Agilent Technologies

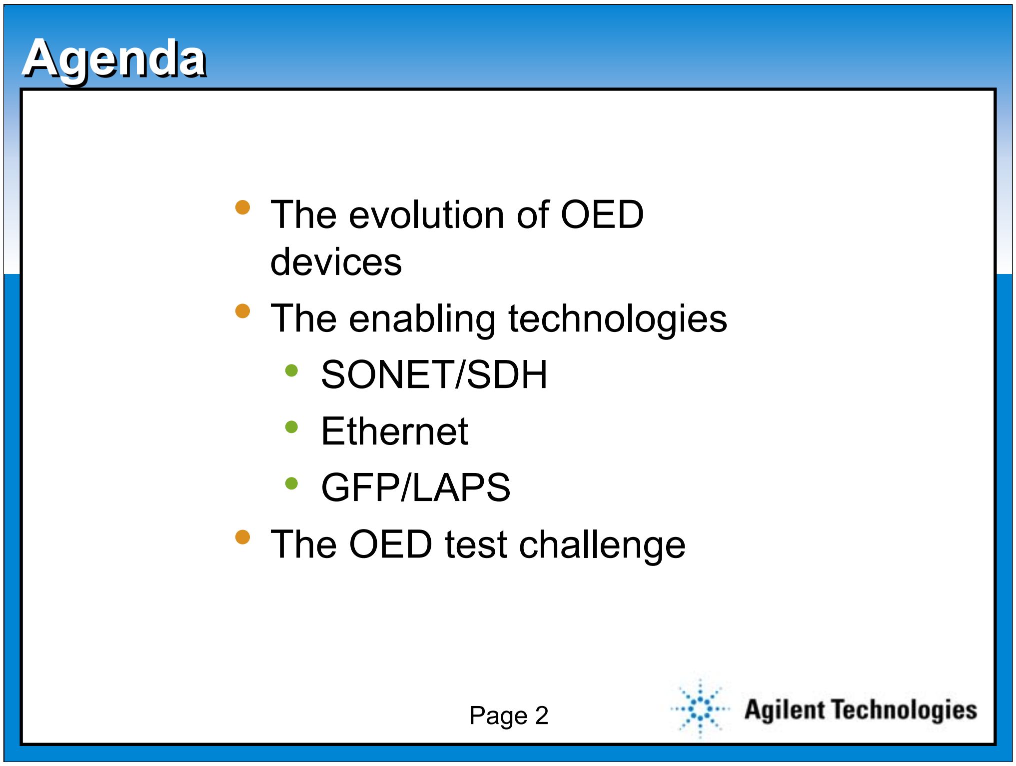
Optical Edge Devices
Technology and Testing Techniques

June 6, 2002

presented by:

Hussain Qureshi

Good morning/afternoon/evening welcome to the eSeminar on Optical Edge Devices. My name is Iain Wilson and with me is Hussain Qureshi. We are Product Managers at Agilent Technologies.



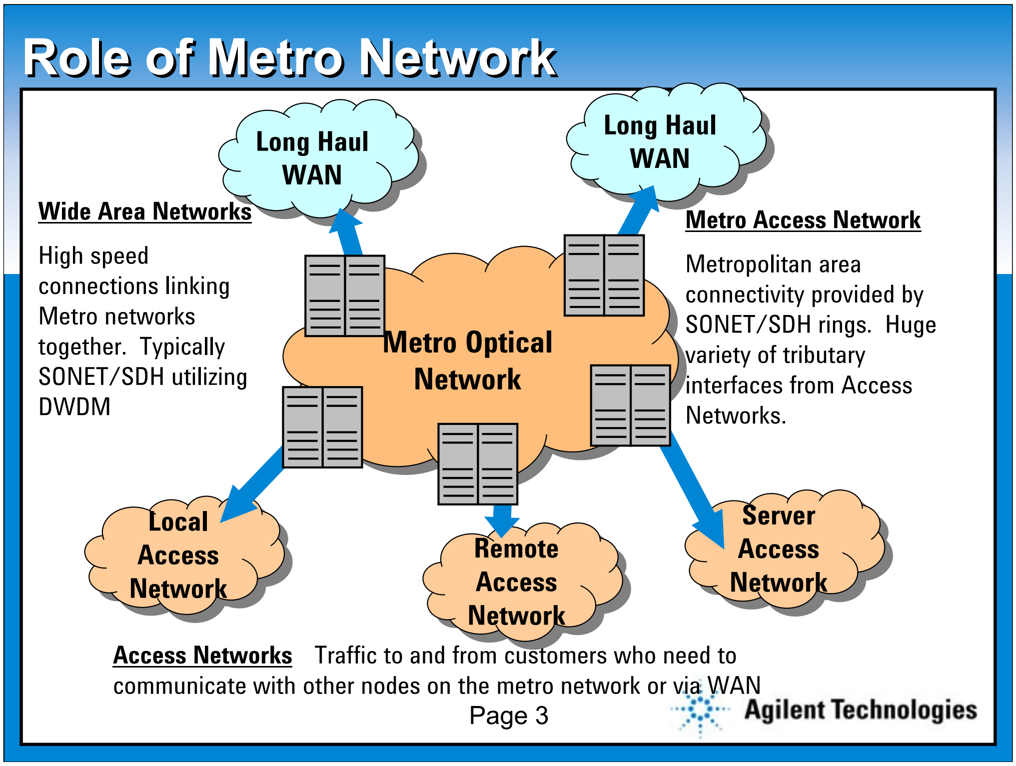
Today our presentation is focused on a new communications industry trend that is becoming increasingly important.

We are going to look at Optical Edge Devices - or OEDs as they are commonly referred to.

Over the course of the presentation we'll examine what an OED is and why they are becoming so popular.

We'll look at the some of the key technologies used in OEDs and particularly focus on SONET/SDH, Ethernet and GFP/LAPS – the encapsulation technology that brings them all together.

Finally, we'll look at some of the ways that Agilent can help meet the test challenge of these devices.

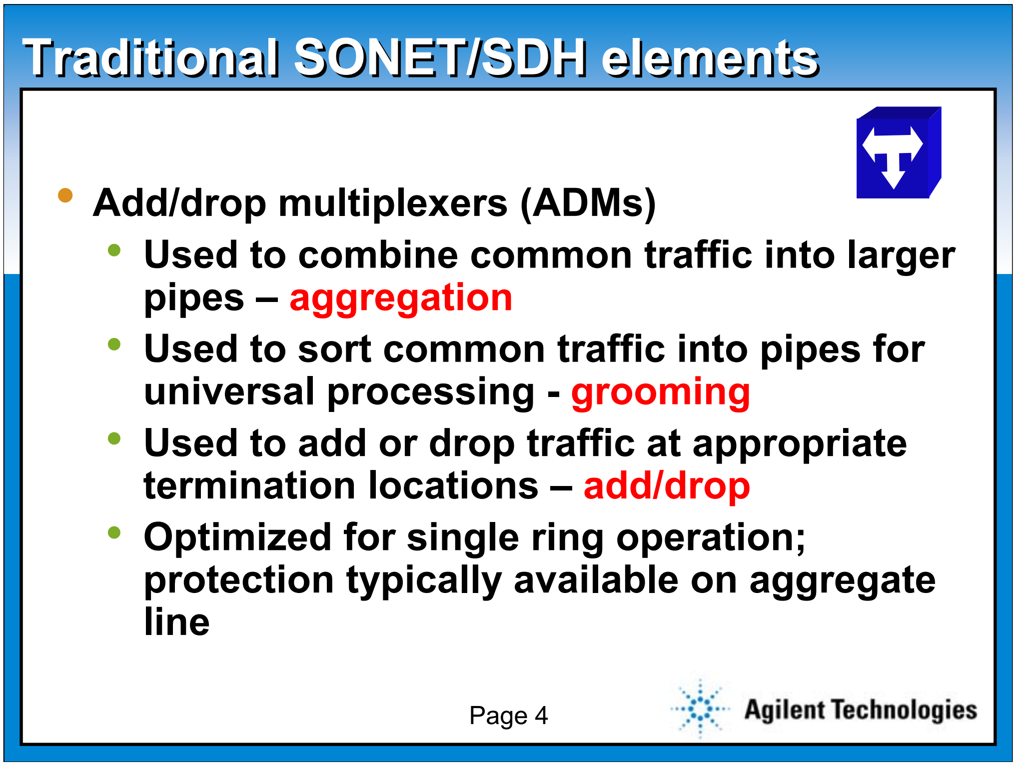


First of all let's have a quick network re-cap. The target area for Optical Edge Devices is not surprisingly, the optical Edge.

But where is this 'optical edge'? It is typically at the points where the metro network connects to that WAN network. At this point in the network, traffic has usually been graded and sorted into various common flows that are directed either to the WAN network, dropped to an access network or switched to another location in the metro.

Historically, metropolitan networks were made up of SONET/SDH rings designed to carry voice traffic. These networks have done an outstanding job in terms of reliability. However, networks are now carrying more data traffic than ever before and this is leading to some fundamental changes in the network elements needed to service the network traffic.

To keep pace with growth, the networks now need to be able to scale rapidly in a cost effective manner, in a way that they never had to before. As we'll see, that is where the OEDs can play a role.

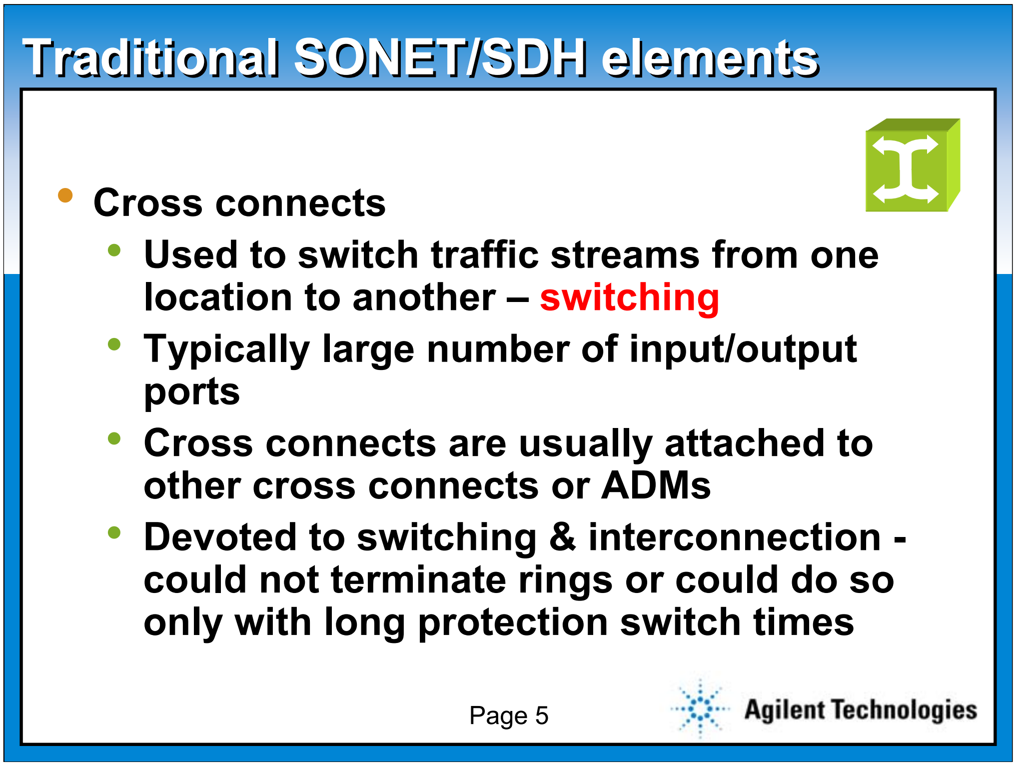


In SONET/SDH technology there are some fundamental terms that we need to understand.

