENVELOPE
STE - SECTION TERMINATING EQUIPMENT
STM - SYNCHRONOUS TRANSPORT MODE
STS - SYNCHRONOUS TRANSPORT SIGNAL
SVC - SWITCHED VIRTUAL CIRCUIT
SYNTRAN - SYNCHRONOUS TRANSMISSION
TE - TERMINAL EQUIPMENT
TM - TERMINAL MULTIPLEXER
TOH - TRANSPORT OVERHEAD
TSI - TIMESLOT INTERCHANGE
UNI - USER NETWORK INTERFACE
VT - VIRTUAL TRIBUTARY
WDM - WAVELENGTH DIVISION MUX

COMMON SONET BIT RATES

OPTICAL	RATE (MB/s)	DS-0'S (1)
OC-1	51.84	672 (2)
OC-3	155.52	2,016
OC-12	622.08	8,064
OC-24	1244.16	16,128 (2)
OC-48	2488.32	32,256
OC-96	4976.64	64,512 (3)

(1) ASSUMES 1 DS-3 PER STS-1 (2) NOT WIDELY DEPLOYED
(3) NEXT RATE TO BE DEPLOYED

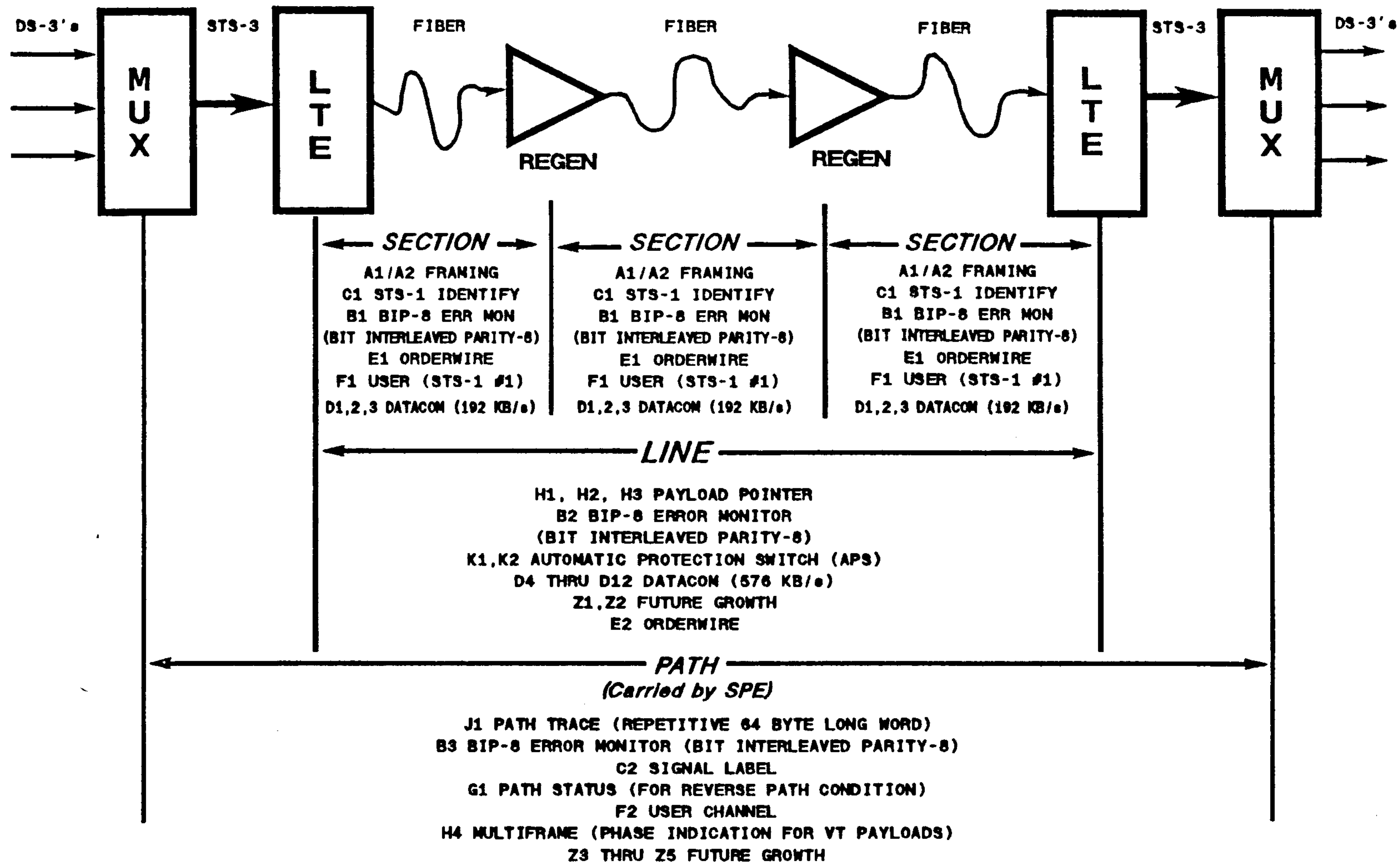
SONET OVERHEAD STRUCTURE



SONET1
S. HAMMOND
3/28/92

HEWLETT PACKARD

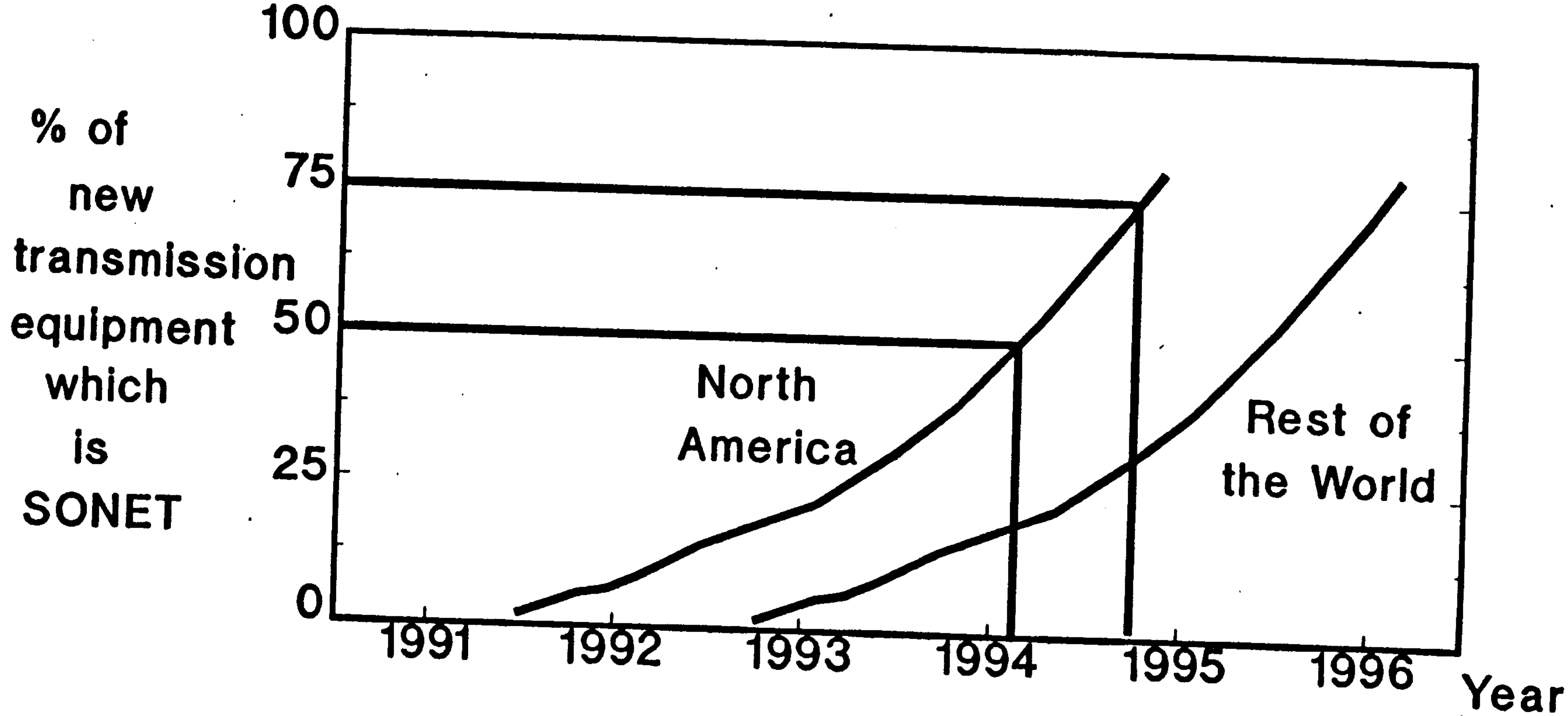
SONET OVERHEAD LAYERS AND OVERHEAD BYTES



NOTICE THAT...

