PLC and SONET/SDH Networks Bridging with Ethernet

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Abstract. Power Line communications (PLC) provides "Broadband Ethernet" connectivity directly to the customer's socket in home without additional cabling. However, PLC networks do not provide global end-to-end connectivity and need to rely on incumbent's telecom networks. In order to lower the cost of CAPEX and OPEX the network interconnection is done at "Ethernet" level. Most of Incumbent's networks are based on SONET/SDH Rings, and efficient transport of Ethernet over those technologies is a prime requirement. Ethernet over SDH/SONET (EoS), enables internet services over existing SONET/SDH systems using a simple structure. However, SONET/SDH is a TDM technology optimized for voice, and the standard rates are bandwidth inefficient when data is transported. With virtual concatenation it is possible to provide fine granularity in the transport of data traffic over SONET/SDH. The combination of these two technologies (EoS and virtual concatenation) in the same system will allow remote LANs to be connected together at lower costs in a very simple and bandwidth efficient way.

1 Introduction

Power Line Communications technologies provide ubiquitous connectivity within buildings (Multi tenant and Multi Dweller), allowing every computer or device with a CPE card or box to be plugged into any socket of any room.

Broadband networks aim to provide High Speed connections at low cost. Protocol translations usually bring complexity and add cost; therefore the telecom industry is pursuing solutions that keep protocol connectivity end to end. The good old Ethernet is breaking its barriers within the LAN world and preparing its invasion into the WAN. The low cost of ports, as well as being well known by the communications industry, make Ethernet the best candidate to bring low cost broadband.

A typical architecture to provide End-to-End Ethernet connectivity over power lines will consist of:

- In-home network, based on the low voltage network, and its network elements:
  - CPE devices that connect end-users to a PLC in-home network;

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  - Home Gateways that connect the PLC in-home network with the PLC access network.
- Access network, based on the low voltage distribution network, and its network elements:
  - Home Gateways;
  - MV/LV Gateways that connect the access network and the aggregation network.
- Aggregation network, based on a medium voltage distribution network, where the network elements are MV/LV gateways that connect the MV network with the LV voltage network, bypassing the transformer. Those gateways can handle the Ethernet traffic generated by 10 to 100 end-users.
- Regional/Core networks based on incumbents SONET/SDH rings. In order to provide Ethernet connectivity an Edge Node is required that handle the Ethernet traffic generated by 3-7 medium voltage transformers and mapped it efficiently into the SONET/SDH rings.

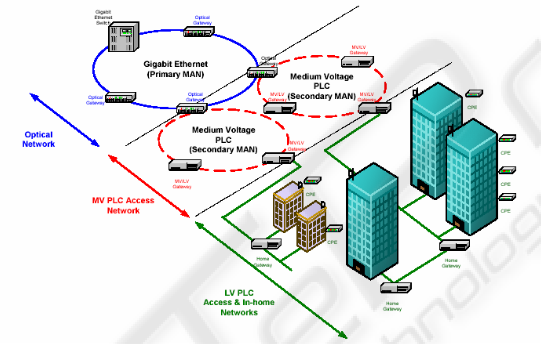

Fig. 1. Ethernet over PLC network example

2 Mapping Ethernet in SONET/SDH

SONET/SDH technology provides a highly resilient, fully managed fiber infrastructure with back-office systems already in place to deploy global services, but the existing SONET/SDH transport structures have been optimized to support traditional TDM voice applications. However, data traffic is now dominating the transport networks, and the standard rates are bandwidth inefficient when data is transported. Tab. 1 shows the SONET/SDH digital hierarchies, with these standard rates.

Table 1. SONET/SDH Digital Hierarchies

SONET	SDH	Bit Rate
STS-1	STM-0	51.84 Mbit/s
STS-3	STM-1	155.52 Mbit/s
STS-12	STM-4	622.08 Mbit/s
STS-48	STM-16	2488.32 Mbit/s
STS-192	STM-64	9953.28 Mbit/s
STS-768	STM-256	39812.12 Mbit/s

This inefficiency has forced the development of a new mechanism that provides fine granularity to transport data traffic (Ethernet, ATM, IP, etc.) through SONET/SDH networks. This mechanism is called virtual concatenation.