SONET/SDH defines a hierarchy of line speeds that can be multiplexed together and just as easily de-multiplexed.

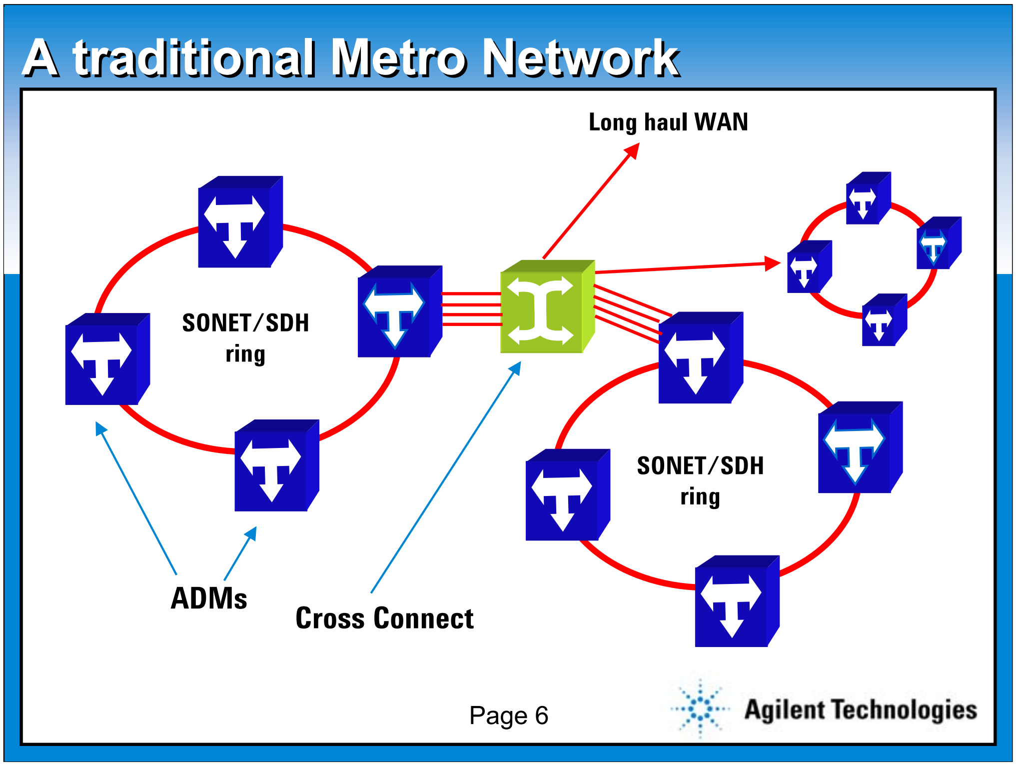
The devices that handle this are called add/drop multiplexors or ADMs. ADMs can take lower speed traffic and combine it into high speed pipes – this is called aggregation. ADMs are also used to sort or combine traffic that has a common characteristic such as a guaranteed quality of service and pass it to an appropriate location – this is called grooming.

The ADMs are typically arranged in a ring format with automatic protection switching capabilities that allow service to continue on a secondary circuit should a fault develop on the primary one.



The second basic SONET/SDH device is a cross-connect, which is used to switch a traffic stream from one location to another so that a circuit or part of a circuit is completed. Cross-connects usually have a large number of ports and will be connected to ADMs in a ring topology or perhaps to another cross-connect on another ring.

The cross connects are designed for switching and interconnect, they would not be used to terminate the SONET rings.

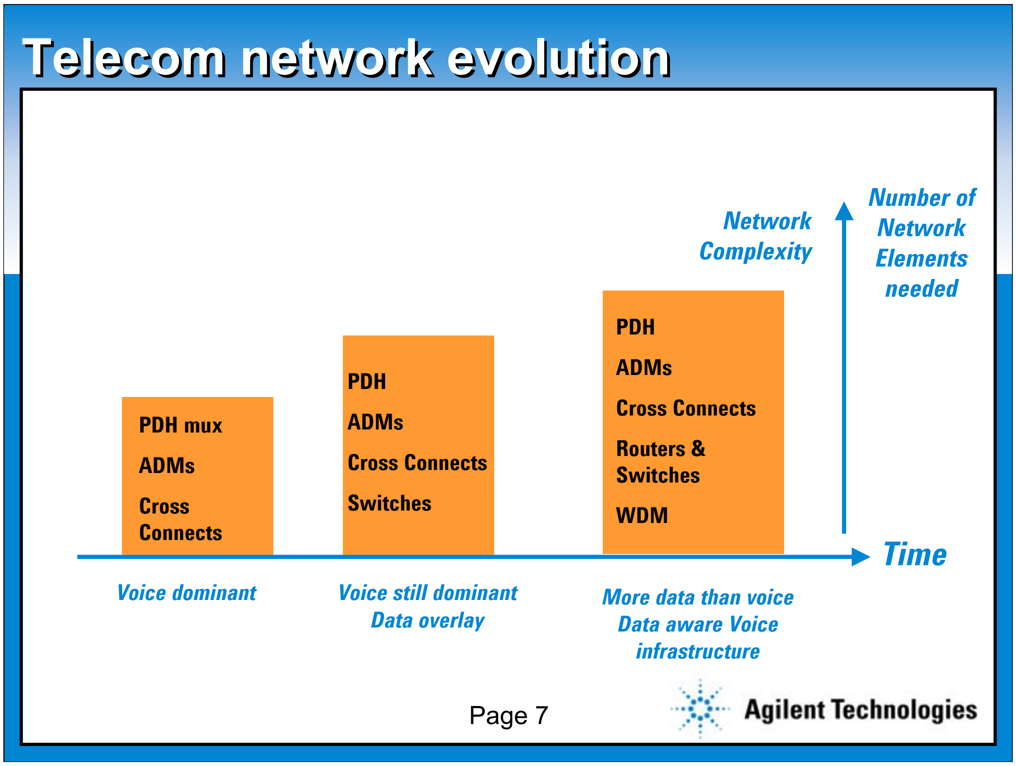


This is what the ADMs and cross-connects can look like in a traditional metro network topology.

The ADMs in the SONET rings will be connected to access networks and devices.

The cross-connects interconnect the metro rings and also connect to the long haul optical WAN network.

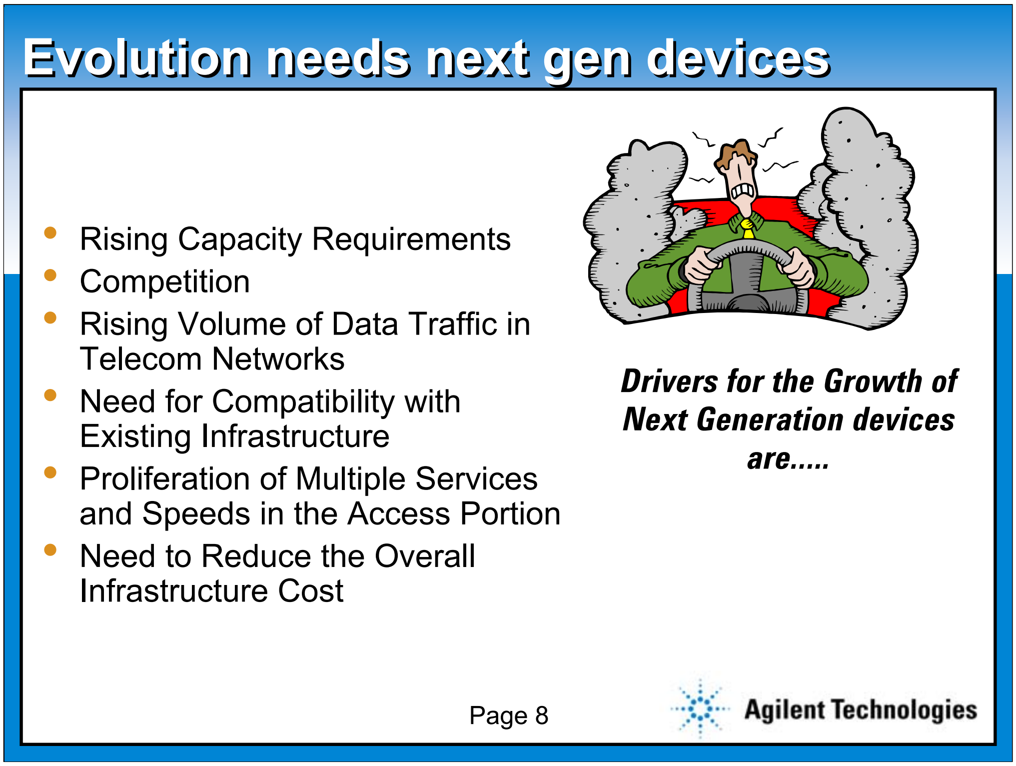
Notice that cross-connects are always connected to the rings via an ADM. This means for every ring to ring connection at least 3 devices are used. In large metro networks this adds up to a lot of devices, costing a lot of money, requiring a lot of maintenance. We'll see later how OEDs can help relieve this situation.



As we've already touched on, our telecom networks are going through an evolution from voice dominant services and traffic to a situation where there is more data traffic than voice.

More data traffic needs new data specific network elements to manage, switch and route the data. This is in addition to all the legacy devices already present.

It means the number and type of network elements has increased dramatically and the overall complexity and maintenance effort has also proportionally increased.



This network evolution has become the catalyst for a new generation of network devices.

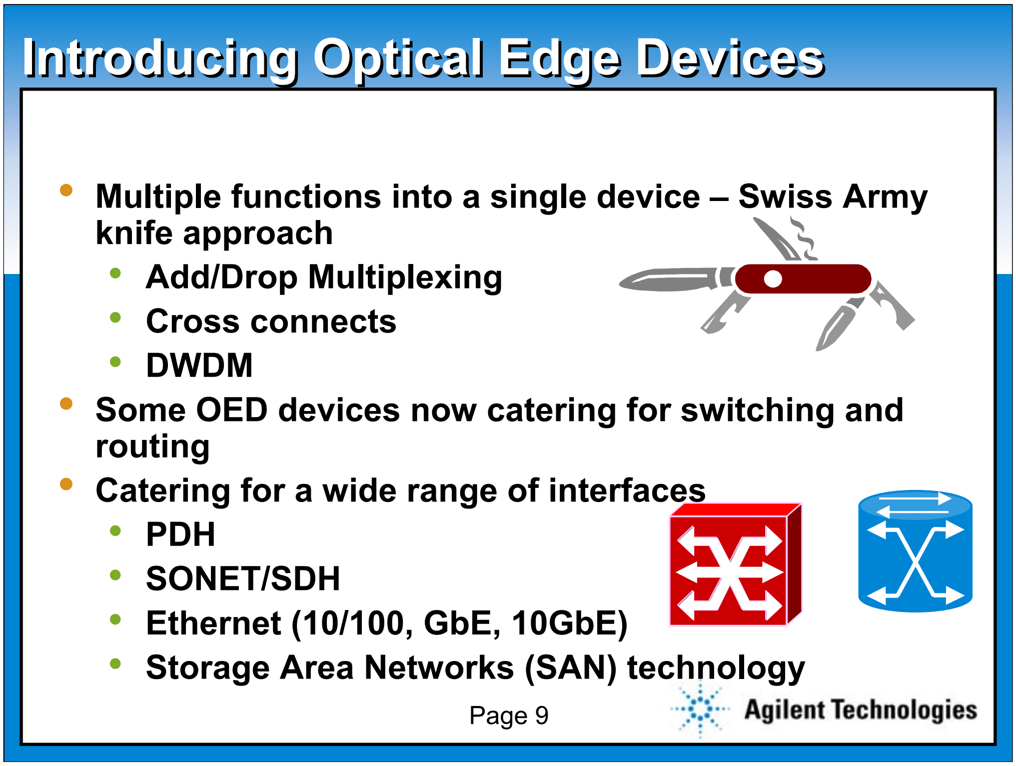
The major driver is the need to scale rapidly to accommodate the increasing capacity requirements. As the volume of data traffic has grown, the metro portion of the network has become a bottleneck.