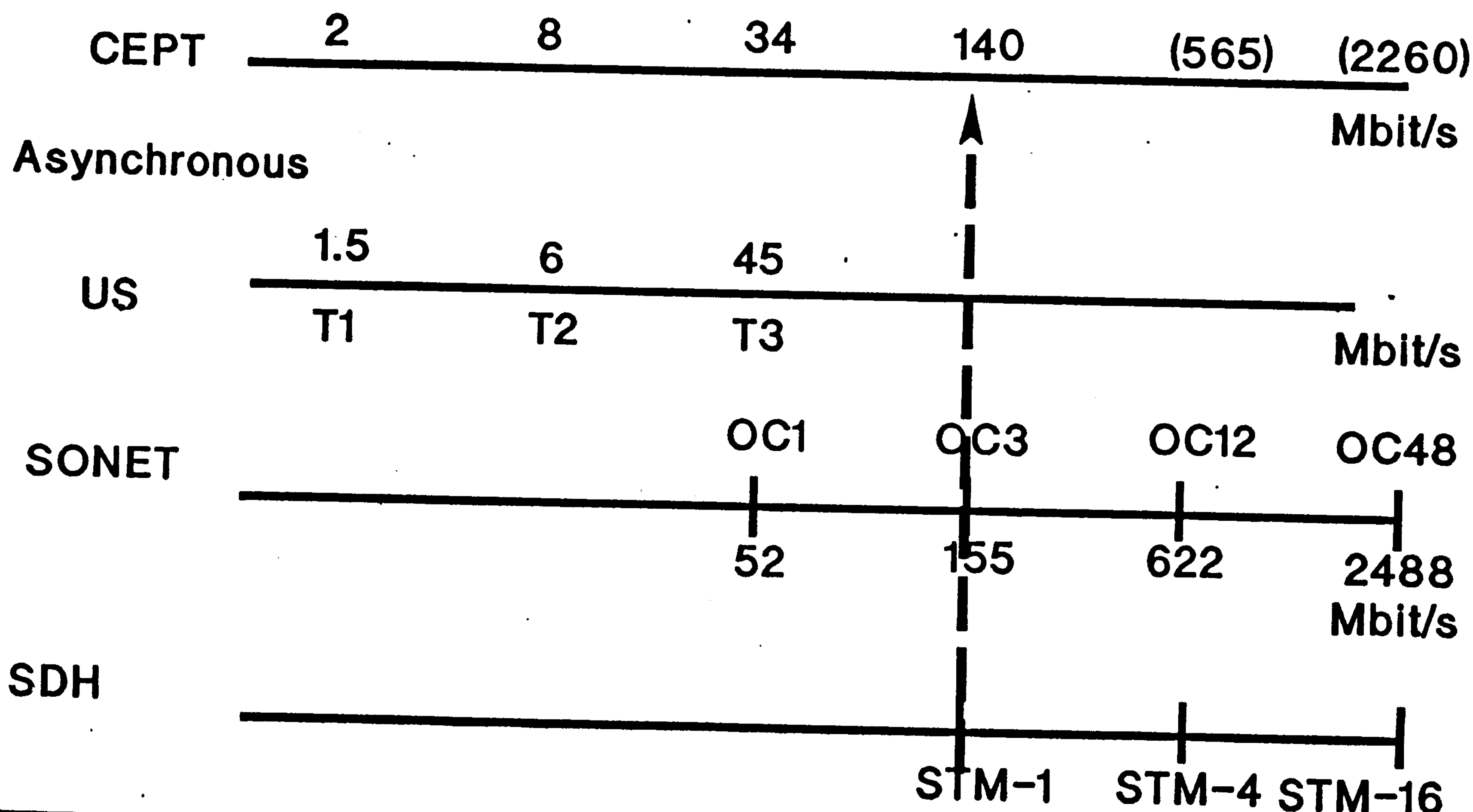
"B" BYTES (B1,2,3) USING BIP-8 ERROR MONITOR TECHNOLOGY, ARE USED IN ALL THREE LAYERS.
"D" BYTES (D1-3, D4-12) ARE DATACOM BYTES...SECTION LAYER (192 KB/s) ...LINE LAYER (576 KB/s)
"C" BYTES ARE IDENTIFIER OR LABEL BYTES, "E" BYTES ARE ORDERWIRE BYTES
"Z" BYTES ARE RESERVED FOR FUTURE GROWTH AND.. "F" BYTES ARE USER CHANNEL BYTES.