Another breakthrough technology in the SONET/SDH world nowadays is Ethernet over SONET/SDH (EoS). EoS technology is expected to greatly simplify and reduce the cost of maintaining corporate networks that span several geographic sites. Fig. 2 shows an EoS network example. Two new different methods for mapping Ethernet frames over SONET/SDH payload envelopes have being specified: Link Access Procedure-SDH (LAPS) standard by ITU-T [2] and Generic Framing Procedure (GFP) draft standard by the T1X1.5 working group [7].

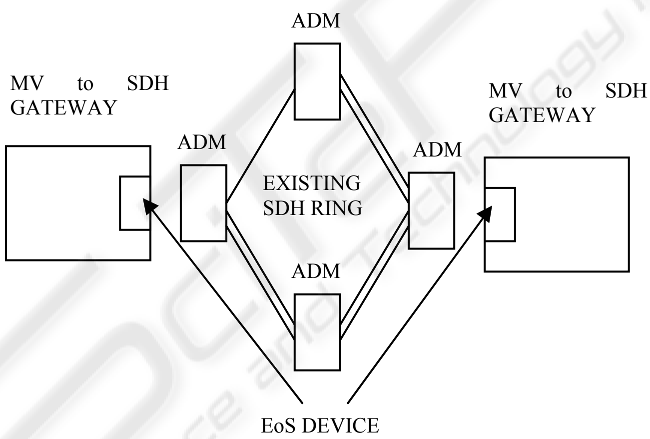

Fig. 2. Ethernet over SONET/SDH network example

Using these new technologies we are trying to develop an EoS mapper with virtual concatenation for a SONET/SDH terminal multiplexer system.

The aim of the project is to map Ethernet frames into OC-3/STM-1 structures using the ITU-T standards X.86 (Ethernet over LAPS) and G.707/Y.1322 and the ANSI standard T1X1.5 (along with GFP contributions).

In this paper we briefly describe these new technologies, virtual concatenation and Ethernet over SONET/SDH using both LAPS and GFP.

3 Concatenation in SONET/SDH

The SONET/SDH structures define a synchronous optical hierarchy with flexibility to carry many different capacity signals. The payload of the basic signal is structured in virtual tributaries (VT), in SONET, or tributary units (TU), in SDH, providing in this way for the transport of lower rate services.

Payloads that exceed the standard payload capacities can be transported using concatenation. There are two methods of concatenation: contiguous and virtual concatenation. Contiguous concatenation groups the payload of several signals forming a payload that is transported as a whole through the network. In virtual concatenation, the individual payloads associated to a concatenated group are transported individually through the network. Virtual concatenation requires concatenation functionality only at the path termination equipment, while contiguous concatenation requires concatenation functionality at each network element. Virtual concatenation only requires up-grading the ends of the path, so the up-grade costs are lower.

Virtual concatenation is defined at two levels: high order and low order. High order virtual concatenation group the payload of different signals of 51.840 Mbit/s or 155.52 Mbit/s, while low order virtual concatenation group the payload of different VTs/TUs which have lower rates such as 1.544 Mbit/s, 2.048 Mbit/s, etc. Tab. 2 and Tab. 3 show the capacity of virtually concatenated tributaries in SDH and SONET respectively.

Bit rates for LAN services are typically 10 Mbit/s and 100 Mbit/s. Other services, e.g. ATM cells stream, may vary from a few Mbit/s to several tens of Mbit/s. These bit rates can be fitted in the virtual concatenated payloads, improving the use of the bandwidth. Besides, voice and data can be sent using the same transport structure.

Associated with virtual concatenation there is also a new methodology for hitlessly changing the payload allocated to virtually concatenated SONET/SDH SPEs. This methodology, called Link Capacity Adjustment Scheme (LCAS), allows to accommodate the SPE (adding or removing tributaries) to situations like requested increases or decreases in capacity requirements or link failure conditions [6].