The telecommunications business is very competitive and the need to provide better services, quicker and at lower prices is also a key objective for the service providers.

For the newer carriers it is easier to take advantage of new technology because they do not have the infrastructure and OSS legacy that the traditional carriers have.

However, given the massive investment in the current networks, it will not be financially possible for most existing carriers to simply replace the existing equipment with new equipment. In practical terms, any new equipment needs to be compatible with existing infrastructure, while at the same time adding new value by providing a solution to the multiplicity of services and speeds that must be catered for.

Finally, as most carriers must become more operationally efficient to achieve profitability in the new economy, any new infrastructure must participate in the need to reduce costs.

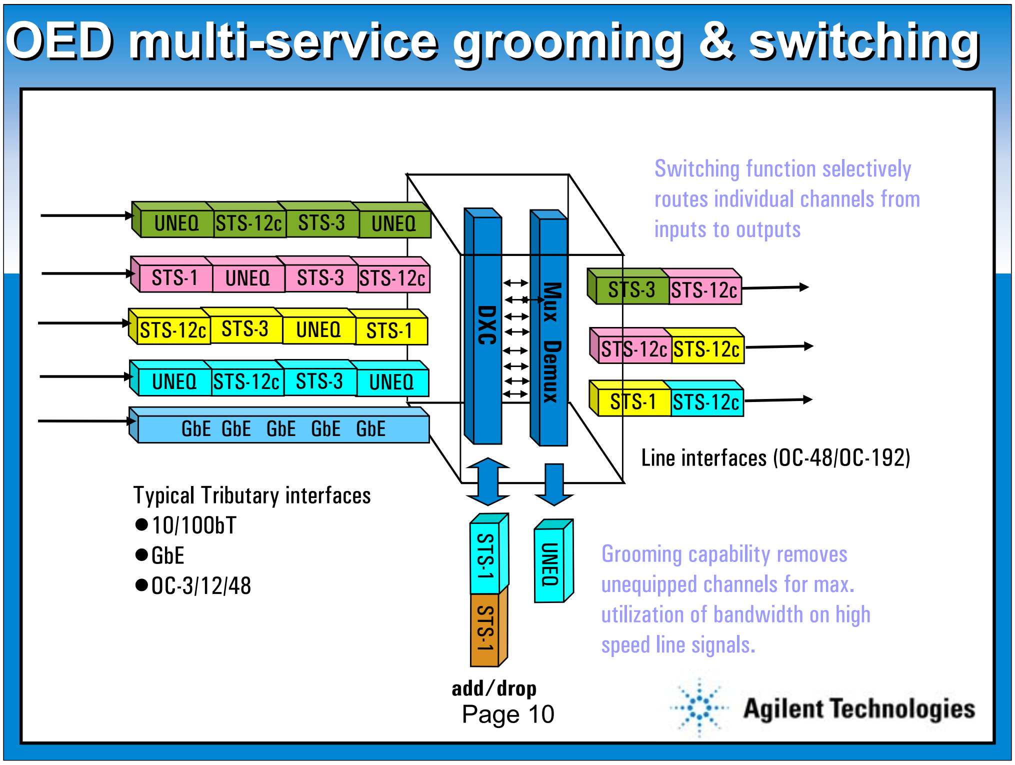


And this is where Optical Edge Devices come in.

OEDs provide a Swiss Army knife type approach to network functions. Instead of having separate devices for each of the disciplines of add/drop multiplexing and cross-connecting switching, the OED provides these functions in a single device. Some OEDs are even being developed which also have data switching and routing capabilities thrown in.

In addition to the multi-function capabilities, another characteristic of OEDs is their capability to provide a wide array of interfaces including PDH interfaces such as T1s and DS3s, the typical SONET/SDH interfaces, a range of the Ethernet interfaces that are becoming so important in the metro, and Storage Area Network technologies such as Fiber Channel, ESCON and FICON.

The benefits are less devices to maintain, reduced cost and a flexibility of configuration and scalability that is just not available with traditional elements.

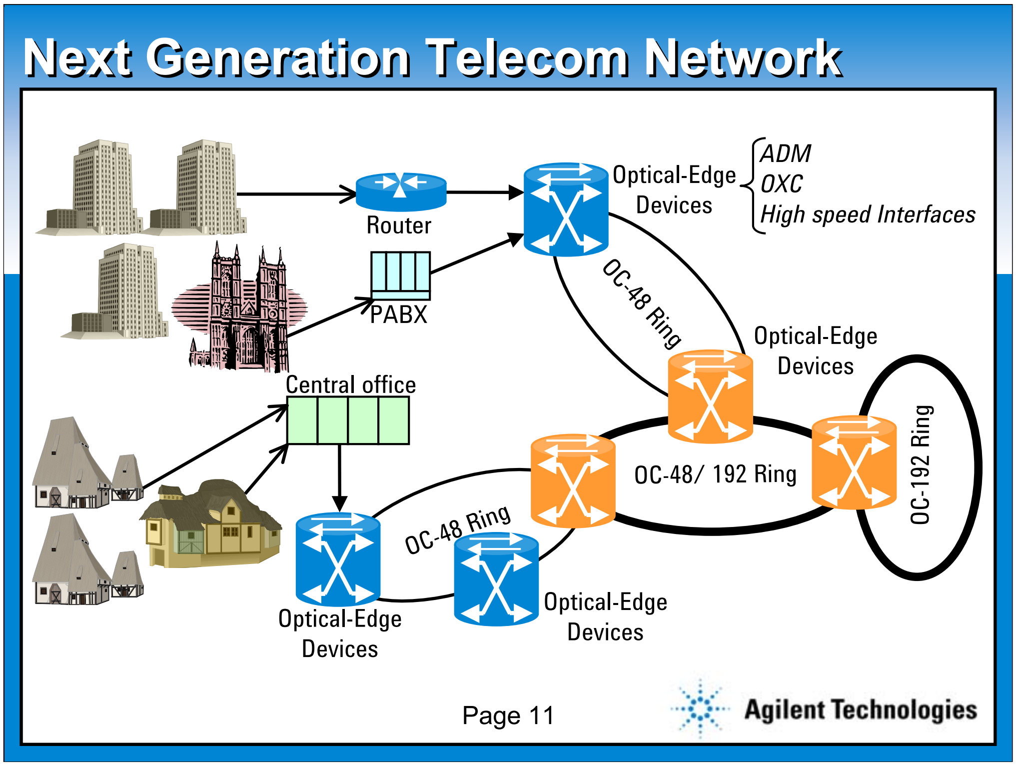


This diagram illustrates what is going on in an OED.

On the left hand side we see the tributary interfaces, which in this case are a mix of SONET and Gigabit Ethernet. The add/drop function sees traffic exiting and entering the device. The cross connect function switches channels from input to output while at the same time ensuring that output channels are fully utilized wherever possible, by grooming the traffic flows into the best output steams and dropping unequipped channels.

Before OEDs, these functions would only be achieved by multiple different devices connected together, with all the additional maintenance and interoperability problems that could bring.

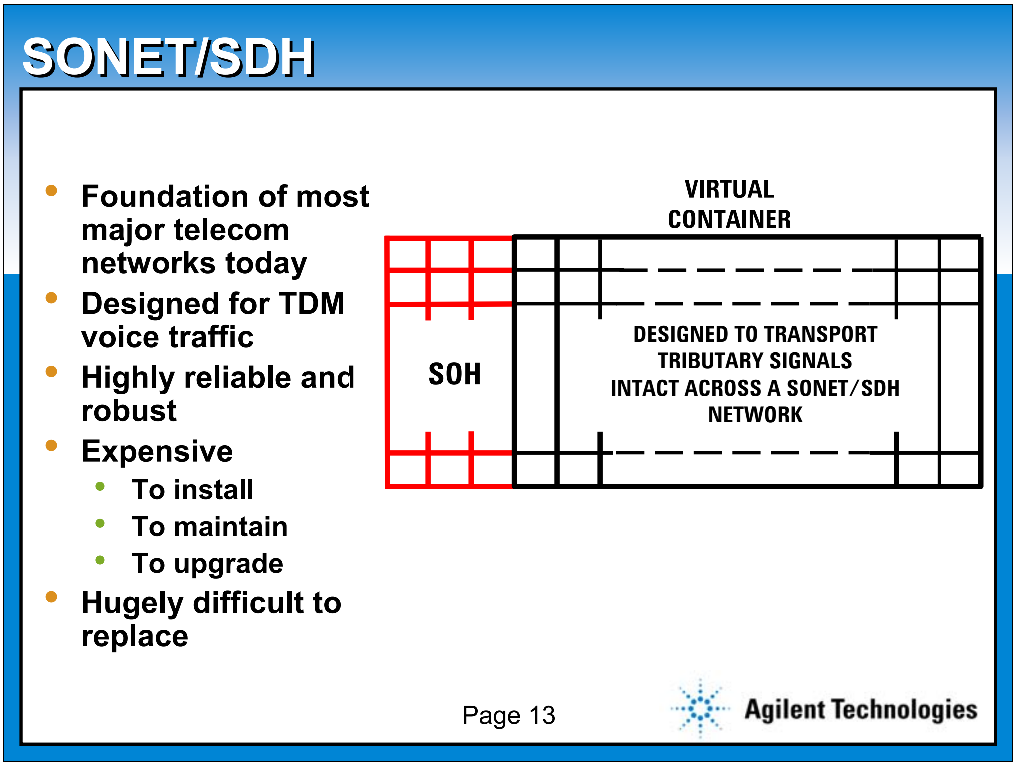
Now a single device, managed through a common interface can carry out all the functions, quicker, better, with more interfaces and cheaper then before.



This diagram outlines typical application of Next Generation SONET Device. As you can see a Next Generation SONET Devices combines the traditional SONET/SDH functions of ADMs and OCXs in a single device.it also integrates the data functions with telecom networks. High speed interfaces like GbE are also supported on these devices. The basic design architecture of these devices provides them to serve both data and voice with same efficiency.

These devices also have a potential of upgrade ability to 10GbE.

OK, now we are going to examine some of the key technologies employed in these devices.



Our first port of call is the SONET or SDH systems of hierarchical TDM transmission.

SONET is the US version of the technology and SDH is the system used by most of the rest of the world.

Most major telecom networks in the world have SONET/SDH at the heart of their architecture.

It has certain characteristics that are behind its popularity.

First of all it is a technology that was designed to cater for a world where voice traffic was dominant. As such, it is highly reliable and robust. Any system that can manage millions of voice calls with good quality, low delay and connection consistency must be founded on a reliable base.