SONET/SDH Development Progress

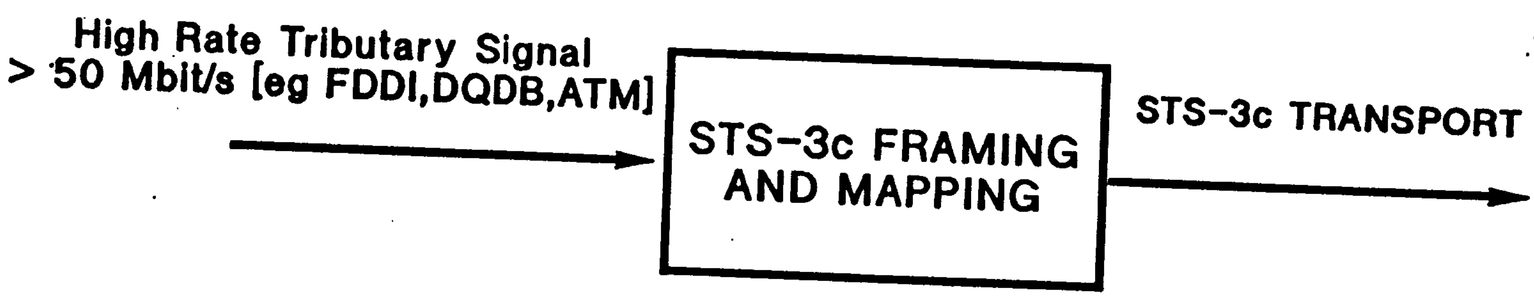


Source: Dataquest

Comparison of existing rates and SONET

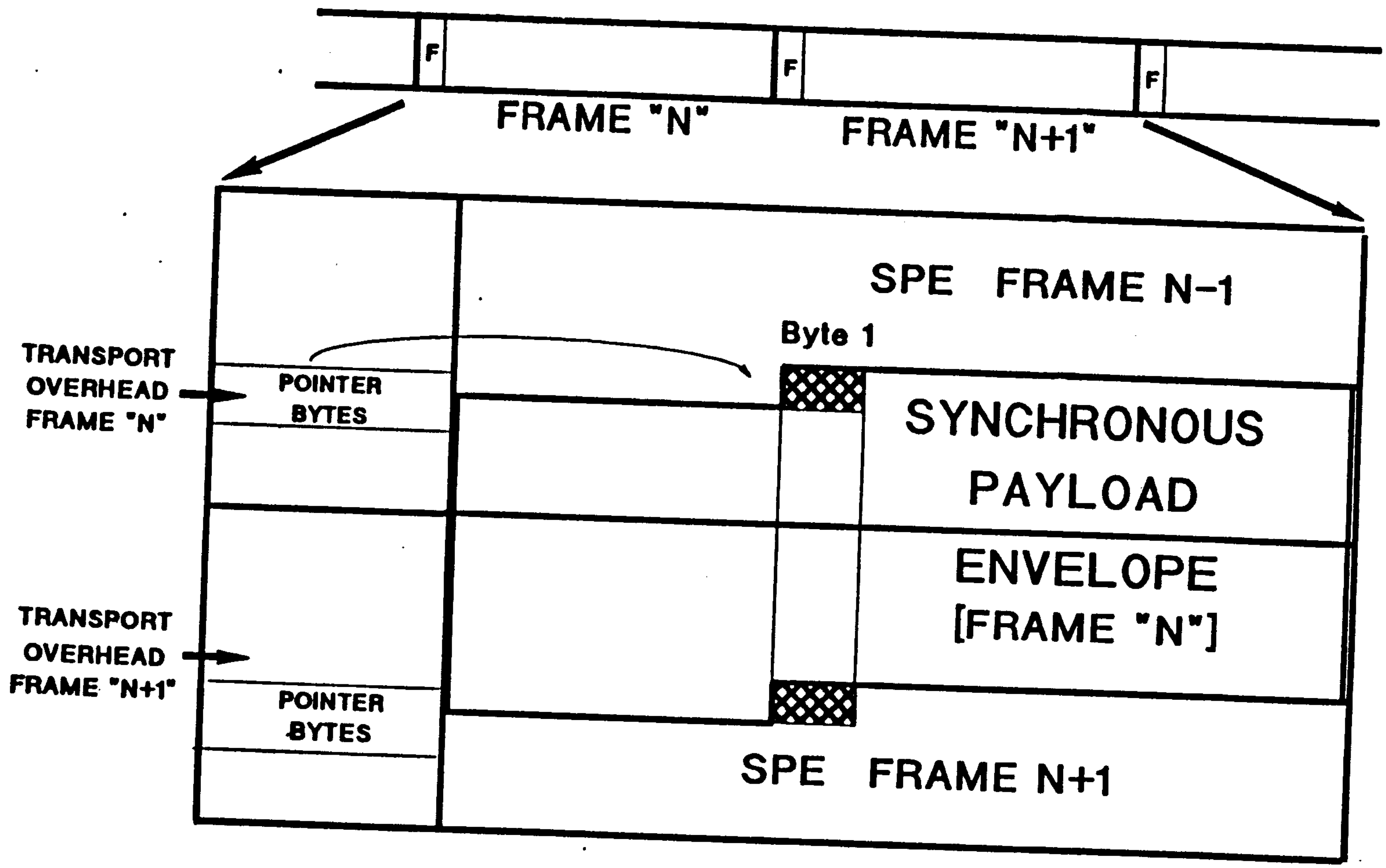


New services with higher bit rate than DS3 - Concatenation

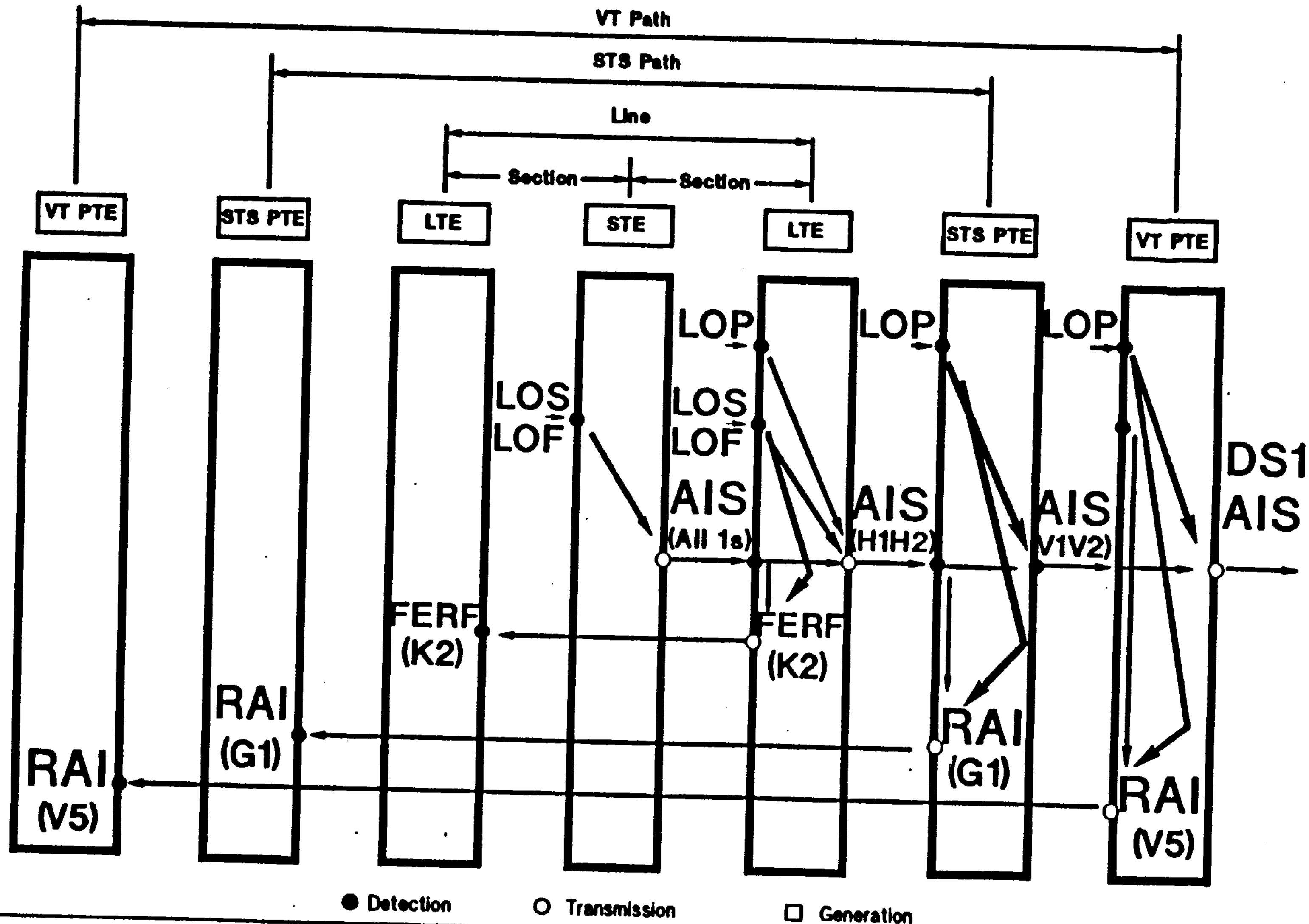


example STS 3c. (c) for concatenation

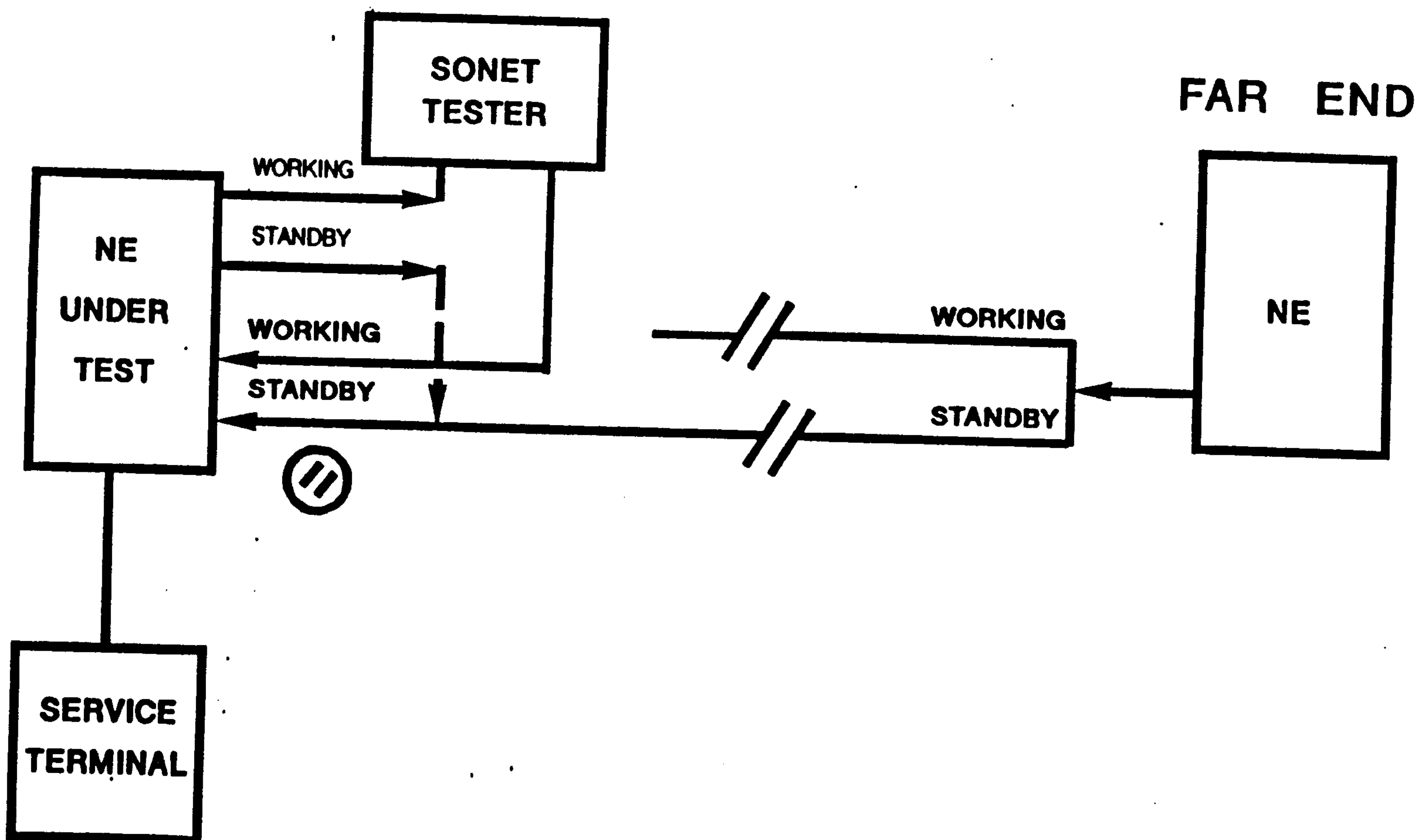
Link Between Transport Overhead and SPE



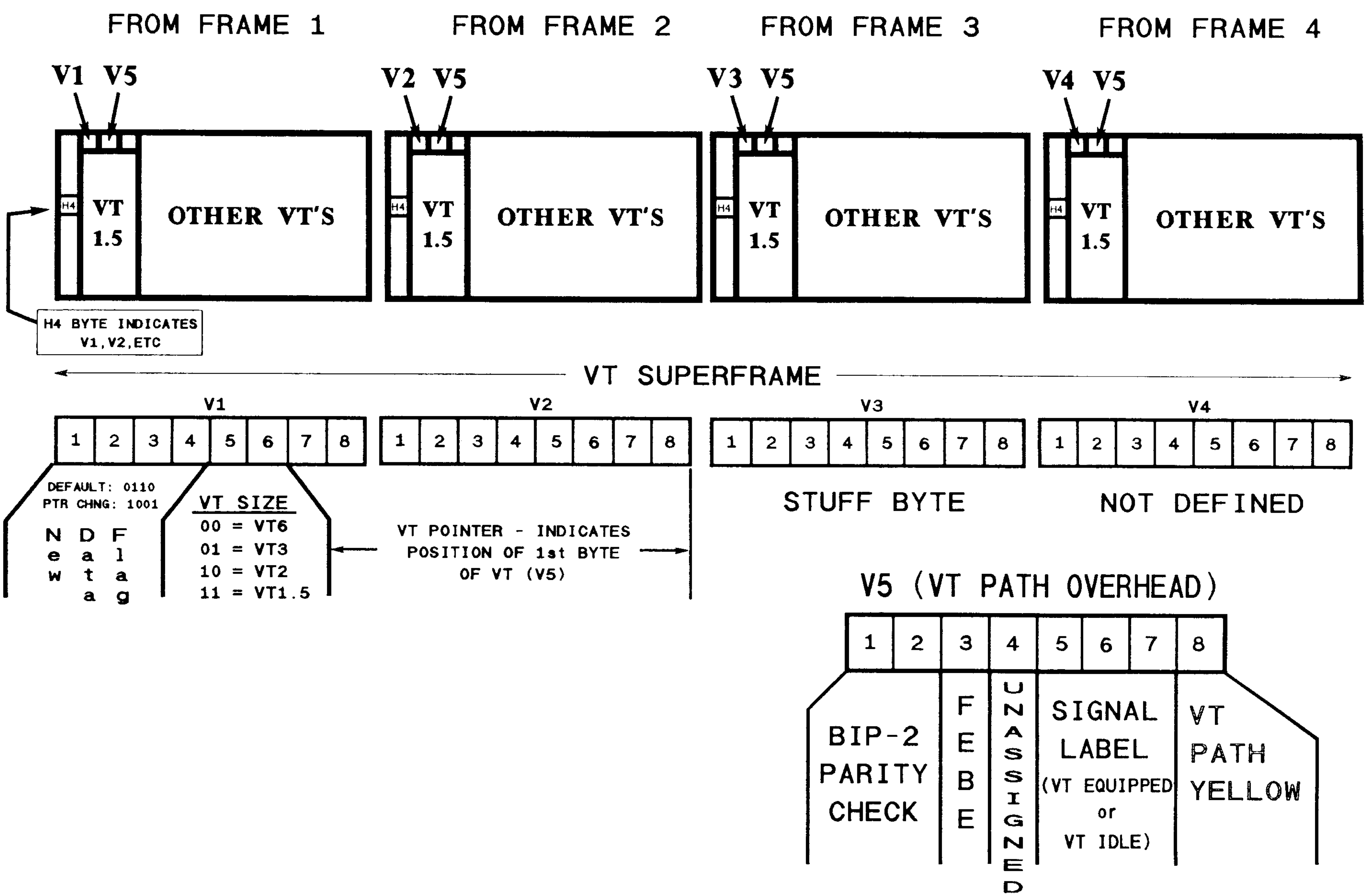
In-service Testing



Protection Testing with a SONET Tester



VT FLOATING MODE STRUCTURE



Testing SONET Networks

by Steve Bates, Hewlett Packard
CERJAC Telecom Operation

Today, SONET equipment is being deployed extensively in telecommunications networks to support transport of digital services and, more recently, ATM services. In order to ensure acceptable levels of service quality, equipment and networks must be tested for proper operation and, ultimately, proper transport of customer signals.

The overhead associated with SONET signals provides a means for quantifying the performance of SONET networks. However, this overhead is not always sufficient for characterizing, installing and maintaining SONET networks. Therefore, testing is often required.

Characterization of SONET Networks

Characterization, or conformance testing, is most often performed at the equipment manufacturer or in first-office applications. The primary purpose of conformance testing is to verify electrical/optical signal characteristics, signal rates and formats, and proper operation of overhead functions (e.g. performance monitoring, maintenance and alarms).

Conformance testing is most often performed at the equipment manufacturer.

Characterization must be conducted to recognized national and international standards for SONET. Some of the applicable standards include:

- TR-NWT-000253 (Issue 2)