4 Ethernet Over LAPS

LAPS protocol and specification was introduced in ITU-T Recommendation X.85/Y.1321 (IP over SDH using LAPS) and was defined as a type of HDLC, including data link service and protocol specification which are used to the network of IP over SDH [1]. LAPS allows the encapsulation of IPv6, IPv4, PPP and other upper layer protocols, and is fully compatible with RFC 2615 (PPP over SONET/SDH) when the address field is set to “11111111”. This protocol provides a point-to-point unacknowledged connection-less-mode service over SDH.

ITU-T Recommendation X.86 describes how to adapt Ethernet frames to LAPS, so they can be later transported through SDH networks. The relationship between the different entities is shown in Fig. 3.

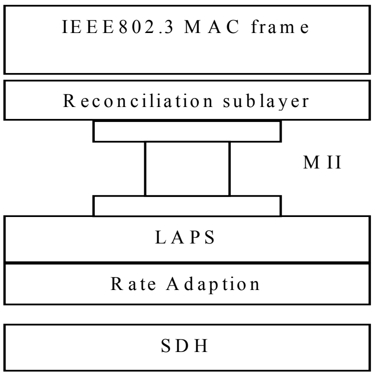

Fig. 3. Relationship between Ethernet and LAPS and SDH

Table 2. SDH Capacity of Virtually Concatenated VCs

	Carried in	X	Capacity (kbit/s)	In steps of (kbit/s)
VC-11-Xv	VC-3	1 to 28	1600 to 44800	1600
VC-11-Xv	VC-4	1 to 64	1600 to 102400	1600
VC-11-Xv	Unspecified	1 to 64	1600 to 102400	1600
VC-12-Xv	VC-3	1 to 21	2176 to 45696	2176
VC-12-Xv	VC-4	1 to 63	2176 to 137088	2176
VC-12-Xv	Unspecified	1 to 64	2176 to 139264	2176
VC-2-Xv	VC-3	1 to 7	6784 to 47448	6784
VC-2-Xv	VC-4	1 to 21	6784 to 142464	6784
VC-2-Xv	Unspecified	1 to 64	6784 to 434176	6784

Table 3. SONET Capacity of Virtually Concatenated VTs

	Carried in	X	Capacity (kbit/s)	In steps of (kbit/s)
VT1.5-Xv	STS-1	1 to 28	1600 to 44800	1600
VT2-Xv	STS-1	1 to 21	2176 to 45696	2176
VT3-Xv	STS-1	1 to 14	3328 to 46592	3328
VT6-Xv	STS-1	1 to 7	6784 to 47448	6784
VT1.5-Xv	STS-3c	1 to 64	1600 to 102400	1600
VT2-Xv	STS-3c	1 to 63	2176 to 137088	2176
VT3-Xv	STS-3c	1 to 42	3328 to 139776	3328
VT6-Xv	STS-3c	1 to 21	6784 to 142464	6784
VT1.5-Xv	Unspecified	1 to 64	1600 to 102400	1600
VT2-Xv	Unspecified	1 to 64	2176 to 139264	2176
VT3-Xv	Unspecified	1 to 64	3328 to 212992	3328
VT6-Xv	Unspecified	1 to 64	6784 to 434176	6784

5 Ethernet Over GFP

GFP defines a standard framing procedure for octet-aligned, variable-length payloads (Ethernet, PPP/HDLC, etc.) for subsequent mapping into SONET synchronous payload envelopes. Fig. 4 shows the relationship between payloads, GFP and SONET.

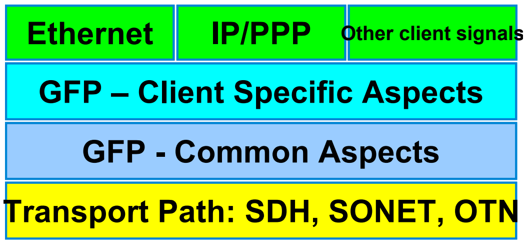

Fig. 4. Relationship between Payloads and GFP and SONET

6 SONET/SDH Mapping of LAPS and GFP frames using Virtual Concatenation

Once the LAPS or GFP frame has been created it must be mapped into a SONET/SDH structure for its transport across the network. There are many different ways to do this, as defined in [4] and [5], but the following are some of the most interesting examples:

- Using a VT1.5/TU-12 structured STS-3/STM-1 and virtual concatenation.
- Using a STS-1-SPE/VC-3 structured STS-3/STM-1 and virtual concatenation.
- Using a STS-3c/STM-1.
- Using a STS-1-SPE/VC-3.