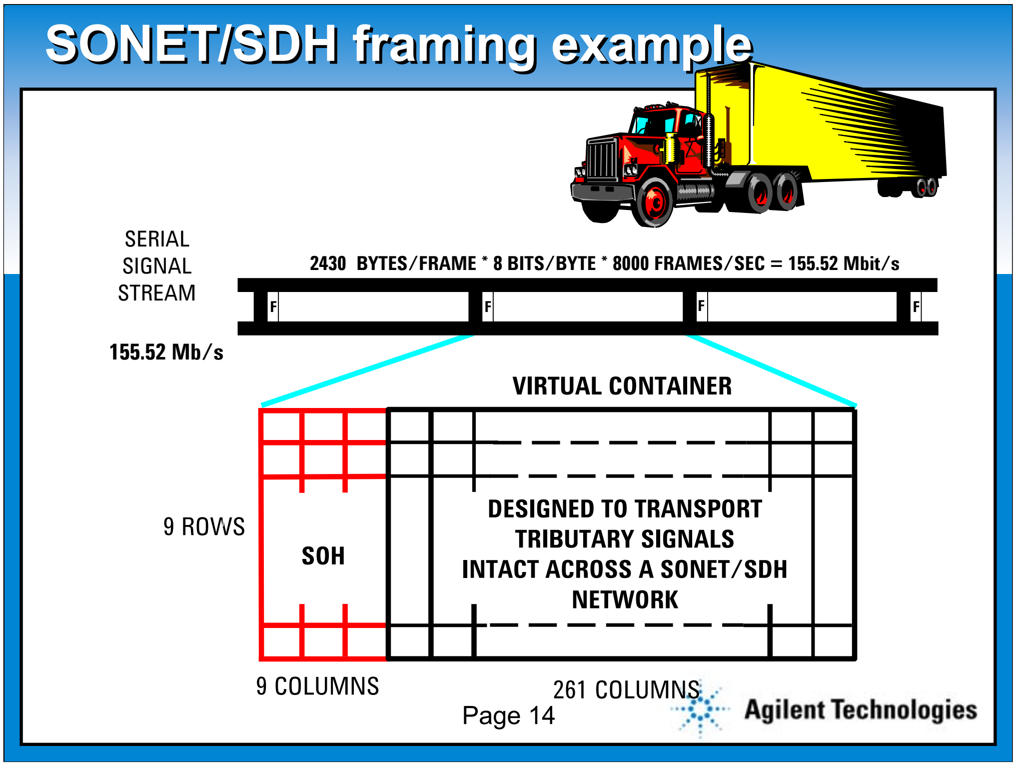
However, the tradeoff from the SONET/SDH technology is that it is quite complex and inflexible, so it has an ongoing high cost structure to install, maintain and upgrade.

It is also not particularly suited to the new data traffic that has now overtaken voice traffic.

In a perfect world it might be nice to replace SONET/SDH with some of the technologies more suited to today's voice and data mix.

Some of the newer carriers have built networks with a data orientation that does not use SONET/SDH.

But given the massive investment in this infrastructure by the existing telecommunications companies, it would be hugely difficult to justify replacing these networks in the short term.



SONET/SDH works on a hierarchical framing system where a mix of different transmission channels can be placed in logical transmission containers and transported across a network section.

The framing system includes administration information that is kept separate from the data in an Overhead area and is used to check for errors and ensure that the signals are transmitted reliably. One of the key features of SONET/SDH is that because of the structured hierarchy of the multiplexed channels, individual channels can be dropped or added as the frame is processed by the network elements that it encounters.

This is precisely the role of the Add/Drop Multiplexors that we talked about earlier.

This virtual containers and adding and dropping of channels is often compared the load of a semi-trailer or truck as it stops at depots on it's journey to its endpoint. At each depot, parts of the load may be taken off or new freight added. SONET/SDH works in exactly the same way, adding and dropping transport signals at each depot.

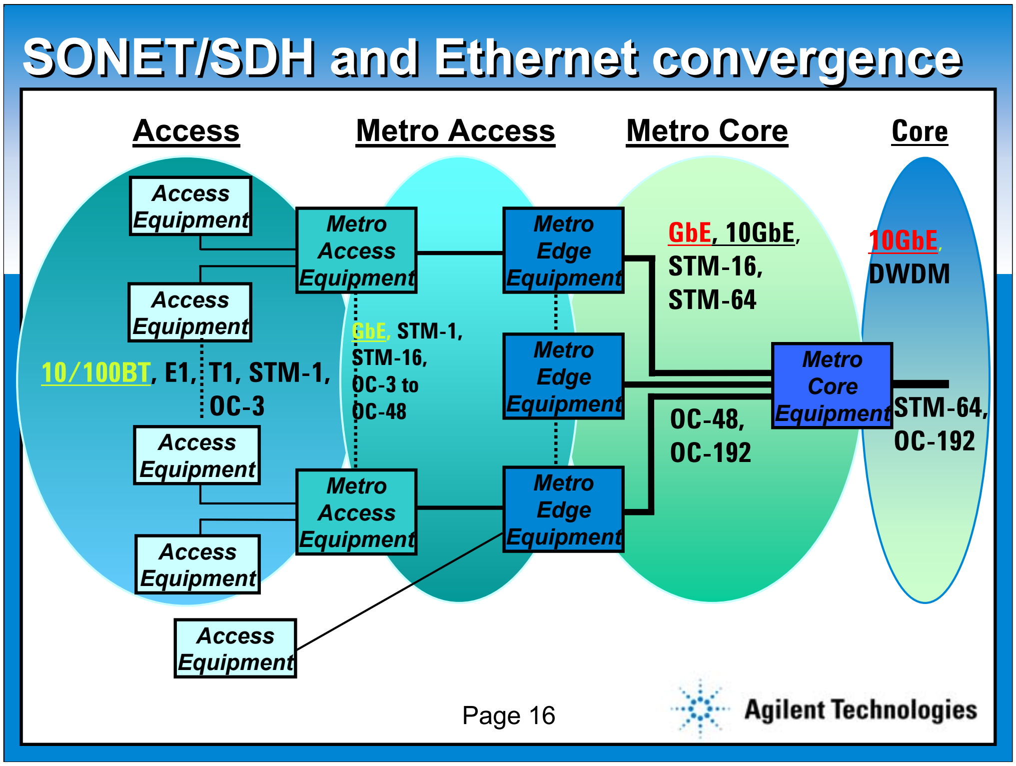
SONET Container sizes

SONET Container	Bit Rates
STS-3c	155 Mb/s
STS-6c	310 Mb/s
STS-9c	466 Mb/s
STS-12c	622 Mb/s
STS-24c	1244 Mb/s
STS-48c	2488 Mb/s

Agilent Technologies

This slide shows some of the container sizes available in SONET. SDH has similar sizes. The ones highlighted in blue are traditionally the most commonly used.

What we'll examine later is how some of the newer services fit better into some of the containers that have traditionally been less used. When considering requirements for new generation elements, it is important to ensure that both the traditional and newer container sizes are being catered for.



The second of the enabling technologies is Ethernet. Ethernet is now present in every segment of the network, particularly the metro networks. This means that network elements at every point in the network must support Ethernet and the SONET/SDH technologies.

Previously, thought of as a dominant LAN technology, Ethernet now offers the benefit of maintaining its framing structure across LAN and WAN networks be it 10 or 100Base T, GbE or 10GbE.

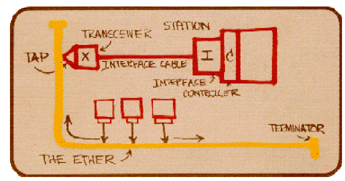
With more and more devices using Ethernet, its popularity as a LAN and WAN technology will only increase and it will be important for it live in harmony with the SONET/SDH equipment.

Ethernet

Ethernet is the IEEE standard 802.3. It has several different flavours with the most common use for the LAN communications.

<u>It is a.....</u>

- Layer 2 transmission system
- Set of physical medium standards
- Set of rules to get data from one location to another

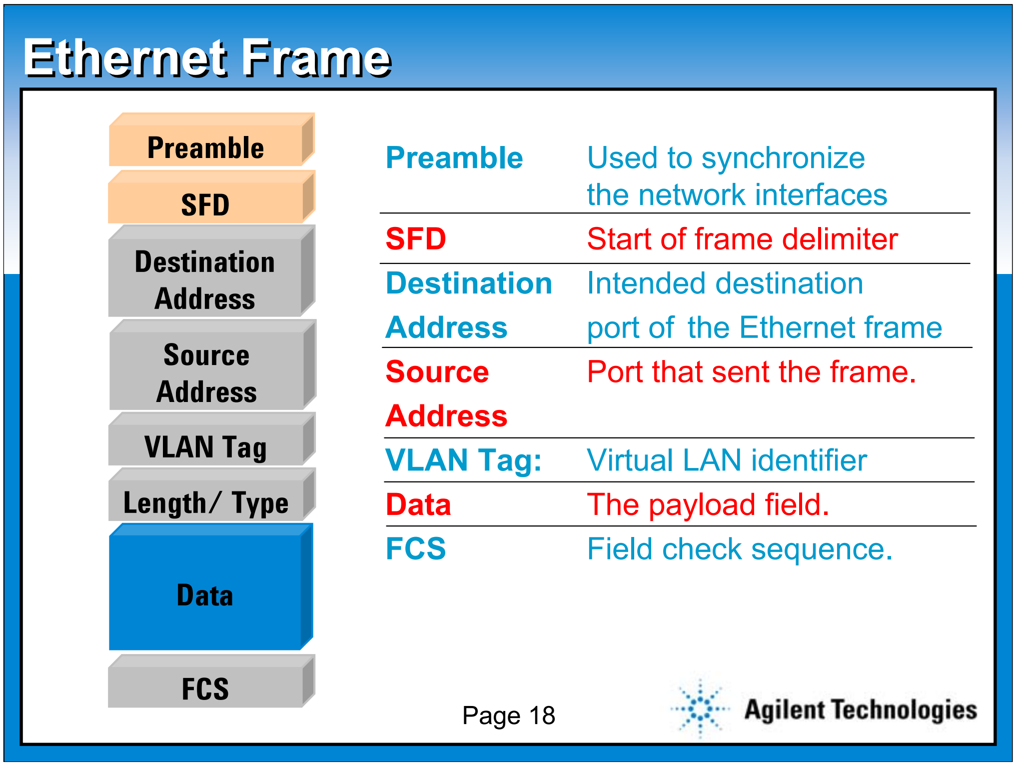


In simple terms Ethernet can be broken into these divisions:

- A transmission system that operates at the Data Link layer of the OSI model.
- A whole range of different physical media support that can transport Ethernet data.
- A set of rules that govern how data is controlled.

This is not dissimilar to most communications systems, but Ethernet has managed to maintain independence of each of the main components as advances in physical technology have evolved. This means that Ethernet has achieved a certain consistency that makes it attractive for all sorts of economical and practical reasons.

Now we're going to look at the construction of the Ethernet transport frame and how it can be used in a SONET/SDH environment.



For all of the Ethernet technologies, from 10megabits per second to 10 gigabits per second, the Ethernet frame looks like this. It is pretty straightforward – the data payload is surrounded by some addressing information and a checksum. Let's go through the fields.

