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Making Ethernet Over SONET Fit a Transport Network Operations Model

Introduction

Many carriers deploy or evaluate deployment of EoS as a private line offering to enhance existing service offerings. Service definitions vary between carriers, but all believe the service needs to interoperate between vendors in a manner similar to current T1 or T3 services.

Several technology and operations issues, including Ethernet transparency, performance management, and alarm and failure propagation, are all important issues in the deployment of EoS.

Most carriers plan to deploy EoS using GFP, an ITU recommendation (G.7041). GFP provides the ability to map various traffic types—in this case, Ethernet—over a transport facility. GFP-F and virtual concatenation offer carriers service definition flexibility, enabling them to offer fractional Ethernet service based on STS-1 or VT1.5 granularity. GFP has an optional client control function that allows for LOS to be propagated across the network. GFP allows two mappings of Ethernet over SONET—Gigabit Ethernet transparent mapping and frame mapping. The benefit of GFP-F for Ethernet is that it handles various bit rates and network topologies. Unfortunately, the existence of variable length frames creates a problem that must be addressed.

EoS, like other private line services, has PM requirements so the carrier can develop SLAs and do trouble-shooting. One key difference between Ethernet and other transport services is that Ethernet does not have a fixed frame size, which impacts the PM data that is created.

Another network operation requirement is that SONET networks, and therefore private line services, have the ability to propagate alarm and failure information through the network. Some Layer 2 Ethernet switched networks must learn about physical faults so they can provide protection.

For your convenience, a list of acronyms can be found on page 10 of this document.

GFP is a process for taking various protocols and adapting them for transport technologies such as WDM and SONET. GFP allows for two mappings of Ethernet—transparent mapping and frame mapping. Frame-mapped GFP uses the structure as shown in Figure 1:

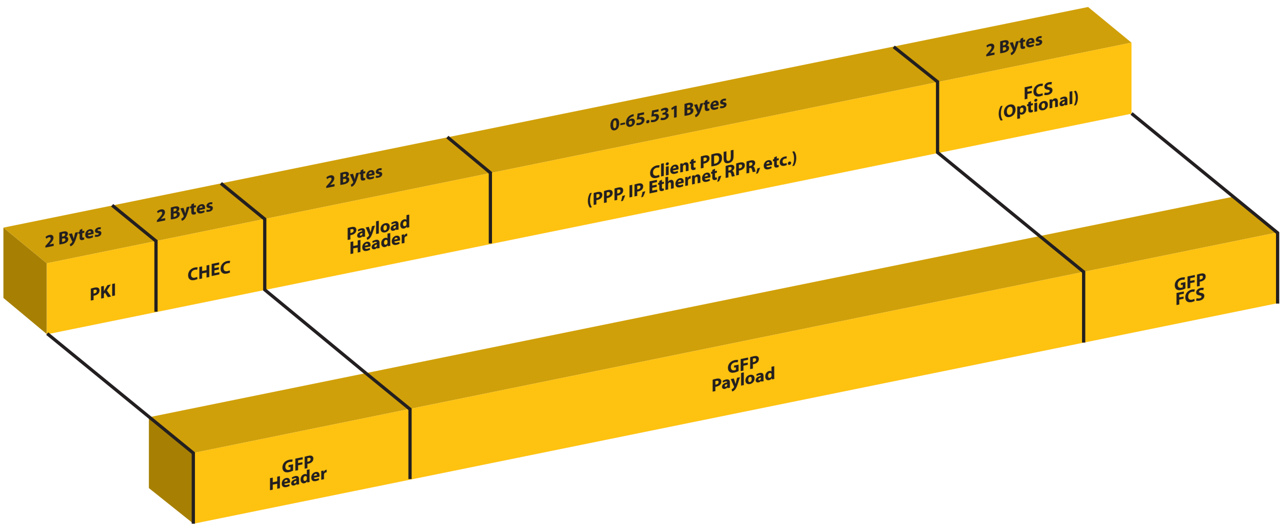

Figure 1: Frame-Mapped GFP

The Client PDU can be up to 65,531 bytes in length, which is quite different than those of standard transport technologies that use fixed payloads. Ethernet MAC payloads of 10 Mbps, 100 Mbps, 1 Gbps or 10 Gbps Ethernet frames are received and then mapped into frame-mapped GFP, which in turn is mapped into either virtually concatenated SONET tributary paths or WDM paths.