- TA-NWT-000253 (Issue 8)
- T1.105
- T1.231

Characterization generally consists of an exhaustive suite of tests that are designed to determine whether the SONET equipment in question performs "as advertised". To ensure impartiality, the test equipment used for characterization must be independent of the network equipment. There are several organizations that offer certification for SONET network equipment against recognized standards.

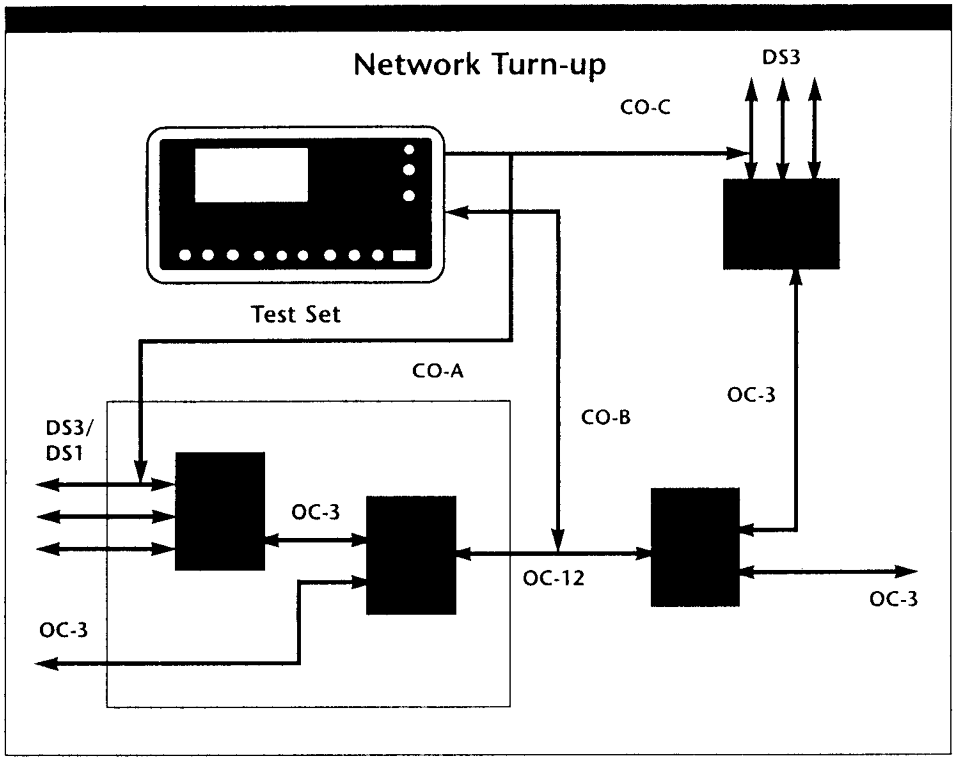


Figure 1.

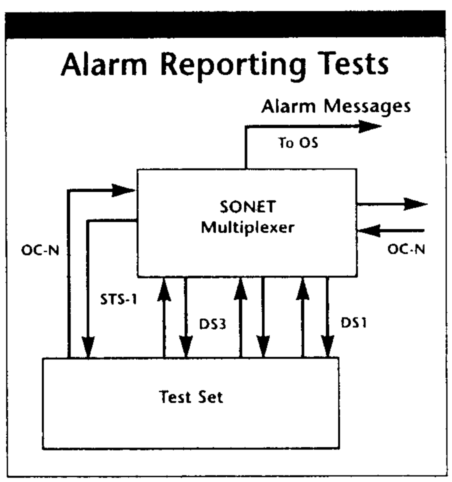


Figure 2.

Installation Testing

Actual equipment installations bring another set of testing challenges. Conformance testing alone does not guarantee that equipment will operate "properly" in the network. Testing must be conducted during installation, to ensure proper connectivity within the network and error-free signal transport.

In most cases, once SONET equipment is installed and functioning properly, an initial battery of tests is performed to verify the provisioning of the system - i.e. to make sure the tributary signals are mapped properly, that timing sources are properly configured, etc. Given the extensive use of SONET add-drop multiplexers and, more recently, SONET digital cross-connects, one of the most important functions of these tests is to verify proper mapping of the tributary signal through the network (see Figure 1).

The equipment used in these tests generally is required to provide the resources to perform end-to-end testing, in order to verify that customer circuits are operating properly. Test equipment should also have multiplexing capability to allow

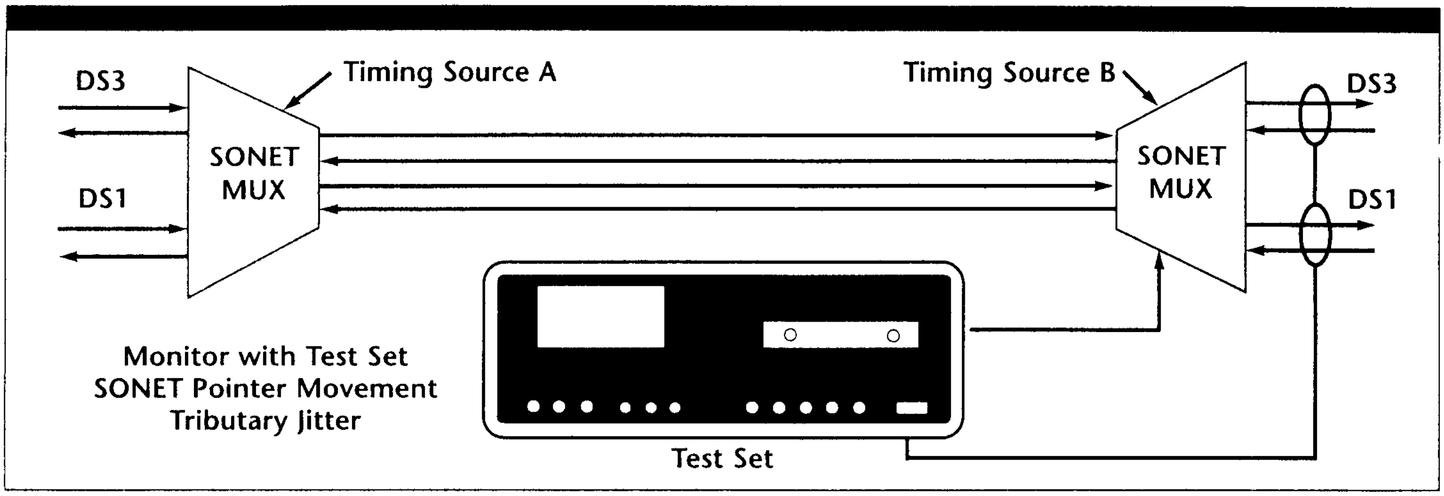


Figure 3.

testing of tributaries within higher-rate signals, such as DS3/DS1 tributaries within SONET OC-12 transport. This enables full transmux testing to take place.