The Preamble is a 64-bit field used to synchronize the network interfaces before the exchange of data. This is not used in Gigabit Ethernet but is left for compatibility

SFD 'the start of frame delimiter' is part of the Preamble

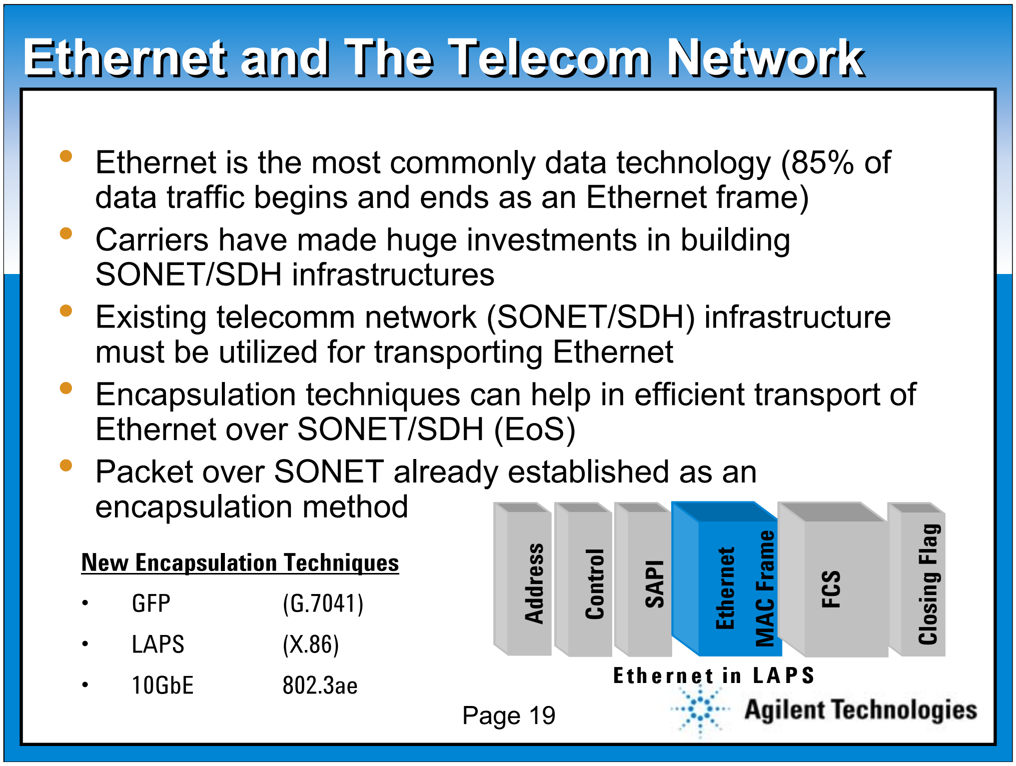
The Destination Address and **source address** contain 48-bit Ethernet hardware addresses, called the MAC address, of the interface to receive the frame and that of the sending interface.

An optional 4-byte long **virtual LAN** tag header can be inserted in an Ethernet Frame between the source address and the Length/ Type field. The VLAN tag is used to classify frames into secure virtual domains and provide a quality of service capability.

The **length/type** relates to the data field and indicates the format of the information in the data field.

The **data field** contains the data payload and will typically contain a higher layer protocol unit such as an IP packet.

Finally, the Field Check Sequence is a checksum to ensure the integrity of the frame. It is calculated by each Ethernet station to ensure that the transmission has been error free.



Ethernet has become hugely popular and there are several pure-play Ethernet carriers who are advocating that everything should run over native Ethernet. Particularly in the Metro Networks we see these carriers proving applications such as LAN to LAN interconnection, Internet Access and wholesale Ethernet metro transport.

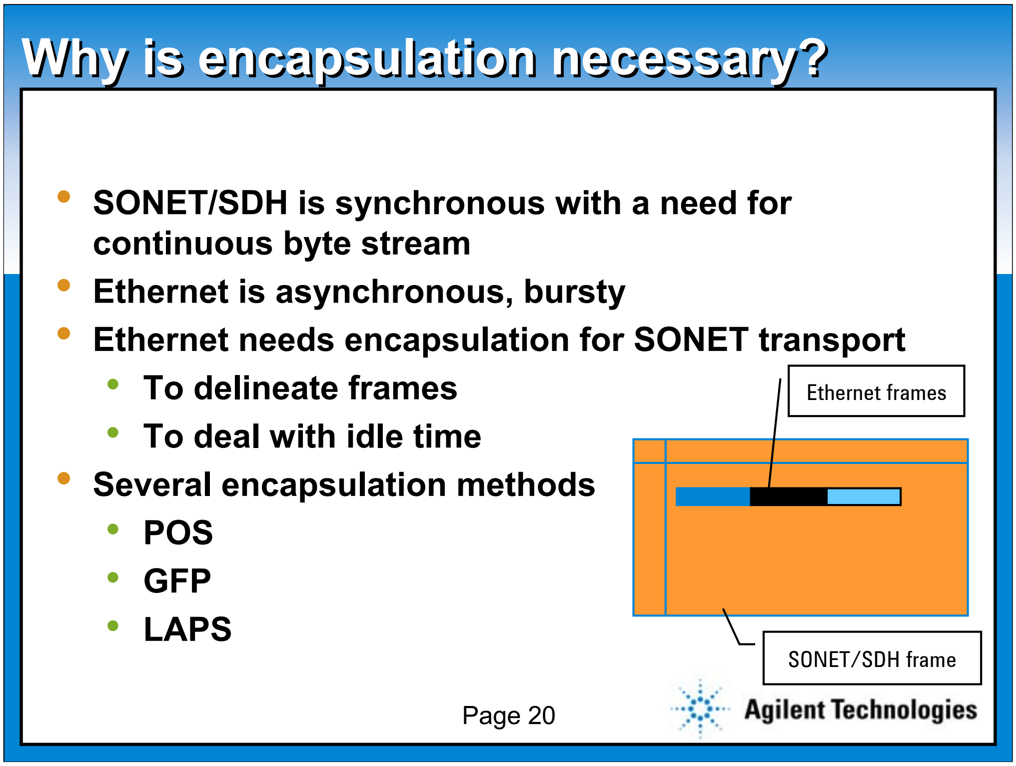
However it is unlikely that overnight every carrier will change their traditional infrastructure to Ethernet. They have years and huge amounts of money invested in their SONET/SDH networks. So it is likely that we will see Ethernet working ***with*** these existing infrastructures instead of replacing them, at least in the short term. It makes a lot of practical sense to transport Ethernet on the existing networks by encapsulating the Ethernet within SONET/SDH and there is new technology evolving that help to this more efficiently than ever before.

Packet over SONET has been available for some time but there are two new ways of encapsulating Ethernet that are emerging.

•General Framing Procedure

•Link Access Procedure

In addition, the 10GbE proposals include a WAN PHY that contains a framing sub-layer that frames 10GbE into an OC-192c payload that can go directly into an interface in an existing SONET device.

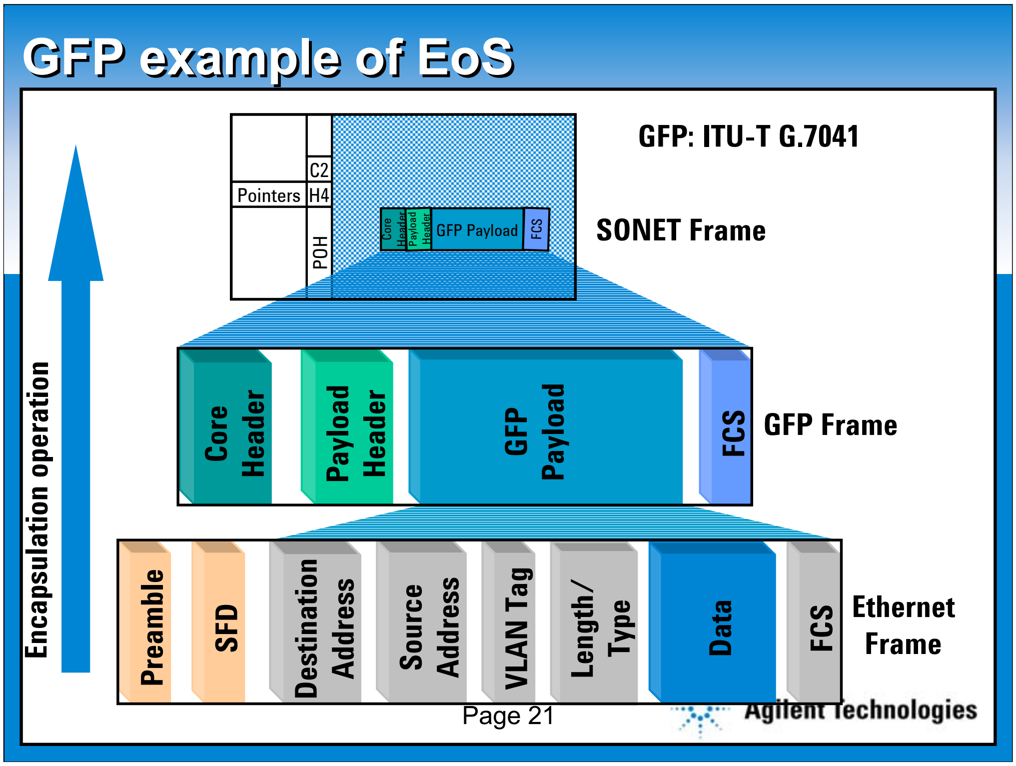


So why is it necessary to encapsulate Ethernet to transport it over SONET/SDH?

Well, the technologies can be quite different in their traffic profiles. Ethernet has a bursty traffic pattern which can have idle time followed by high traffic whereas SONET/ SDH have synchronous, continuous byte streams.

For frame delineation and in order to compensate for the idle time in between frames SONET/SDH needs to have a set of rules to transport the Ethernet frames.

We're now going to look at how the Ethernet over Sonet encapsulation is done particularly for Generic Framing procedure (GFP) and Link Access Procedure for SDH (LAPS).



In principle the operation of the encapsulation technologies are very similar. In this example we look at how an Ethernet frame ends up in a Generic Framing Procedure encapsulation

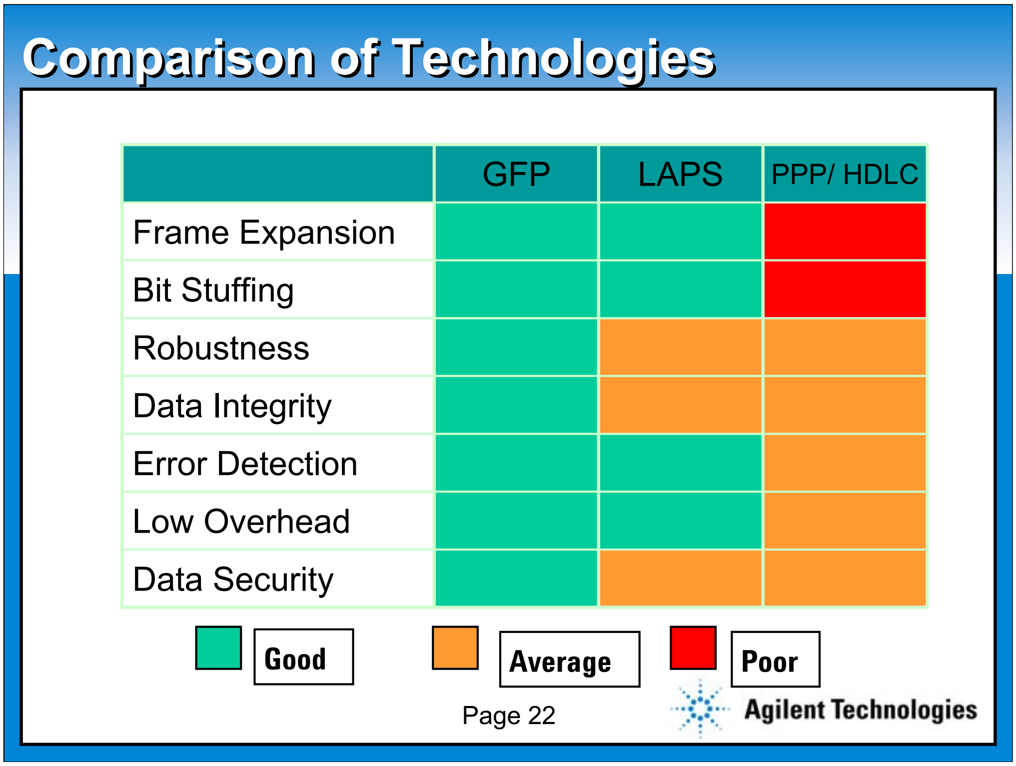
GFP is the ITU-T G.7041 standard. It provides a generic mechanism to adapt traffic from higher-layer client signals (e.g Ethernet) over synchronous transport network.