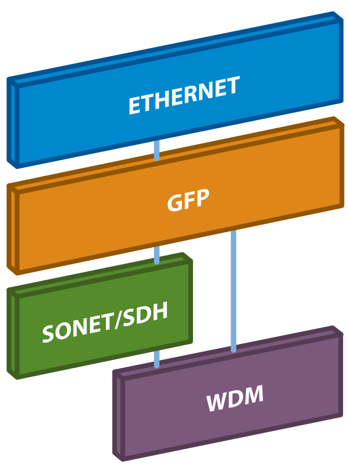

Figure 2: GFP Mapping Hierarchy

Gigabit Ethernet interfaces can also be mapped using the transparent mode of GFP. Transparent mode takes an 8B/10B-coded Ethernet stream and provides a low-latency mapping to SONET/SDH or WDM. This process is accomplished by de-mapping the characters from the Gigabit Ethernet signal block codes and mapping them into periodic fixed-length GFP frames. Since this process only looks at characters, the system will consume the full bandwidth of a Gigabit Ethernet connection even when less bandwidth is needed. To help illustrate the difference between the two mappings and private line services, please refer to Figure 3:

	Frame Mapped GFP	Transparent Mapped	Private Lines via SONET
Services Supported	10 Mbps, 100 Mbps, 1 Gbps and 10 Gbps	1 Gbps	T1, E1, T3, OC-3, OC-12, OC-48
Frame Type	Variable Length	Fixed Length	Fixed Length
Bandwidth Efficient	Yes	No	Yes
Variable Rate	Yes	No	No
Needs Flow Control (Pause Frame)	Yes	No	No
Failure Signals	No	No	Yes
Performance Management	Frame errors	Based on error codes or Character errors	Code violations

Bandwidth Efficient	The transport device can provide an incremental interface that may provide a WAN transport rate that is less than the port interface. For example, a 100 Mbps interface can be mapped into a 51 Mbps STS-1.
Variable Rate	Customer traffic as seen by the transport element can vary over time.
Failure Signals	The ability to signal the client or end-user about a failure in the network.
Performance Management	Key metrics to measure faults.

Figure 3: GFP Mapping Comparison

Virtual Concatenation

Virtual concatenation provides the ability to split and recombine different SONET signals that may or may not ride different paths (similar to inverse multiplexing). For example, a 100 Mbps signal can be mapped into two STS-1s (STS1-2v) and transported across a SONET interoffice or long haul network taking two different paths as shown in Figure 4. Virtual concatenation provides the ability to use existing bandwidth across a network more efficiently.

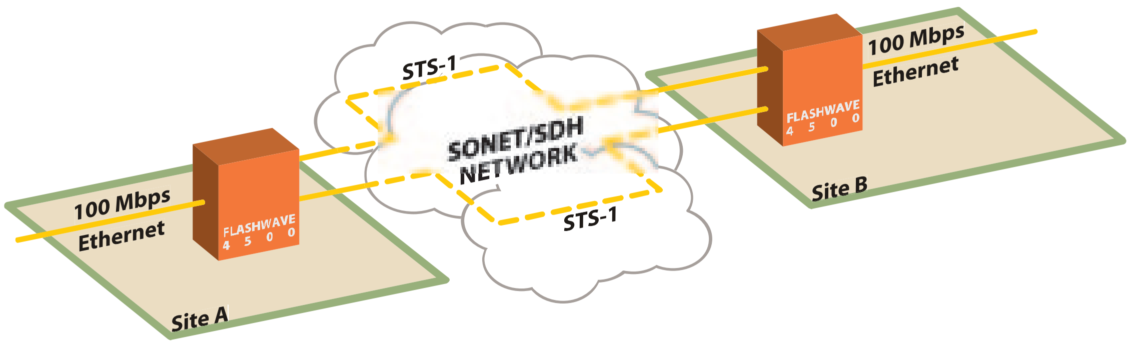

Figure 4: Virtual Concatenation

To further illustrate the point on network efficiency, a core IOF network may have only 12 STS-1s in one path, while there are nine in another path. With this amount of bandwidth and virtual concatenation, a full-rate Gigabit Ethernet circuit can be mapped into this SONET network. Examples of possible concatenations are shown in Figure 5:

Interface / Virtual Concatenation	Number of Supported VT1.5 Connections	Number of Supported STS-1 Connections	Number of Supported STS-3c Connections
10 Mbps Ethernet	2-7	1	NA
100 Mbps Ethernet	2-64	2-3	1
1 Gbps Ethernet	N/A	2-24	2-8

Figure 5: Number of Supported Connections per Interface Type

Virtual concatenation adds a challenge to operations management because a single service can be routed over multiple paths. Thus, an outage of one of the STS-1 timeslots may have an impact on the service. In addition, due to the ability to route over any path, the network planner has to be aware of the issue of delay compensation. Using Figure 4 as an example, the two STS-1 timeslots are utilizing different paths that may have different delays. The NE is designed to compensate, but if a protection switch occurs or the network is reconfigured, the delay could fall out of bounds. In such cases, the NE will generate an alarm about the failure. The EMS will report the alarm and correlate it with any other network failures.