As SONET networks grow, it becomes increasingly common for equipment from different vendors and service providers to meet mid span. Today, most vendors conform to the broad outlines of SONET standards. However, while these standards help to ensure that different vendors' equipment will interconnect reasonably well, they do not guarantee that the equipment will interoperate properly. Thus, testing may be required to identify and correct interoperability problems.

Some of the most common interoperability difficulties that can be diagnosed by testing include:

• VT1.5 Mappings - Vendors have developed a variety of interpretations of the VT1.5 numbering scheme, based on the input VT number or the VT ID number. For example, VT1.5 #2 may be mapped to VT1.5 #5. All VT1.5 are present, but may not appear on the expected output port, depending on the actual mapping scheme in use.

• H1 Byte - The SONET standard states that bits 5 and 6 in the H1 byte are a "don't care" for SONET mappings and should be ignored by SONET equipment. (In SDH, they are normally set to 01 as an indication that the signal is SDH.) Several equipment vendors have discovered, however, that many pieces of SONET equipment will alarm and not pass traffic correctly if this bit is set. In reality, this bit should be set to zero to guarantee proper operation.

• DCC Communication - Standards for DCC communication continue to be in development. In the interim, vendors have implemented proprietary schemes of communication over the section and line DCCs. In a mid-span meet, there is the possibility of unintended actions resulting from communications over the DCC. Testing allows direct access and monitoring of these channels as the traffic is being passed. It may also be important to block these channels.

Maintenance Testing

Once a system is up and provisioned properly, testing can be useful for verifying proper alarm generation and reporting (including APS switching), and reporting to higher-level OS systems (see Figure 2). Signals can be generated and errored from a test source to ensure that the appropriate alarms are being generated and reported by the network, and that APS switching is occurring at the proper thresholds. This is particularly important as rings become more prevalent.

Maintaining SONET networks requires testing capabilities beyond those used in characterization and installation. Maintenance testing requires both in-service and out-of-service monitoring and testing, with the ability to attain full visibility into the SONET and tributary overhead.

Probably the most common scenario for SONET problems is when there are no SONET alarm or error indications, yet errors are occurring on the customer service. Often, this is due to synchronization difficulties between equipment, which results in substantial SONET pointer movement (see Figure 3). This leads to excess tributary jitter and, ultimately, errors in customer data. Diagnosing this problem requires the ability to look at the SONET pointer values, movements/movement directions, and tributary jitter.

As SONET networks grow and become increasingly interconnected, problems can arise when transport is provided by multiple service providers. When a service provider supplies only line terminating equipment, there is often no visibility into the path transport level overhead and performance data, without an ancillary means of extracting this information. It is possible for errors to occur at the path level and be passed at the line level, with no indication that these errors exist. (A classic finger-pointing situation.)

SONET has extensive overhead that provides excellent visibility into the performance of the network. However, experience has shown that testing is critical for verifying proper operation and installation, and for isolating and diagnosing problems as they occur. The application of available testing tools enables the network to provide the high quality of service expected by today's customers.

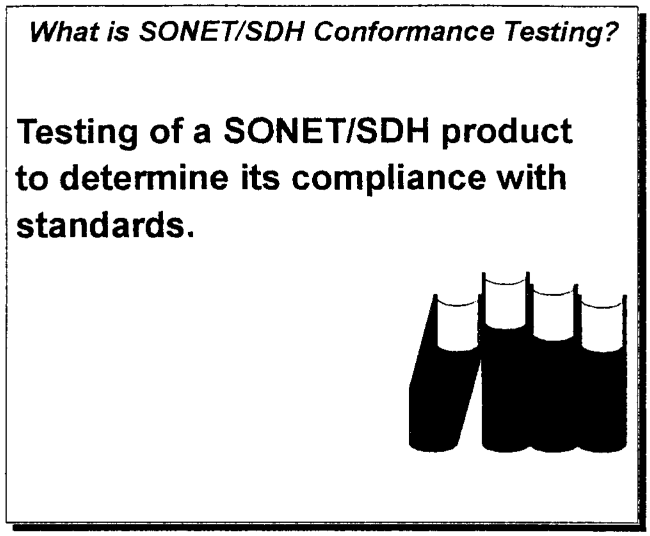
CERJAC Telecom Operation
2 Robbins Road Westford, MA 01886
508-266-3300 Fax 508-266-3350
Technical Support 800-923-7522

5963-9908EUS

Conformance Testing SONET/SDH Network Elements

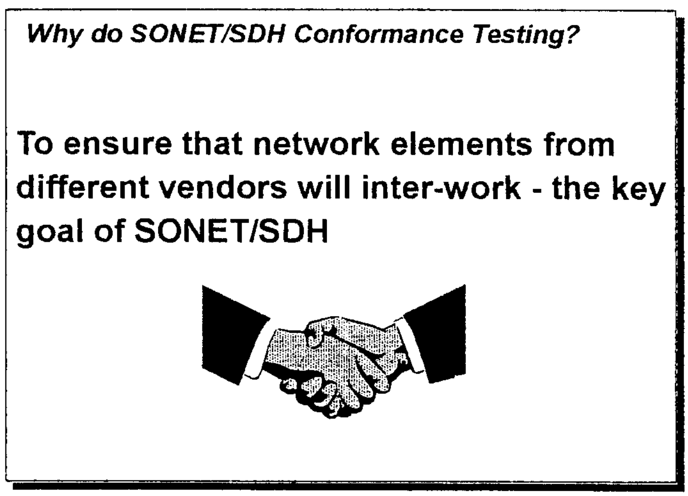
A Review of Automatic Test Suites for Conformance Testing of N.E.'s

Scott F. Hammond
Telecommunications Application Engineer
Hewlett Packard Co.



What is SONET/SDH Conformance Testing?

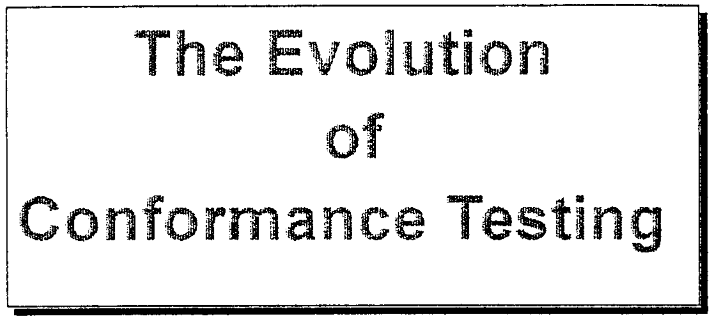
Conformance Testing is testing that is based on a set of tests written to reflect a specific set of specifications. In this case, the appropriate ANSI, Bellcore and CCITT specifications must be analyzed and tests written so that the equipment under test can be tested to these spec's.



Why do SONET/SDH Conformance Testing?

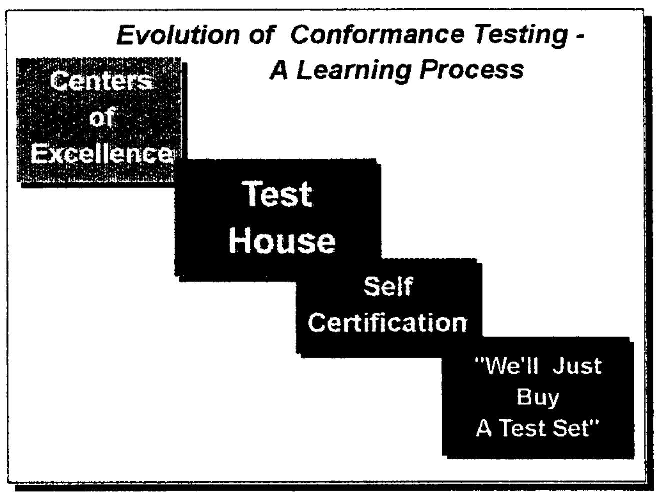
One of the many advantages of SONET and SDH are that equipment built to these standards will not be of a proprietary nature. Unlike the older technologies, this equipment will allow different vendors equipment to operate in the same network. For example, at one end of a system there may be an AT&T mux, at the other end, a Fujitsu mux.