Working up from the bottom of the diagram, we see the Ethernet frame with its preamble, header fields, data payload and FCS. In GFP encapsulation all the Ethernet fields, except the preamble, are mapped into the GFP payload field of a GFP frame. The Ethernet preamble and Inter-frame Gaps are discarded.

The GFP frame headers and FCS are the same size as the Ethernet preamble so the GFP frame becomes the same size as the Ethernet frame, there are no additional bytes introduced in the encapsulation. This is a nice advantage GFP has over some of the other encapsulation techniques, which use escape characters and byte stuffing and increase the overall size of the payload.

The GFP frame is then mapped into the SONET frame, either a contiguously concatenated container or perhaps via virtual concatenation, which allows the encapsulation to be placed in non-contiguous SONET/SDH containers and can utilize the SONET/SDH bandwidth to its maximum. The SONET C2 byte is used to describe which encapsulation is being used.

At the receive end, the reverse happens. The GFP frames are de-mapped from the SONET frame, then the Ethernet frames are de-mapped from the GFP frame, the inter-frame gaps are re-introduced and the Ethernet stream passed to a MAC layer for further processing.



This slides provides a comparison of GFP, LAPS and PPP/HDLC.

Since the GFP frame header is the same size as the Ethernet preamble, GFP does not incur any net bandwidth expansion in the translation from Ethernet frames to SONET or SDH.

The throughput capacity is predictable because the mapping doesn't inflate the frame length in a non-deterministic way.

GFP minimizes the protocol-specific processing and protocol translation associated with Packet over SONET/SDH. It also allows transparent transport of character stream in addition to frame-based client signals.

GFP provides the ability to identify the encapsulated client protocol separately from the Extension Header.

GFP is more efficient and robust than HDLC and is low overhead

The native Ethernet error detection capability is protected, since the FCS is preserved.

Containers that fit new technology

Possible Payloads	SONET Container	Bit Rates
Fast Ethernet (100 Mb/s), FICON 133Mb/s	STS-3c	155 Mb/s
ESCON (200Mb/s), Fibre Channel (266Mb/s)	STS-6c	310 Mb/s
Fibre Channel (425 Mb/s)	STS-9c	466 Mb/s
Fibre Channel (531Mb/s)	STS-12c	622 Mb/s
GbE (1000 Mb/s), Fibre Channel (1062 Mb/s)	STS-24c	1244 Mb/s
2 x GbE's (1000Mb/s)	STS-48c	2488 Mb/s

Encapsulation of some of the newer technologies such as Gigabit Etherent and Fiber Channel is resulting in the use of some SONET/SDH containers that have not been particularly popular in the past. This is because some of these technologies fit very badly into the popular containers, and much better into some of the less popular. In this diagram, the traditionally popular containers are highlighted in blue and the containers that are now becoming popular are highlighted in green.

As an example take 266Mb Fiber Channel. Fitting it into the popular STS-12c container wastes almost 60% of the available 622mb bandwidth. Putting it into an STS-6c container which has a much more appropriate 310mb makes a saving of over 40%.

Using virtual containers can improve the utilization even more.

Technology summary

- SONET/SDH WAN infrastructures
  - Reliable, robust, voice oriented, expensive to replace
- Ethernet
  - LAN all-pervasive data transport, now valid in MAN and WAN
  - Gigabit and 10 Gigabit Ethernet
- New Ethernet over SONET encapsulations
  - GFP/LAPS
  - Cost effective, secure way for data across existing infrastructures
  - Maintains Ethernet frame end to end including FCS for robustness
  - Predictable network throughput

Agilent Technologies

So, let’s summarize this tour through the enabling technologies.

First of all we have the established SONET/SDH wide area networks, offering high reliability and performance but come with high capital and operating expenses.

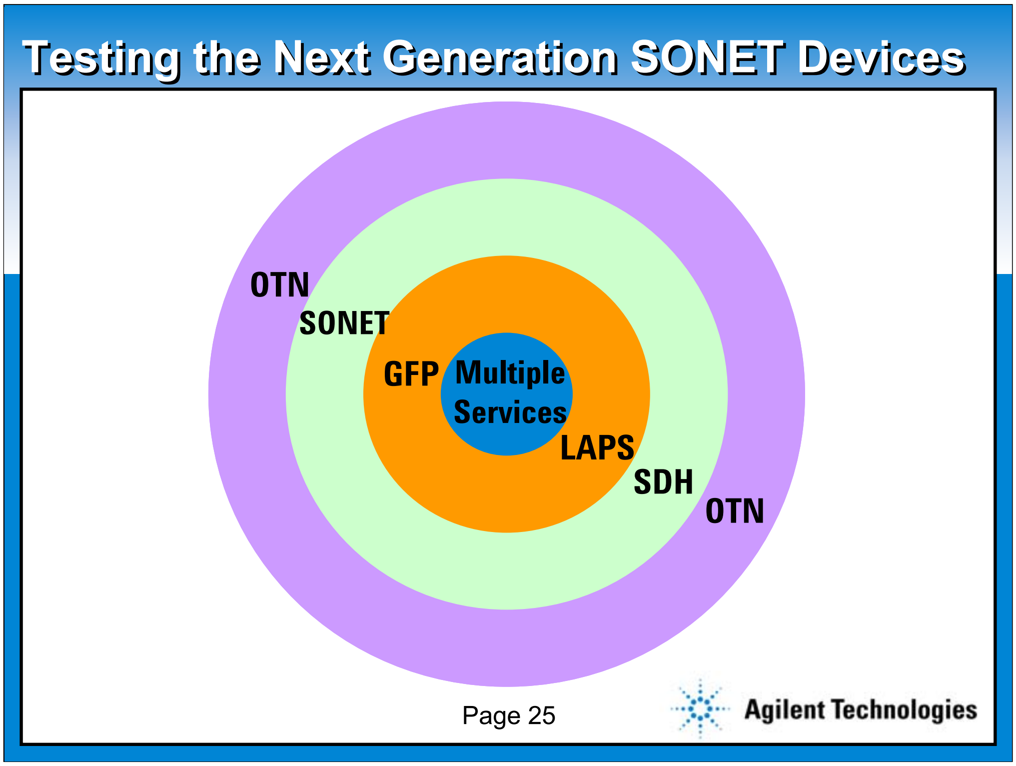
Then we see Ethernet becoming more than just the dominant LAN technology, extending data traffic into the metro network with Gigabit Ethernet and even into the WAN networks with the 10Gb Ethernet technology.

Then lastly we see the new Ethernet over Sonet encapsulations, GFP and LAPS, which can work within existing networks, and bring additional benefits to established technologies such as Packet over Sonet.

They minimize or eliminate the need for expensive re-build network costs.

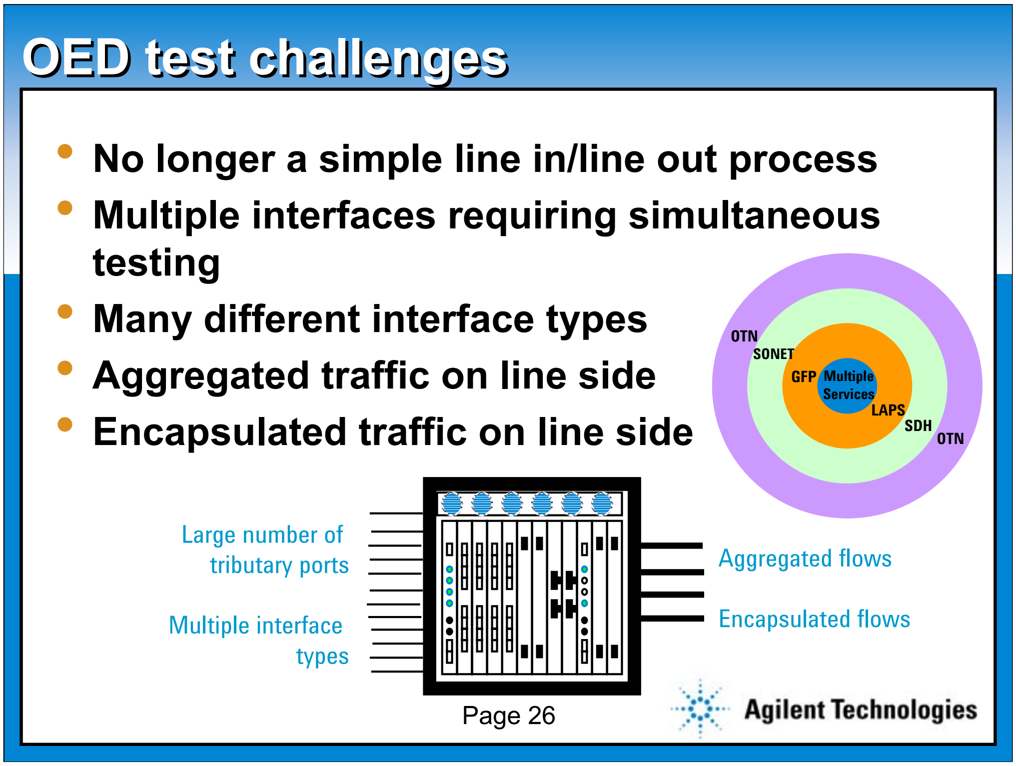
They provide the same look and feel of Ethernet to LAN, MAN and WAN administrators by transparently preserving the Ethernet MAC layer as the entire frame is transported unaltered. This means the native Ethernet error detection capability is protected, since the preserved FCS is available for error checking by receiving stations.

Last but not least, the predictability of the network throughput capacity is maintained since the mapping does not inflate the frame length. This helps to protect the network from overload conditions.



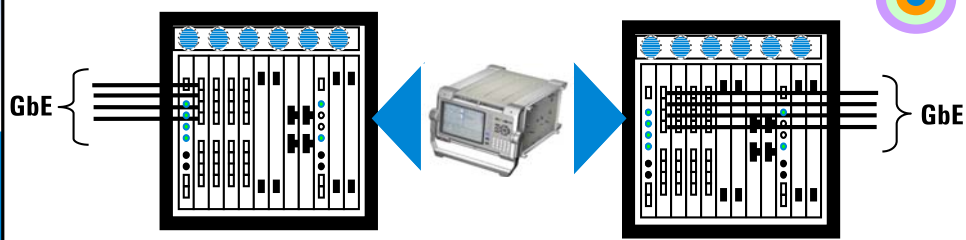
Clearly, these new optical edge devices and the new technologies they support are going to be critical components of the metro networks as the world moves to this next generation of networking. As such, it is essential they receive the necessary test disciplines at each stage in their development, verification, production and deployment.

I'd now like to hand over to Hussain who is going to take you through some of the testing scenarios needed for these devices.



With the evolution of Optical Edge Devices the device intelligence has started to move up in the hierarchy from the Access towards the Metro networks. This implies that networks will get simpler, but the next generation SONET devices will get complex. These devices are no longer just a Line in line out rather by virtue of multiple interfaces they now support multiple service. One of the main functions for these devices is aggregation and since the aggregated traffic has to be transported over the existing SONET backbones these devices need to support encapsulation. Increasingly these devices are required to support bandwidth efficiency functions as well. With the passage of time as more and more intelligence gets build into these devices their complexity will increase. Testing these devices has already become complex. The penetration of multiple services in the multi vendor environment requires the equipment manufacturers to ensure standards compliance and interoperability. Equipment manufacturers are now looking for test solutions that can reduce the test complexity and at the same time enable them to ensure standards compliance and interoperability. The evolving next generation SONET/ SDH devices may support and payload like Ethernet, ESCON, FICON or Fibre Channel from the available multi services. They can be encapsulated using GFP or LAPS into the SONET or SDH pipes which can then be transported using OTN networks. Thus in order to have a comprehensive debug capability your tester must support the enlisted mapping structures as well as the evolving virtual and contiguous concatenations. In the coming slides we will be covering the characteristics of various testing techniques that can be employed to test these devices. We would be supposing that the consolidated signal on the line side consists of a valid combination of services enlisted earlier.