PAUSE Frames

GFP-F and virtual concatenation provide service definition flexibility, enabling carriers to offer fractional Ethernet services based on STS-1 or VT1.5 granularity. For a fractional service to work, carriers will use PAUSE frames as defined by IEEE 802.3x to delay the incoming pipe if a customer bursts too much traffic onto a SONET network. A PAUSE frame is an Ethernet frame that tells another device to stop sending packets for a set time due to congestion. This process is very similar to the way a stop light functions—when the light is red all traffic stops; when the light is green all traffic can go. For example, if a customer has a 100 Mbps Ethernet service, but the available bandwidth is limited to an STS-1 at 51 Mbps, the carrier will use a PAUSE frame to slow down incoming traffic.

Implementing this PAUSE frame and fractional Ethernet functionality is quite different from how a T1, T3 or OC-3 private line service is offered. Ethernet devices will react only to the last PAUSE frame sent (as defined in IEEE 802.3x). For example, if PAUSE frame A is sent first with a delay of 50 and then PAUSE frame B is sent with a delay of 10, the Ethernet device will react only to the last PAUSE frame (PAUSE frame B in this case).

Typically, two types of PAUSE frames are deployed. One type uses a PAUSE frame timer and the other uses an XOFF/XON type. They both use the same PAUSE frame format although they put different values in the PAUSE field. The PAUSE frame timer type puts a value with the number of frames to delay. The XOFF/XON type sends a PAUSE frame with an "FF" (hex) value that tells the far-end to stop. When the buffer is cleared, the Ethernet device sends a PAUSE frame with a "0" value that tells the packets to start again. The transport network must count PAUSE frames that are created or received to highlight when congestion issues occur on the link.

Performance Management

EoS, like other private line services, has PM requirements so the carrier can develop SLAs and do trouble-shooting. One key difference between Ethernet and other transport interfaces is that Ethernet does not have a fixed frame size, which impacts the PM data that is created.

Numerous parameters can help with trouble-shooting but only a couple relate to SLAs. The SLA-relevant PM parameters for Ethernet services riding a SONET network include transport link status, virtual concatenation failure and encapsulation failure. These errors will inform the carrier and the customer about the performance of the transport network in regard to the Ethernet service.

Other parameters are just as important for trouble-shooting. For example, the number of frames received in error can tell the carrier when a problem exists with the connection between the transport element and the customer's equipment. Frames can be in error because of a coding violation or improper format.
In comparison with other private line services, errors on the Ethernet side will be counted on frames as opposed to bits.

Different frame sizes can relate to the number of frames being sent and thus impact performance differently. To further clarify the point, Figure 6 shows the difference between frame size, interface and frame violations for a standard error rate per second used for TDM. A frame violation is any invalid frame format of Ethernet (e.g. FCS error).

Ethernet	Overhead Bytes		Frame Error Rate		Utilization	
	20		1.00E-03		50%	
MAC Size Bytes	10 Mbps Ethernet	Frame Violations	100 Mbps Ethernet	Frame Violations	1 Gbps Ethernet	Frame Violations
64	14880	8	148809	75	1488095	745
128	8445	5	84459	43	84459	423
256	4528	3	45289	23	45289	227
512	2349	2	23496	12	23496	118
1024	1197	1	11973	6	11973	60
1518	812	1	8127	5	8127	41
9618	129	1	1296	1	1296	7

Figure 6: Frame Violations per MAC Size

Failure Handling

Another network operational requirement is that SONET networks, and therefore private line services, have the ability to propagate alarm and failure information throughout the network. Some Layer 2 Ethernet switched networks must learn about physical faults so they can provide protection. This section will review the various aspects of alarm and failure propagation necessary for EoS.

Certain types of Ethernet equipment and applications require a fault to be propagated across the network:

1) **The Ethernet switch or device requires a failure in order to do a protection switch.**
The network is providing a private line Ethernet connection via either SDH or OTN, and the Ethernet devices on the ends require a failure to be propagated in order to provide protection. Figure 7 illustrates a transport network that cannot repair the problem. The Ethernet switches would be responsible for the repair, but they must understand whether the failure occurred at the 10/100 Mbps or Gigabit Ethernet interface.