If one set of standard test exists, that adhere to the standards, all Network Elements (NE's) could be tested to that standard. This would verify the inter-operability between equipment brands.



The Evolution of Conformance Testing

If you've been in the communications industry for a while, you've surely seen some major changes in how testing is performed. From the old "test everything you can think of" technique, to fully automated testing. Let's take a look at some of the changes that have occurred.



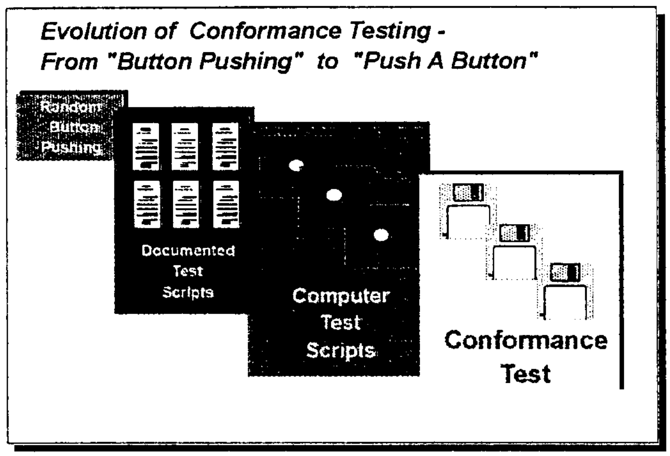
A Learning Process

With any technology there are the front runners who seem to lead the group in using the latest, perhaps unproven methodologies. These might be known as the "Centers of Excellence". They include Bellcore and several common-carrier evaluation labs which the industry looks to for leadership regarding the emerging technologies.

The next step in the evolution might be certain test houses. In the case of consumer electronics this would include Underwriters Laboratory (UL). The UL stamp of approval, is somewhat of a standard for consumer as well as commercial electronic products.

At some point large manufacturers may conduct "self certification". This is when a test house like UL may license an employee at a manufacturer to perform certification. This certifier would be employed by the manufacturer, but his work would be monitored by the Test House and conduct frequent checks for compliance.

At some point in time accepted test methods become very routine and common. This is where certification may not be important but just routine testing is performed. An example of this is X.25 Testing. Most manufacturers of this equipment just buy a high quality test set which has been widely accepted by the industry. Certification is not a criteria here, proven industry accepted testing is relied on.



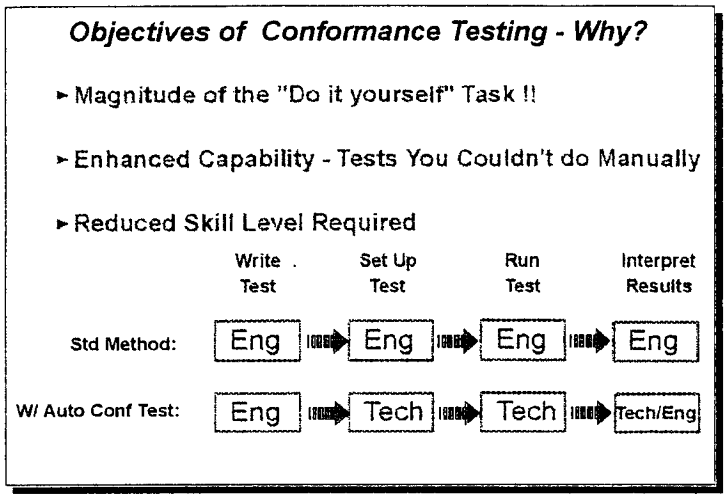
From "Button Pushing" to "Push a Button"

In the early days of electronic equipment, the standard method of testing was to connect the appropriate test set(s) and begin pushing buttons and recording and/or monitoring results. This method may appear random in nature, but hopefully would ultimately cover all the appropriate tests.

At some point, especially in a manufacturing environment, standard tests were written and documented. The objective is that while the level of expertise required may not be lower, at least the same tests were being performed every time.

When computer and instrument controllers became available, those same documented tests were converted to test scripts. These scripts, possibly written on floppy disks could be loaded into an instrument controller and run in an automated fashion. this could require less expertise at the test operator level.

With faster computers and better software, the concept of "Conformance Testing" can be realized. A standard set of tests run with a minimum of test operator involvement which adhere to the equipment specification and the manufactures standards of quality.

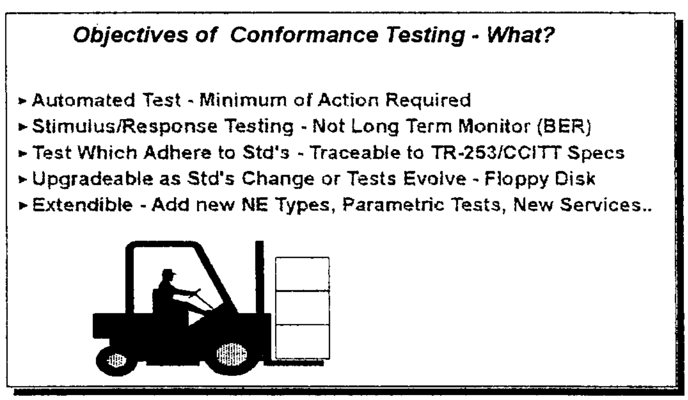


Objectives of Conformance Testing - Why?

One of the very fundamental reasons for purchasing a conformance test package would be the saving in money in development time. To "do it yourself" could take an enormous amount of time and tie up engineering resources that could be used for other tasks.

Whenever you consider employing computer controlled testing techniques, the concept of advanced, intelligent testing is a major consideration. The fact is that using this method allows for tests that couldn't be performed manually, such as "on for X frames - off for Y frames".

Until automated testing was available, the entire testing program had to be done by an engineer or at least a highly qualified technician. With Automatic Conformance Test Suites, an engineer would only be needed to oversee the writing of the tests or the specifying of the applicable tests.



Objectives of Conformance Testing - What?

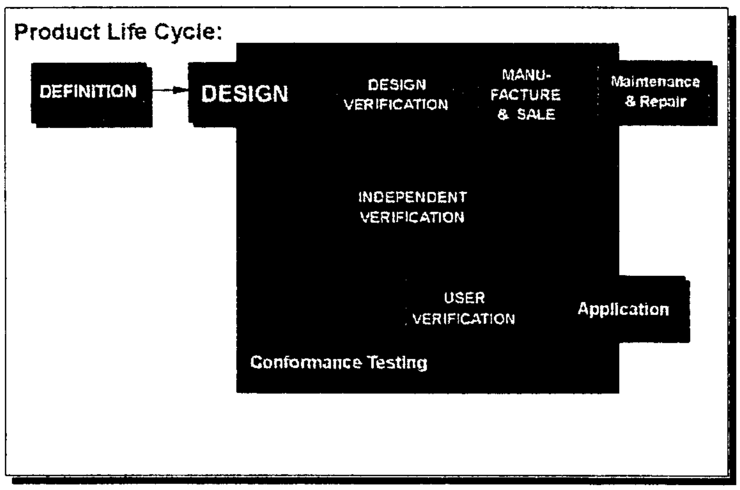
The advantages of automated tests requiring a minimum of test operator involvement have become commonly accepted by industry.

Generally long term BER testing would not be considered part of conformance testing. Stimulus/response, where an action is performed and a result is expected is the type of test preferred.

The tests scripts, as are most manual tests, written to check the unit-under-test's adherence to the applicable specifications.

It's important that the tests be upgradeable. As the specifications change or accepted test methods change, the tests need to reflect that change. Software upgrades via a floppy disk are one of the most convenient methods of supplying the upgrades.

As set of test suites which is extendible is a must. New services and new NE types will certainly be devised and will require new and/or more advanced tests.



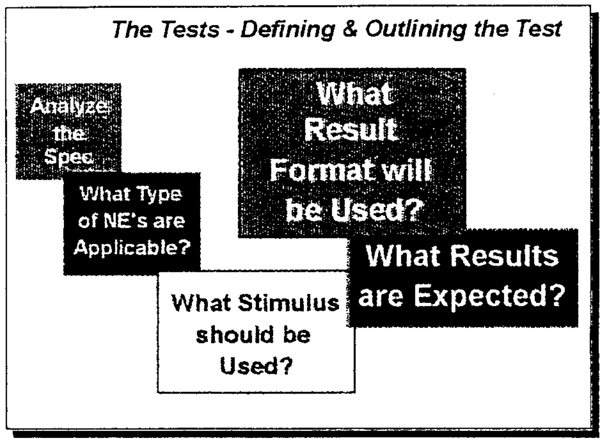
Objectives of Conformance Testing - When?

There will be several times during the product life cycle when conformance testing will be needed. Everything from discovering if a new design will work , to maintenance and repair will be the manufacturers prime interests. The Network operator, on the other hand, might have their own test set to verify that a product meets their needs.

The Tests

The Tests

There will be as many tests as engineers deem necessary to test any one network element. This will be an ongoing process. Let's take a look at some of these tests.