Testing A Network Element **Thru-Mode**

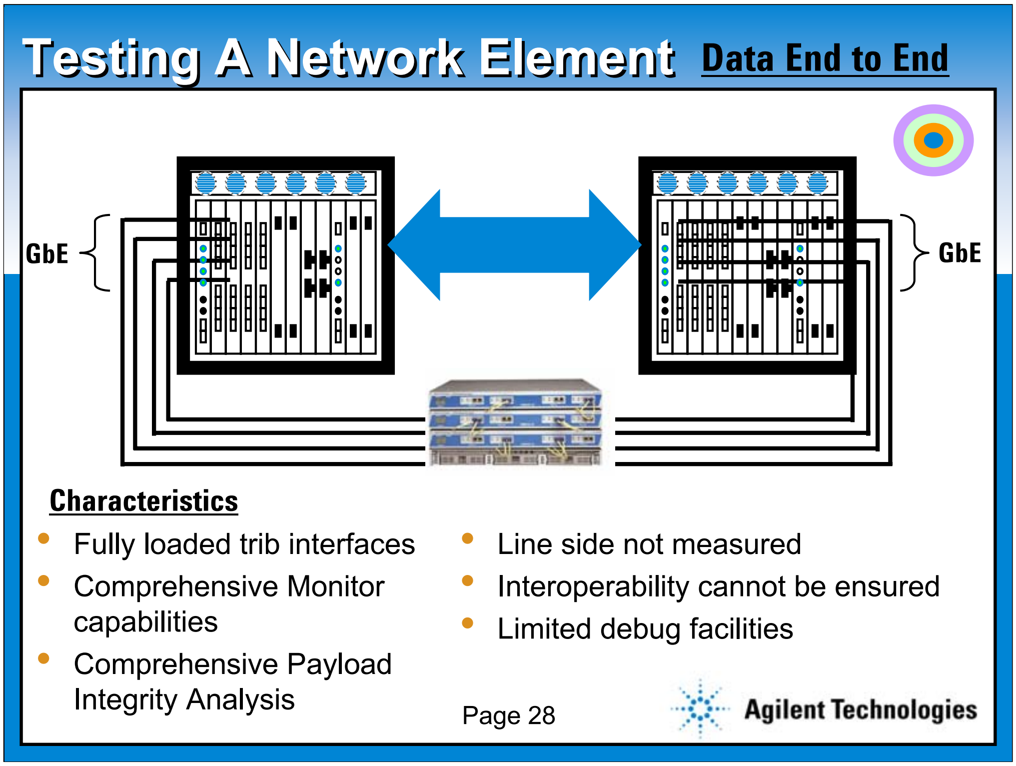


Characteristics

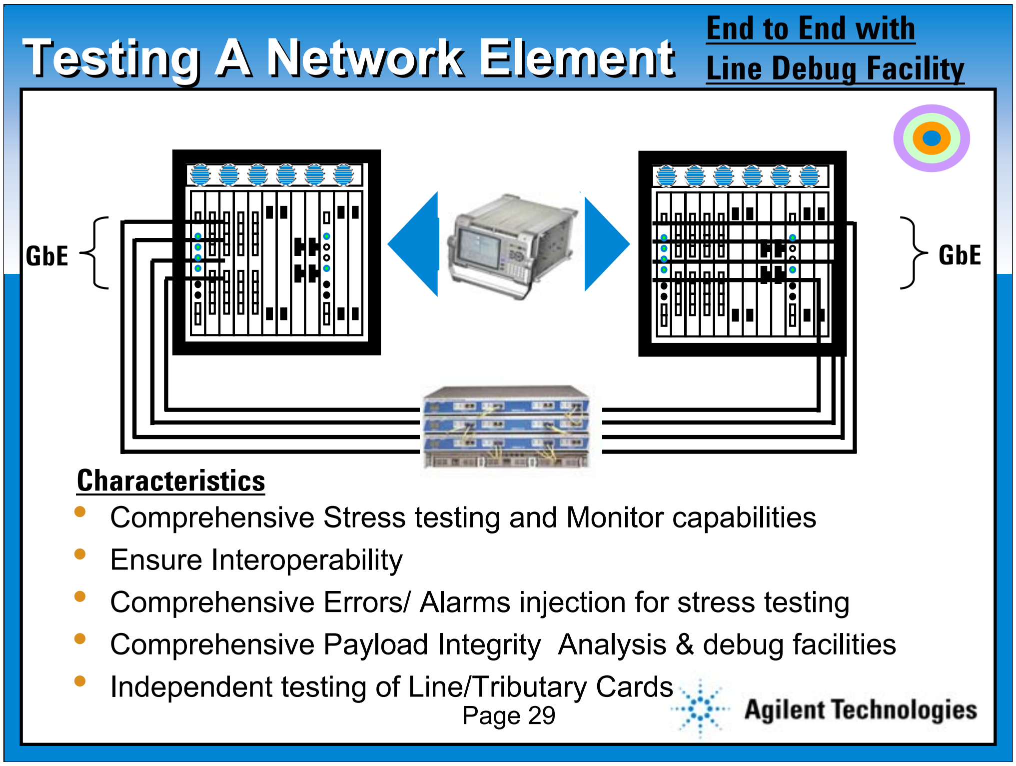
- Comprehensive Monitor capabilities
- Ensure Interoperability
- Errors/ Alarms injection facilities for stress testing
- Payload Analysis
- Comprehensive debug facilities

- Stress testing of Mapping functions cannot be performed
- Throughput analysis cannot be done
- Lack of Payload Integrity analysis

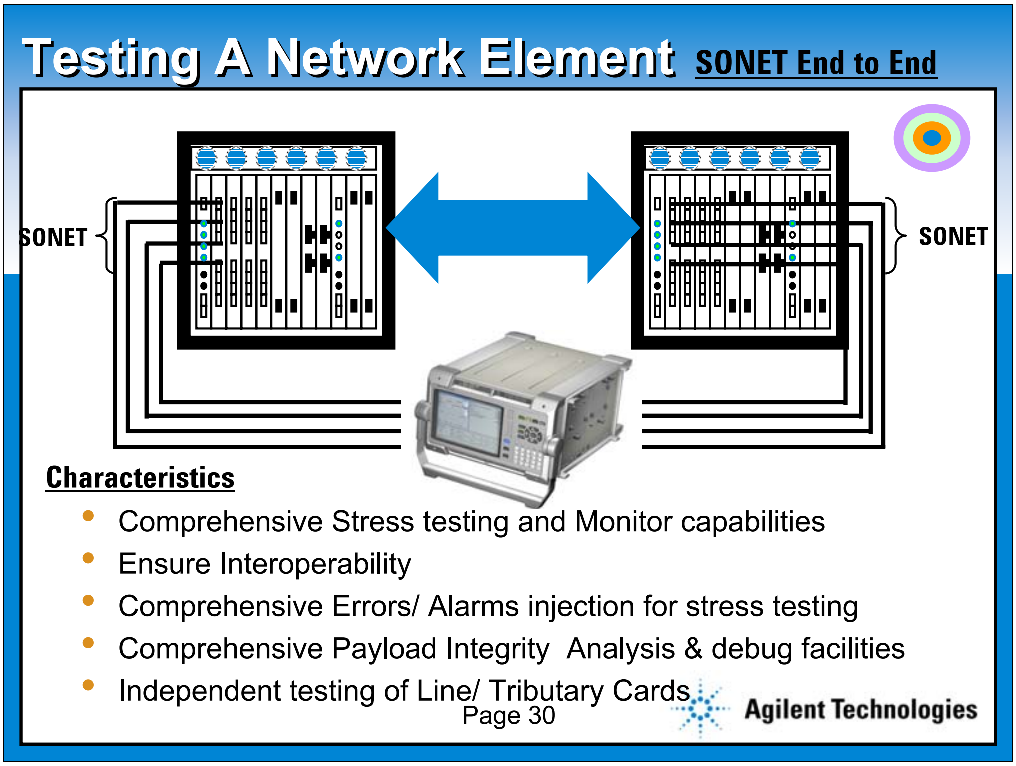
Proceeding to slide 30.



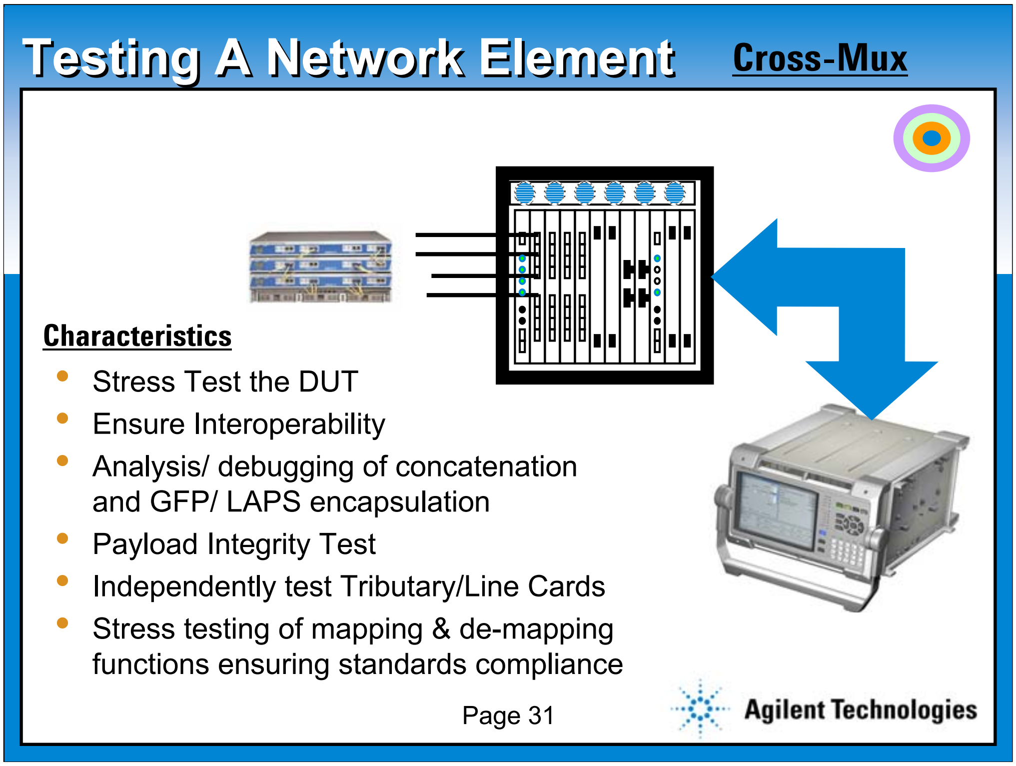
Lets now discuss about the end to end test for data services on the next generation SONET devices. In this mode you connect the two device under tests back to back and employ a multi-port tester in between the tributary sides also referred as client sides. The obvious benefit of this mode being reduced test time since you can simultaneously load and test all the client ports. This mode provides a comprehensive monitor capability for errors and alarms. You can perform a comprehensive payload integrity test since the same instrument is used to generate and receive the payload. In this test mode it's a given that the two device under test can interoperate and therefore no coverage is given to the Line side testing. The obvious demerit being the lack of confidence for interoperability. You cannot stress the concatenation, mapping and de-mapping functions. Thus we can summarize that this mode provides comprehensive monitor capabilities with measurements like throughput, latency and frame count, but limited line side debug capabilities



The next testing mode is the End to End testing with Line debug capabilities. This testing technique has the benefits of both the End to end and thru-mode. In this mode the tester on the client side is used to generate/load as well as analyze the test signals. Another tester is placed in thru mode in between the device under test which provides the line debug facility. This mode provides stressing functions for your mappings and concatenations so that you can ensure interoperability and standards compliance. Further due to the availability of thru-mode comprehensive error and alarm injection and monitor capabilities are also supported. The payload is generated and received by the same instrument which enables the payload integrity test. Measurements like latency, throughput and Frame count can also be performed. To summarize we can say that this testing mode enables the independent and comprehensive testing of both Line and Trib cards or functions.