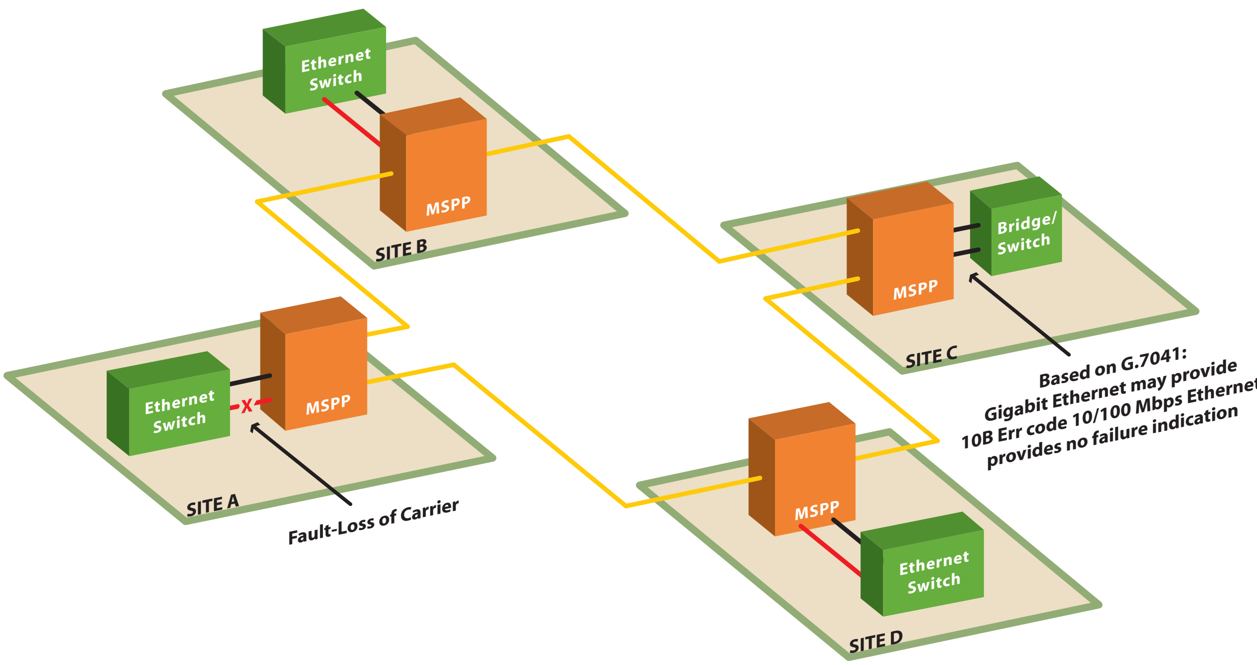

Figure 7: Protection Switch as a Result of a Failure

2) The carrier wants a failure between domains.
In this scenario shown in Figure 8, the carrier has two different business groups: one that provides private line services and one that provides Ethernet services. The Ethernet services group will need to see the failures going on in the network if they buy Ethernet private lines from the other division or other wholesale carriers.