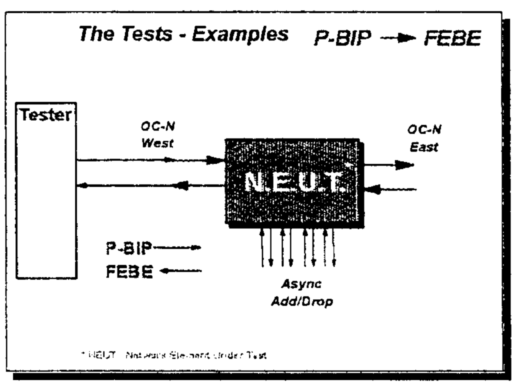
Defining and Outlining the Test

The first function that must be performed, and it should not be underestimated, is to take an equipment specification and create a test from it. This may be quite involved and in many cases, be subject to interpretation. These specifications often do not call out tests to be performed, even outline a test, so the test engineer must create it.

Obviously some tests must be specific to some types of NE's while others won't be needed. So a category of tests per NE types or a test matrix must be devised.

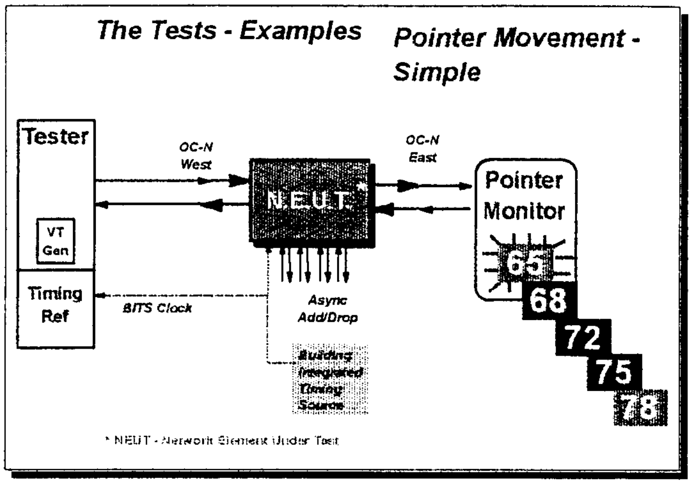
The two major parts of the test will be what stimulus should be sent to the NE, and what result should be expected. The expected result is critical in determining a Pass/Fail result rather than a quantifiable result which could be subject to interpretation.

The last step is to specify the result format. Will all information including test results be displayed or just a message saying "*Unit xyz Passes, Ship It*!!".



Examples P-BIP...FEBE

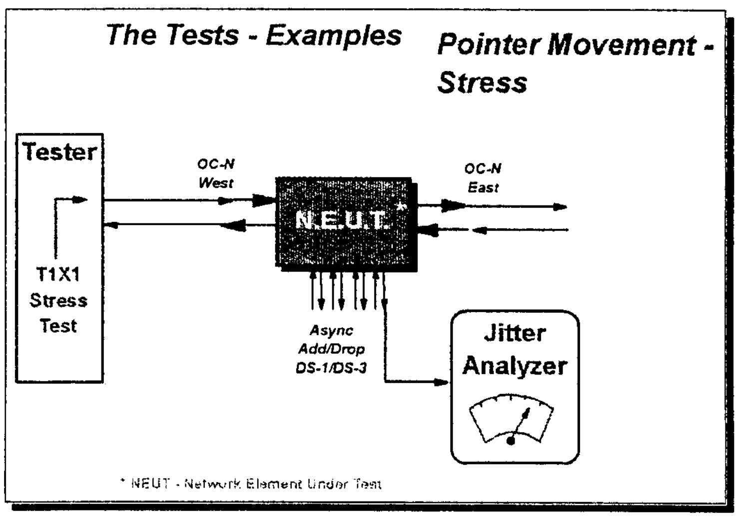
The tests will range from very simple to very complex. The above is an example of a very simple test where Path-BIP (Byte - Interleaved - Parity) errors are sent into an NE. and FEBE's (Far-End-Block-Errors) are expected back.



Examples: Pointer Movement - Simple

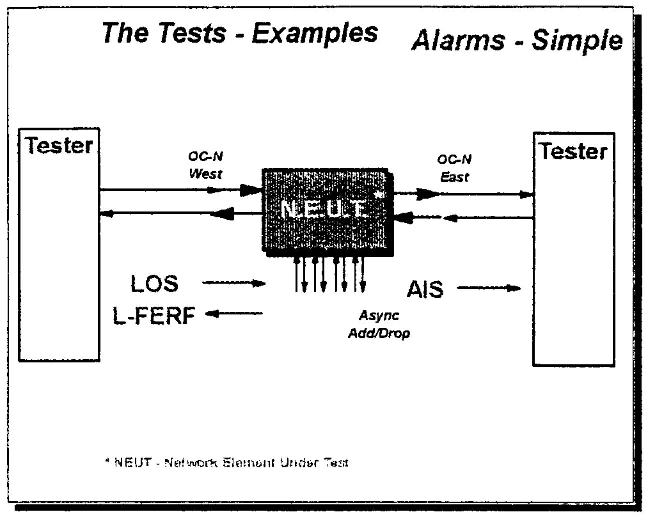
The Payload Pointer is an important function of SONET and SDH. Pointers allow the transport of Asynchronous signals in a Synchronous environment. Testing the pointer is and will continue to be vital.

The above is an example of a simple pointer test, where the NE and test set are clocks to the BITS clock and the line frequency is offset. This will cause the Pointer to move in value. The value of the pointers are monitored by the test set. The expected value(s) of the pointer could be written into the test script to obtain a Pass or Fail condition.



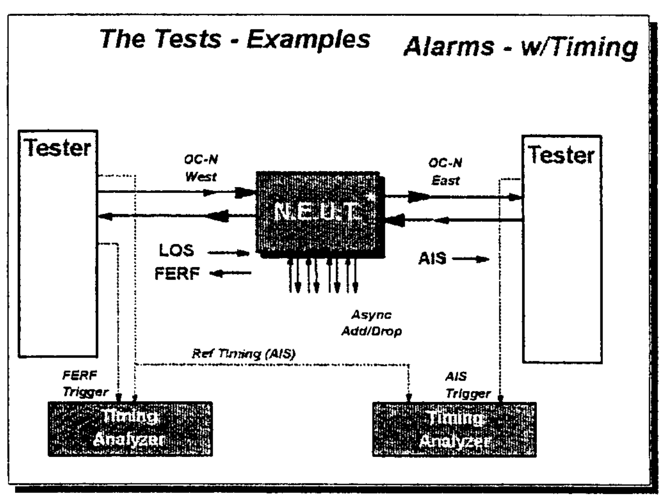
Examples Pointer Movement - Stress

One of the key issues in testing NE's is the problem of tributary jitter in an active pointer system. In this example, a sequence of pointer movements specified in the T1X1 document is applied to the NE. Due to the difficult job that the de-synchronizer must do, large magnitudes of jitter are sometimes present at the tributary output. It is important to monitor and quantify especially the peak jitter with a jitter analyzer.



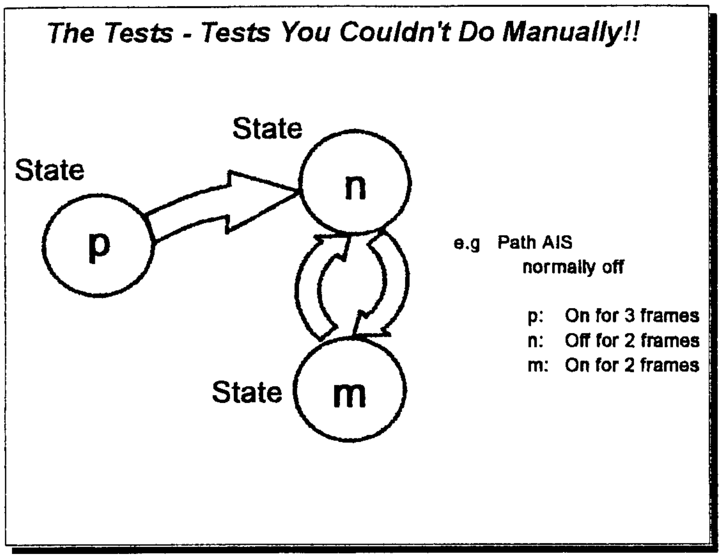
Examples Alarms - Simple

This is another example of a relatively simple test. In this case, there are two responses; the upstream response, the L-FERF (Line-Far-End-Receive Failure) and the downstream; the AIS (Alarm Indication Signal). This may complicate the test set in that it requires two receivers to verify conformance or complicate the test if the operator chooses to reconfigure the test system to check one response and then the other.



Examples Alarms - w/Timing

A more complex version of this simple test would include measuring the timing of the alarms. The basic alarm indications would be checked as above, but the time delay between stimulus and response could also be checked.



Tests You Couldn't Do Manually

The advances in test hardware and software provide the ability to create tests that could not be performed manually.