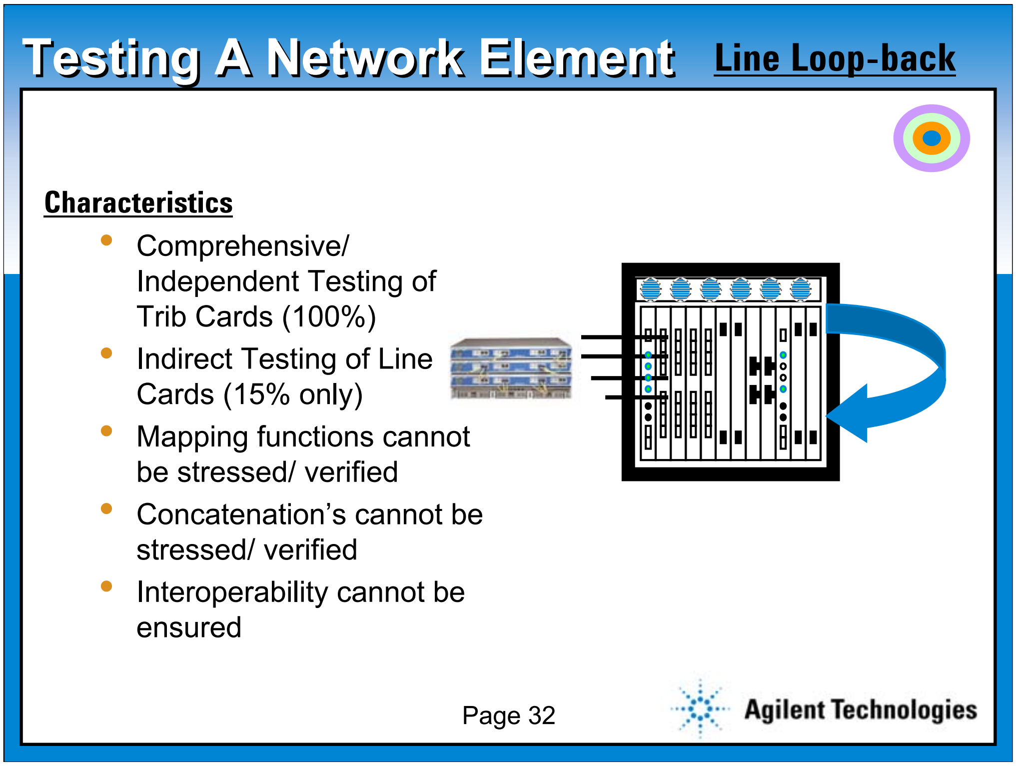


This testing technique is referred as end to end testing for SONET/ SDH services. The characteristics of this testing mode are similar to the ones discussed earlier for data end to end technique. As you can see from this slide a SONETor SDH tester is used to generate and analyze the test signals on the client side. This testing mode targets the SONET/ SDH services which allow Line/ Trib testing of the device. This mode provides a comprehensive monitor capability for the errors and alarms. Since the same tester is used to generate and receive the payload you can perform a comprehensive payload integrity test. To summarize the capabilities we can say that this mode provides comprehensive monitor and debug capabilities for SONET and SDH services but the data services would require you to employ a second tester.



Cross Mux Testing is the mode that provides a comprehensive test coverage for your device under test. In this mode a multiport tester is employed on the Tributary side to load the device and a SONET/ SDH tester is employed on the Line side which can test and generate the aggregated traffic. By employing this mode you can ensure interoperability and comprehensively test your mappings and concatenations. In one direction, when the client side multiport tester is generating the traffic, you can perform payload integrity test for the standards based payload's. In the reverse direction you can perform the measurements like throughput, latency and frame count. In short you can independently and comprehensively test and verify your Line & Trib functions as well as cards.

.



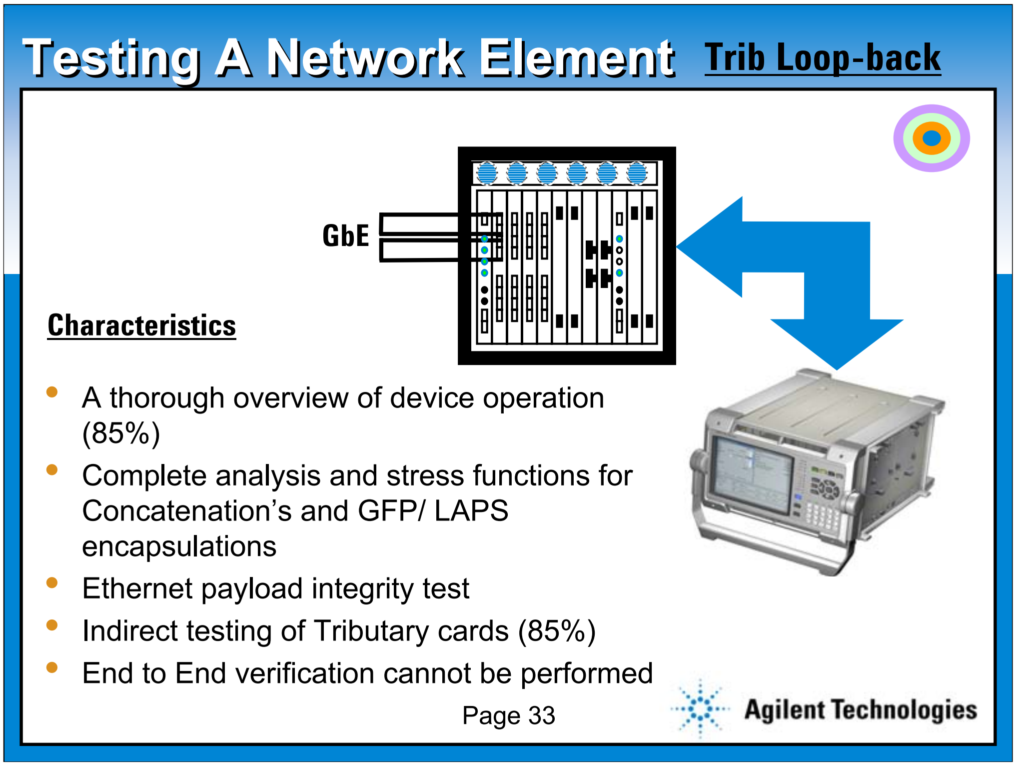
Today the commonly used testing technique is by looping back the Line Side. This capability provides you limited visibility of the device being tested.

This technique has its benefits in providing independent testing of your tributary cards but unfortunately your line cards suffer and cannot be comprehensively tested.

This results in lower confidence for confirming the mapping functions and concatenations which would end up in a lower confidence level for interoperability.

The main headache for engineer's designing these new devices is interoperability and standards compliance. They need a device that can peel of the layers within the SONET line side dig down to the payload and confirm that all the layers were in conformance to the standards.

Line loop back is the most commonly employed testing mode. In this mode a Multiport tester is employed to load and test the tributary ports and the Line side is looped back. Due to the loop back the Line cards can only be indirectly verified which means that the mapping and de-mapping cannot be stressed or verified. The signal is generated and analysed by the same tester which allows you to perform the payload integrity test. A 100% test coverage is provided for the tributary functions/ cards but due to the indirect testing of the Line side the interoperability can not be ensured.

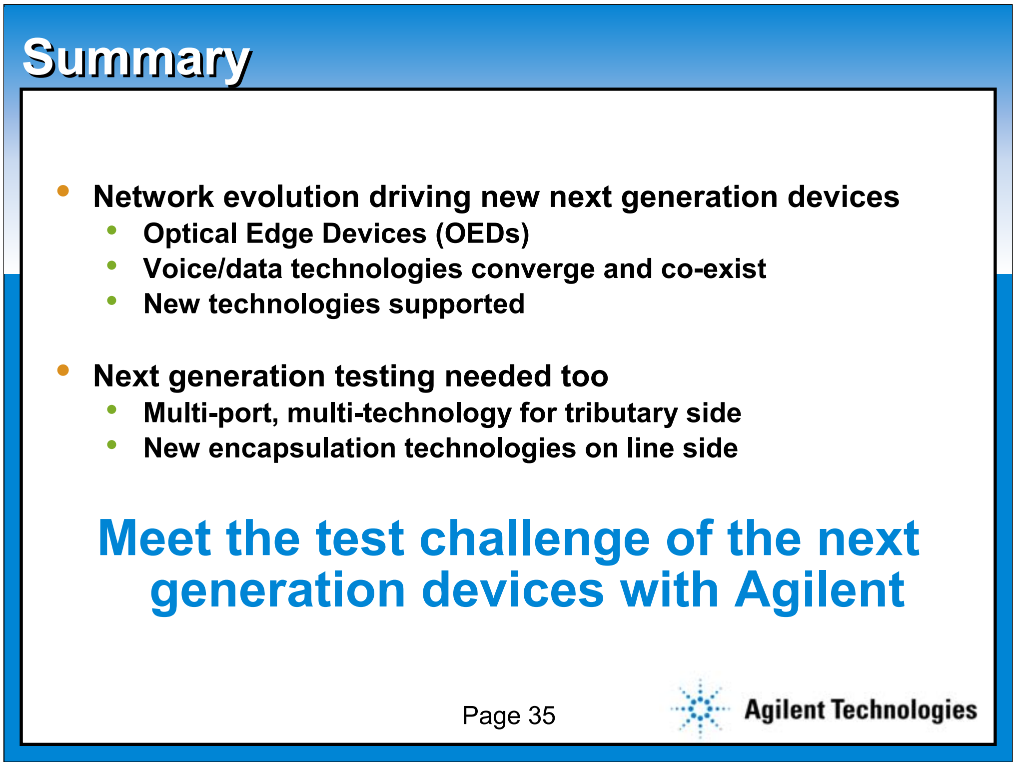


This testing mode allows a thorough overview of your device under test with simple test set-up. In this mode you employ a tester on the Line side and loop back your tributary inputs. If your test instrument is able to generate a comprehensive test signal, with mapping and concatenations, then you can stress test your device under test. Payload integrity test can also be performed since the same instrument would be used to generate and receive the signal. You can independently test and verify your Line cards but only an indirect testing can be performed for the tributary cards. End to end verification cannot be performed with this testing mode which is the de-merit.

Meeting the NG SONET test challenge

Agilent OmniBER OTN 2.5Gb/s

- Single Input/ Output
- Multi-Rate Up to OC-192
- GbE/10GbE mappings into SONET/SDH
- GbE/ 10GbE Payload Analysis
- Virtual Concatenation
- OTN
- Jitter



So to summarize what we've been through today.

Networks are changing. There is more data traffic now than voice. Next generation devices are becoming multi-functional. There are new technologies being introduce to support convergence.

The new devices need to be tested at every level in the product cycle.

Agilent are the leading communications testing company in the world. Let us help you succeed in the new generation. Thank you.

Q & A

Thank you