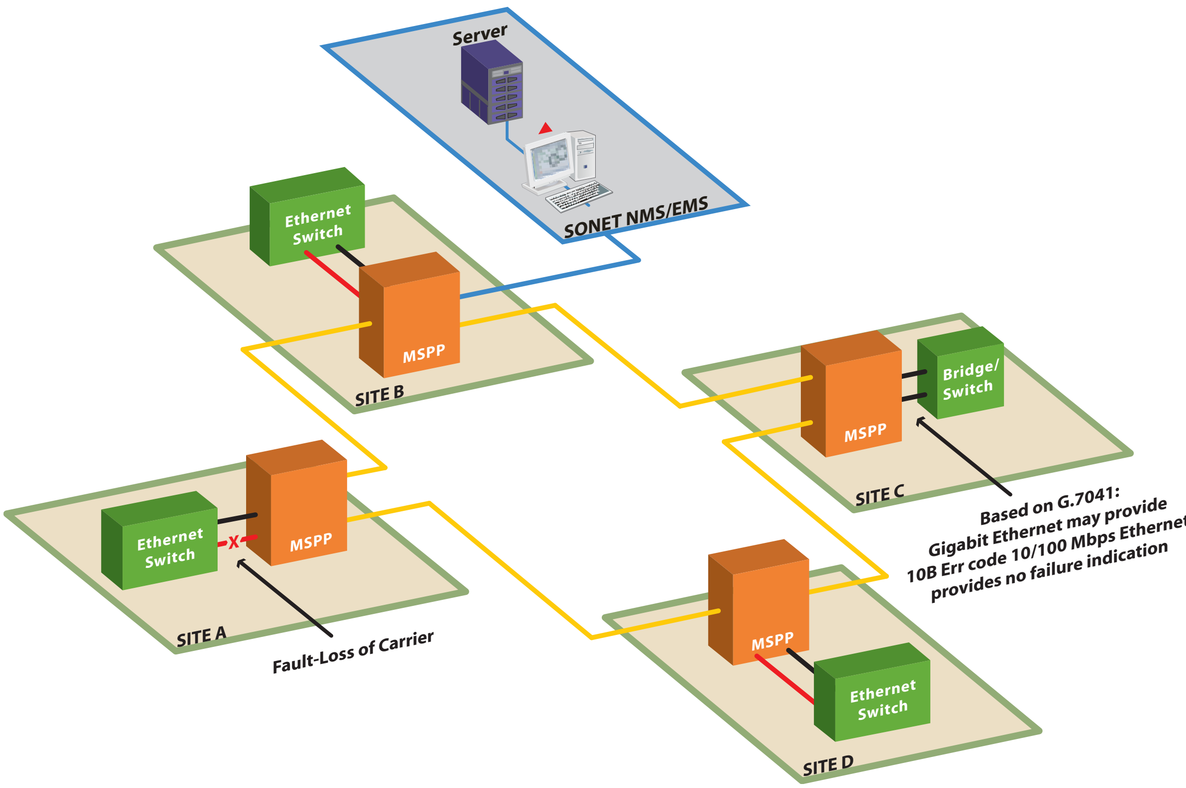

Figure 8: Failure Visibility

Sending failures across the network is extremely important. Two ways currently exist (with a future third way under development) to inform client equipment about a network failure. These methods are listed in Figure 9 along with their advantages and disadvantages.

Recovery Method	Error Type	What the client sees	Issues
8B/10B Err	8B/10B error code	Error code	Not all equipment will react to this error
Link Failure	Create a "hard" link failure like loss of Signal	Looks like cable was removed	Can create alarm storms. Works better for optical interfaces
Future: Ethernet OAM (IEEE 802.3ah)	Send an Ethernet OAM frame with the link status	Ethernet OAM frame (Connection stays up.)	Only IEEE 802.3ah interfaces (Ethernet First Mile) are required to send or respond to OAM frames. Participation is optional for existing 10/100 Mbps or Gigabit Ethernet interfaces

Figure 9: Ways to Inform Client Equipment about Network Failures

Standards groups are currently working to determine an appropriate method for providing failure information. Independent of the standards work, support for the various types of failures will be required due to the range of Ethernet products that may be attached to the transport network.

Summary

With the emergence of the Internet and data traffic, the North American network, which is mostly based on SONET technology, will have to adapt and ubiquitously support Ethernet with the same OAM capabilities as today's legacy DS1 and DS3 services. Various standard groups, such as T1X1 and ITU, have recognized this challenge and standardized new technologies, which enable this level of support.

Techniques, such as GFP, virtual concatenation and the upcoming IEEE 802.1ad Ethernet OAM standard, go a long way toward the successful integration and management of Ethernet services over SONET. However, many issues still have to be resolved in the area of virtual concatenation delay management, performance management and fault management.

Fujitsu is committed to helping resolve these technological issues and is actively participating in the various standards groups. Our FLASHWAVE® 4000 next-generation SONET MSPPs already include many of these advanced EoS management techniques, and we are committed to the successful introduction of carrier-class quality Ethernet over SONET services.

References

[1] ITU G.7041, *Generic Framing Procedure*

[2] ITU G.783.1

[3] IEEE Communications, May 2002, *The Generic Framing Procedure (GFP) An Overview* Enrique Hernandez-Valencia, Michael Scholten, and Zhenyu Zhu.

Acronyms

Acronym	Descriptor
EMS	Element Management System
EoS	Ethernet over SONET
FCS	Frame Check Sequence
GFP	Generic Framing Protocol
GFP-F	Frame-based Generic Framing Protocol
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
LOS	Loss of Signal
MAC	Medium Access Control
MSPP	MultiService Provisioning Platform
NE	Network Element
OAM	Operations, Administration and Maintenance
OTN	Optical Transport Network
PDU	Packet Data Unit
PM	Performance Monitoring
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
SONET	Synchronous Optical Network
TDM	Time Division Multiplexing
WDM	Wavelength Division Multiplexing

FUJITSU NETWORK COMMUNICATIONS INC.
2801 Telecom Parkway, Richardson, Texas 75082-3515
Telephone: (972) 690-6000
(800) 777-FAST
us.fujitsu.com/telecom