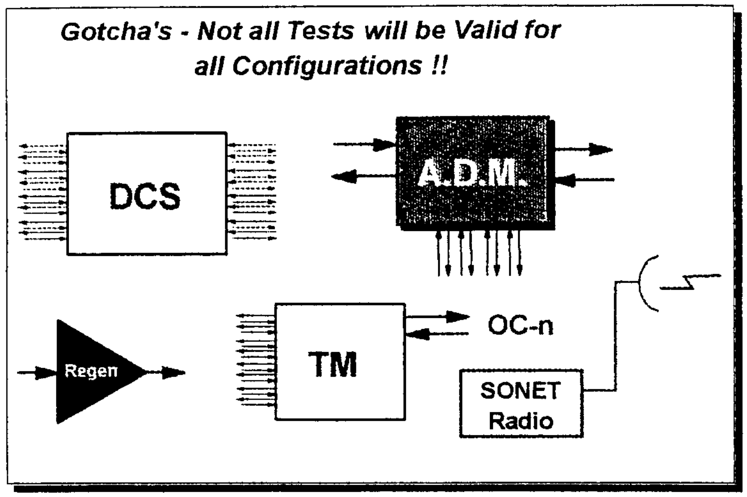
In the case of SONET and SDH there are some tests which require the presence of a condition for X frames, followed by another condition for Y frames.

The above illustrates initial condition (P) followed by two alternating conditions (n & m).

The Gotcha's
of
Conformance Testing

The Gotcha's of Conformance Testing

There are several issues which need to be addressed when designing a set of tests or an entire conformance test system. These are known Gotcha's. Lets take a look at a few of them.

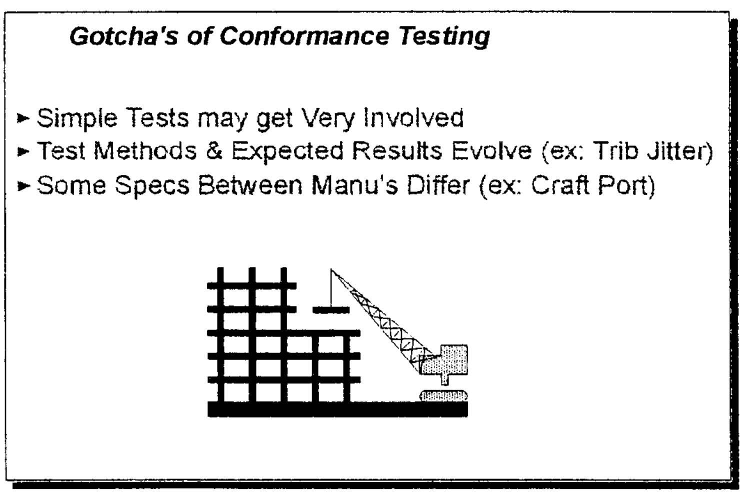


Gotcha's - Not all tests will be valid for all configurations

Obviously any one test may be valid for that specific NE type it was written for, but may not be valid for all NE types.

For instance, the *ADM (Add/Drop Mux)* may have certain test which include mapping & de-mapping. The *Regen* however does neither one of those functions and may require tests which the *ADM* would not need, such as Section Order Wire.

The *SONET Radio* would be a completely different type of NE and would require some tests which no other N.E.s would.



More Gotcha's

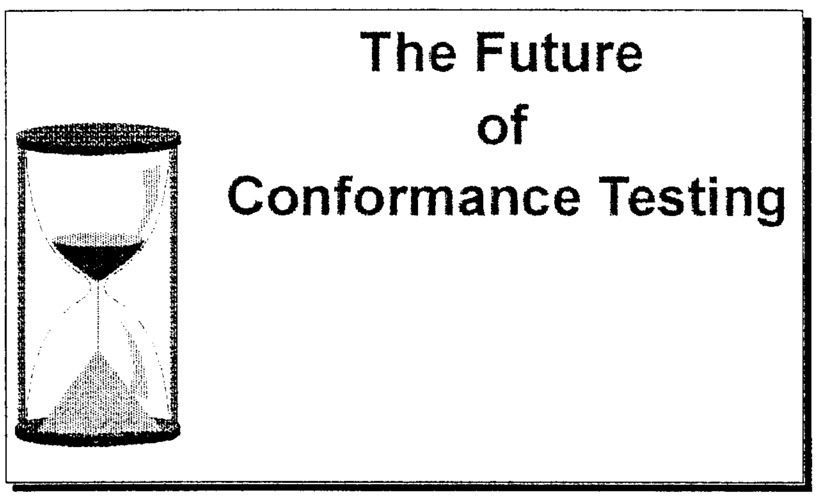
While a test may seem quite simple to write, it's implementation may be quite involved. The Alarm test mentioned earlier for instance, would be a small effort for an *ADM (Add/Drop Mux)*.

If that same test were written for a *DCS (Digital Cross-Connect System)*, it would be quite involved due to the amount of ports involved and how they inter-act.

The methods which manufacturers may test an NE may differ. They may even differ among test engineers within the same organization. An example of this might be the testing of an order wire channel. One method could be to send a 1 KHz digital word and simple detect a tone at the far end. A more robust, rigorous method would be to sweep a tone through the operating range of the order wire and compare the response to plus/minus tolerance limits.

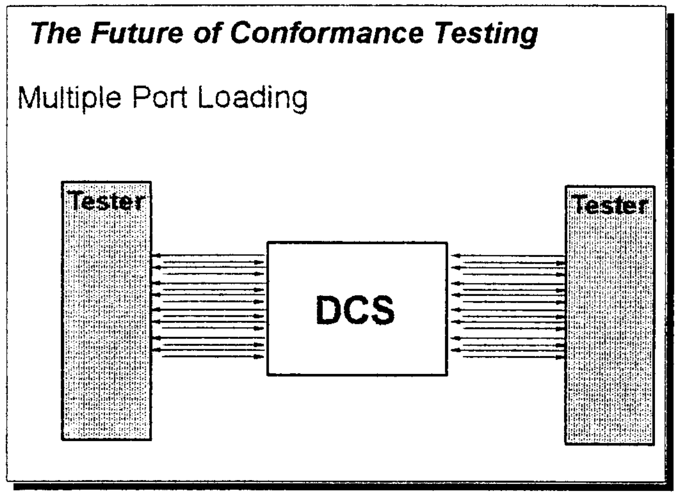
As standards change and industry knowledge increases, there will be newer and better techniques for testing. Tributary Jitter testing, today a hotly contested issue, will continue to be looked upon as an evolving, changing task. As real world considerations become better known and test equipment evolves, the test techniques will change.

It is understood that all N.E.s of a specific type should adhere to the adhere to the applicable specification. There are some features which may be vendor specific. The craft port is an example of this. The physical interface is generally RS-232C, but the messages and data format may be quite different between manufacturers.



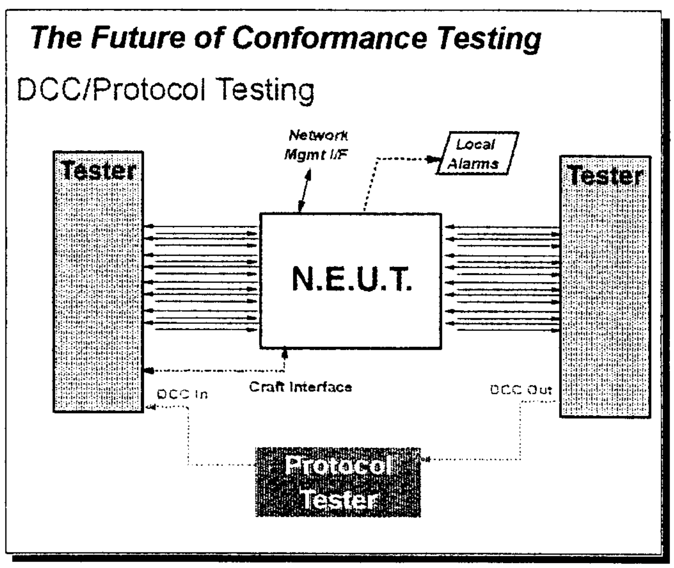
The Future of Conformance Testing

Once the industry has widely accepted Conformance Testing, it will be looked upon as "the" way to test N.E.'s. The more it's relied upon, the more it will be changed and updated to meet requirement. Some of the anticipated requirements are:



Multiport Loading

Most of the tests mentioned so far have included one, two or three ports connected to the test set. For several reasons, speed being the obvious one, future testing may be performed with all ports loaded. This would eliminate changing the connections to test different ports on a *DCS* for instance.



DCC/Protocol Testing

There are many overlooked aspects of SONET/SDH testing. We previously mentioned the craft port and how ultimately the tester should be able to test it's reporting functions when a stimulus is applied. It should also be possible to command the N.E. through the craft port and expect a response.

As the DCC's become more standardized and industry accepted messages become the norm, it will be advisable to test the DCC's. This will include sending the NE a message and expecting a response as well as creating a stimulus and expecting the DCC to respond appropriately.

Local Alarms and the Network Management Interface will also be part of conformance testing.

The Future of Conformance Testing

New services will Require Expanded Testing and Force New Look at Previously Overlooked Features!

i.e.

ATM ⇨ OC-3c ⇨ OC-12c

New Services will Require Expanded Testing and Force a New Look at Previously Overlooked Features!

The advent of *ATM* on SONET is an example of a service which has driven the testing of a somewhat overlooked standard; OC-3c.

If a network is only to transport VT/TU's or DS-3's, the testing of OC-3C would not be required. As ATM and other services such as HDTV proliferate, features like concatenation must be tested.

Summary

- Conformance testing will allow the same tests, better, faster and more economically.
- Due to the advantages, Conformance testing may become the standard, accepted test method.
- Conformance test suites must evolve as standards and accepted test methods evolve.
- Test updates may need to become a parallel effort with product development.