The first method is an example of low order virtual concatenation, and the second is an example of high order virtual concatenation. The third method is an example of contiguous concatenation, while the fourth one does not make use of any kind of concatenation.

We are going to describe briefly the first two mapping methods proposed, as they make use of virtual concatenation, allowing for fine granularity and better bandwidth efficiency.

7 Low order virtual concatenation

The first method proposed is an example of low order virtual concatenation, and allows us to create virtual pipes of multiples of 1.544 Mbit/s in SONET or 2.048 Mbit/s in SDH.

Virtual concatenation allows us to create a synchronous payload envelope (SPE), different from those in the standard set, to efficiently transport the LAPS or GFP payload. As an example, if we want to transport a payload of around 10 Mbit/s

(Ethernet) we would need to virtually concatenate 7 VT1.5s. In Fig. 5 we show the SPE created by virtually concatenating X different VT1.5s.

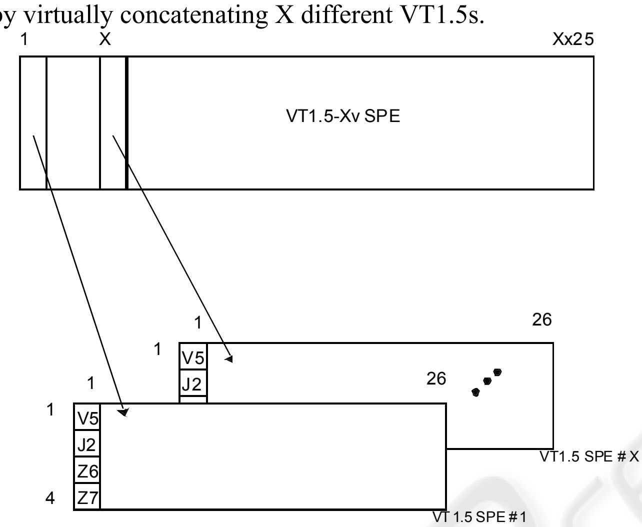

Fig. 5. X virtually concatenated VT1.5s SPE structure.

The payload (LAPS or GFP frames and inter-frame fill octets) is mapped in X individual tributary SPEs which form the virtually concatenated SPE. Each of the tributaries SPE has its own POH, and is transported individually through the network.

8 High order virtual concatenation

The second method is an example of high order virtual concatenation. LAPS or GFP frames are inserted in the payload of 1 to 3 virtually concatenated STS-1s/VC-3s. As an example, the SPE created by virtually concatenating X different STS-1s is shown in Fig. 6.

As in the case of low order virtual concatenation, each STS-1 has its own POH and is transported individually through the network.

9 EoS Mapper System Overview

Using the technologies described we are developing a system to transfer voice (T1s and/or E1s) and Ethernet data (10Mbps and 100Mbps) over an OC-3 (SONET) or STM-1 (SDH) link. The main innovation introduced consists in the use of virtual concatenation to map Ethernet data using LAPS or GFP encapsulation. The system's interfaces include an OC-3/STM-1 optical interface, eight 10Mbps/100Mbps Ethernet ports, and up to 28 T1s and 16 E1s.

