The Efficient Bandwidth Solution for Data Services over TDM Networks - Virtual Concatenation and Link Capacity Adjustment Schemes

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The Problem

The rise of Internet usage and the widespread adoption of different data protocols and technologies deployed within corporate Intranets are straining the SONET/SDH networks, originally designed to carry voice (static) traffic. The growth of data applications has put to question some of the SONET/SDH TDM-based architectures for handling data-oriented traffic, and the inefficiency in bandwidth usage.

One of the main caveats is the mismatch of rigid SONET/SDH rates with native data application rates. For example, in the case of Fast Ethernet applications, if an STS-3c circuit is provisioned, 33% of the provisioned bandwidth is not used. There is also potential waste in the 67% of the bandwidth intended for Fast Ethernet service. This is a result of the statistical and bursty nature of data traffic, where the actual use of bandwidth may be much lower than the allocated amount for a given time period.

Another inefficiency is the lack of flexibility in dynamic allocation of bandwidth. In many applications, the size of the 'pipe' may be required to change over time – more bandwidth during the peak usage and lower bandwidth during idle period. For example, bandwidth demand may increase at nights and on weekends when corporate data backup is being performed from a remote site. Ideally, a customer should be able to buy a 100 Mb/s connection that increases to 300 Mb/s between 1:00 am and 2:00 am every night as their computer system performs data backups. During the daytime when this bandwidth is not needed, the bandwidth may be re-allocated to other customers.

The contiguous fixed-rate method of SONET/SDH has no accommodation for sharing, reallocating, and reusing bandwidth, since the pipes are fixed in size.

The Solution

Virtual concatenation provides a means for creating the right-sized pipes over the transport layer, thus reducing bandwidth waste. Virtual concatenation breaks the bandwidth into individual payload containers (e.g., SONET/SDH High Order or Low Order paths) at the source transmitter but logically represents them in a virtual concatenation group (VCG). The members of the VCG are routed and transported individually across the SONET/SDH network and recombined into a continuous bandwidth at the far end destination VCG receiver. The routing of the individual members can be done in a physically diverse and distributed manner because of the different propagation delays associated with individual members of the VCG transport path. Intermediate network elements (NEs) do not need to be aware of the virtual concatenation payload. The terminating network elements are the only equipment that need to handle the different delays; this is performed by realigning the VCGs and introducing them as a single entity.

Nevertheless, virtual concatenation alone cannot provide a solution for dynamic bandwidth allocation for data applications, without disrupting the service. Link Capacity Adjustment Schemes (LCAS), defined by ITU-T draft G.7042/Y.1305, offers a solution to this problem. With LCAS, channels can be resized at any time, without disturbing traffic on the link. Additionally, connectivity checks are continuously performed and failed links are automatically removed and added back as the link is repaired; all this is accomplished without intervention of the network management system.

Virtual Concatenation Basics

Virtual concatenation, defined by ITU-T draft G.707/Y.1332, breaks the bandwidth into individual payload containers, SONET/SDH HO or LO paths, at the source transmitter but logically represents them in a VCG. The members of the VCG are routed and transported individually across the SONET/SDH network and recombined into a continuous bandwidth at the far end destination VCG receiver. The routing of the individual VCG members can be done in a physically diverse manner. Because of different propagation delays associated with individual members of the VCG, a multi-framing and sequencing approach has been developed to help identify the differential delay and the associated realignment process. Intermediate NEs do not need to be path terminating and therefore do not need to be aware of the virtual concatenation.

Individual paths can be transmitted, received, and recombined in different ways, using different increments. With the traditional SONET/SDH contiguous concatenation, the granularity increments are defined in multiples of four.