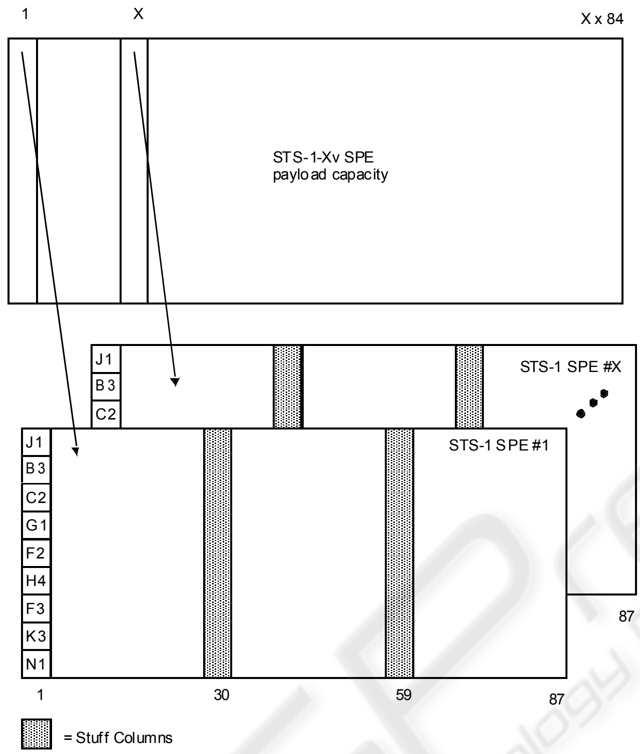

Fig. 6. X virtually concatenated STSs SPE structure

The SONET/SDH overhead terminator, T1 and E1 mappers, framers and LIUs and Ethernet MAC and PHY are based on commercial application specific integrated circuits (ASICs), while the Ethernet over LAPS or GFP framing and the subsequent SONET/SDH mapping is performed by a FPGA. This FPGA supports four mapping modes: low order virtual concatenation, high order virtual concatenation, contiguous concatenation and without concatenation.

10 Conclusions

PLC networks provide a good alternative within the home, access and aggregation networks. However, in order to offer end to end Ethernet connectivity, there is a need to be interconnected to metro and regional networks through SONET/SDH networks.

In order to provide an efficient way to transport the Ethernet traffic coming from the PLC networks into the metro/regional networks, new ways of encapsulation and transmission are requested in the SONET/SDH world.

The Next Generation SONET/SDH networks will incorporate Ethernet data encapsulation and virtual concatenation.

This paper has sketched the current alternatives for "Ethernet encapsulation", one within the HDLC world (LAPS) and a GFP. From both, GFP is nowadays gaining momentum due to its flexibility, bandwidth efficiency, single mechanism for multiprotocol encapsulation and interoperatibility.

Besides, the Next Generation SONET/SDH will incorporate the Virtual concatenation mechanism, eliminating the bandwidth waste that results from a mismatch between the granularity required for Ethernet data transport and the bandwidth offered by traditional TDM structures. One step forward will be the inclusion of link capacity adjustment schemes (LCAS).

Therefore, in order to provide end-to-end efficient Ethernet transport between PLC access/aggregation networks and SONET/SDH metro/regional networks, there is only the need to up-grade the path termination edges at the SONET/SDH rings with GFP encapsulation, Virtual concatenation and LCAS.

The solution presented in this paper will reduce the CAPEX and OPEX and thus provide a solution for efficient low cost high speed Ethernet transmissions.

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References

1. ITU-T: Recommendation X.85/Y.1321. "IP over SDH using LAPS". 03/2001.
2. ITU-T: Recommendation X.86. "Ethernet over LAPS". 02/2001.
3. IEEE 802.3. "CSMA/CD Access Method and Physical Layer Specifications", 2002.
4. ITU-T: Recommendation G.707/Y.1322. "Network node interface for the synchronous digital hierarchy (SDH)". 12/2003.
5. ANSI: Synchronous Optical Network (SONET) - Basic Description including Multiplex Structure, Rates, and Formats (Includes T1.105a-2002): May, 2001.
6. ITU-T: Recommendation G.7042/Y1305: "Link Capacity Adjustment Scheme (LCAS) for SONET Virtually Concatenated SPEs". 02/2004.
7. ITU-T: Recommendation G.7041/Y130.: "GFP: Generic Framing Procedure" 12/2001. Amendment and Corrigendum 12/2003.