For example, in SONET, the next step up from STS-3c/~155 Mb/s is STS-12c/~622 Mb/s. The contiguous concatenation bandwidth constraints can be alleviated with the virtual concatenation method which allows for granularity increments down to a VT1.5 level. Whereas virtual concatenation requires concatenation functionality only at the source and destination SONET/SDH NE ends, contiguous concatenation, on the other hand, requires concatenation functionality at the source, destination, and every intermediate SONET/SDH NE. With virtual concatenation, the necessary information for the successful alignment of the payload at the receiving end is carried in the H4 path overhead byte in SONET/SDH. The following two indicators are used to provide this information:

- **MFI (Multi-frame Indicator)** – The MFI is a running frame number, which is incremented with each new frame at the transmitting end. It is used to realign the payload for all group members (VC-3/VC-4 slots) that may not arrive at the receiving end in the same order in which they were transmitted. For high order (HO) VC, the range is 0 – 4095, which allows differential delay compensation of up to 256 milliseconds.
- **SQ (Sequence Indicator Field) –** The SQ contains the sequence number assigned to a specific member in a VCG. Each member of the same VCG is assigned a unique sequence number, so they can be correctly reassembled at the receiving end. For HO VC, the SQ range is 0 – 255.

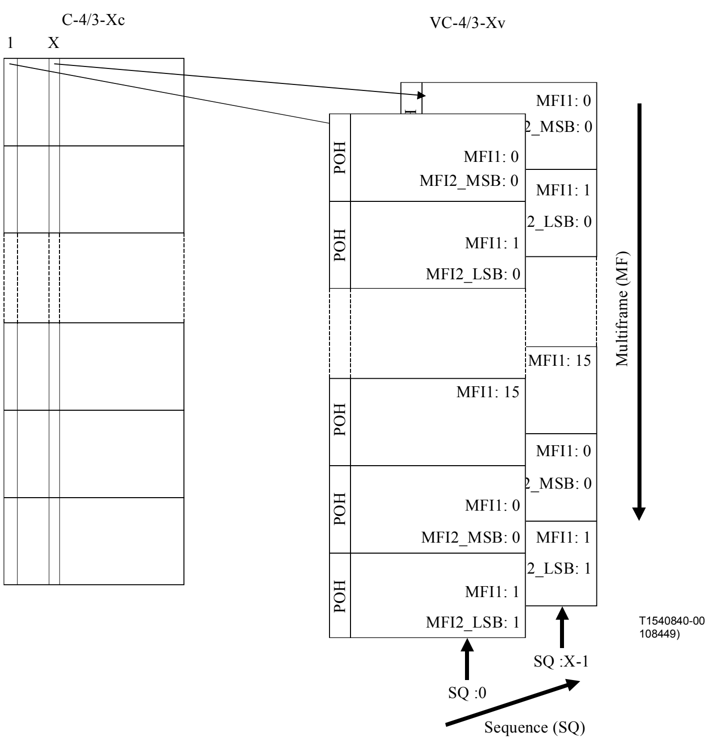

Figure 1- VC-3/4-Xv multi-frame and sequence indicator

Virtual concatenation, as described above, enables use of the TDM network to efficiently transport data traffic through the network. The allocated bandwidth is fixed and cannot be changed while the service is operational. Changing the allocated bandwidth means removing the connection and defining a new connection with the correct bandwidth. Using LCAS, however, the allocated bandwidth can be changed dynamically, without affecting the data service.

Link Capacity Adjustment Scheme Basics

Virtual concatenation can be used without LCAS, but LCAS itself requires virtual concatenation. While virtual concatenation is a simple labeling of individual STS-1s within a channel, LCAS is a two-way handshake signaling protocol. Status messages are continuously exchanged and consequent actions taken. This enables synchronization of changes in the capacity of the transmitter (So) and the receiver (Sk).

The LCAS control-messaging channel is also performed via the H4 path overhead byte in SONET/SDH. The following LCAS information is exchanged between source and sink, in addition to the MFI and SQ used by virtual concatenation:

- **CTRL (Control Field)** – provides the status of the individual member of the group. This field is also used to request the addition or removal of members from the VCG.
- **GID (Group Identification bit)** – used for identification of the VCG. The GID bit of all members of the same VCG has the same value in all frames with the same MFI.
- **CRC** – used to protect each control message.
- **MST (Member Status Field)** – carries information from Sk to So, regarding the status of all members of the same VCG.
- **RS-Ack (Re-Sequence Acknowledge bit)** – sent from receiver to transmitter to indicate that the changes initiated by the transmitter were accepted and the transmitter can begin accepting the new member status information.

Figure 2 depicts a sample application of a packet-based link using VC and LCAS over the SONET/SDH network. Note that only the source and destination points of the Gigabit Ethernet client need to support VC and/or LCAS.

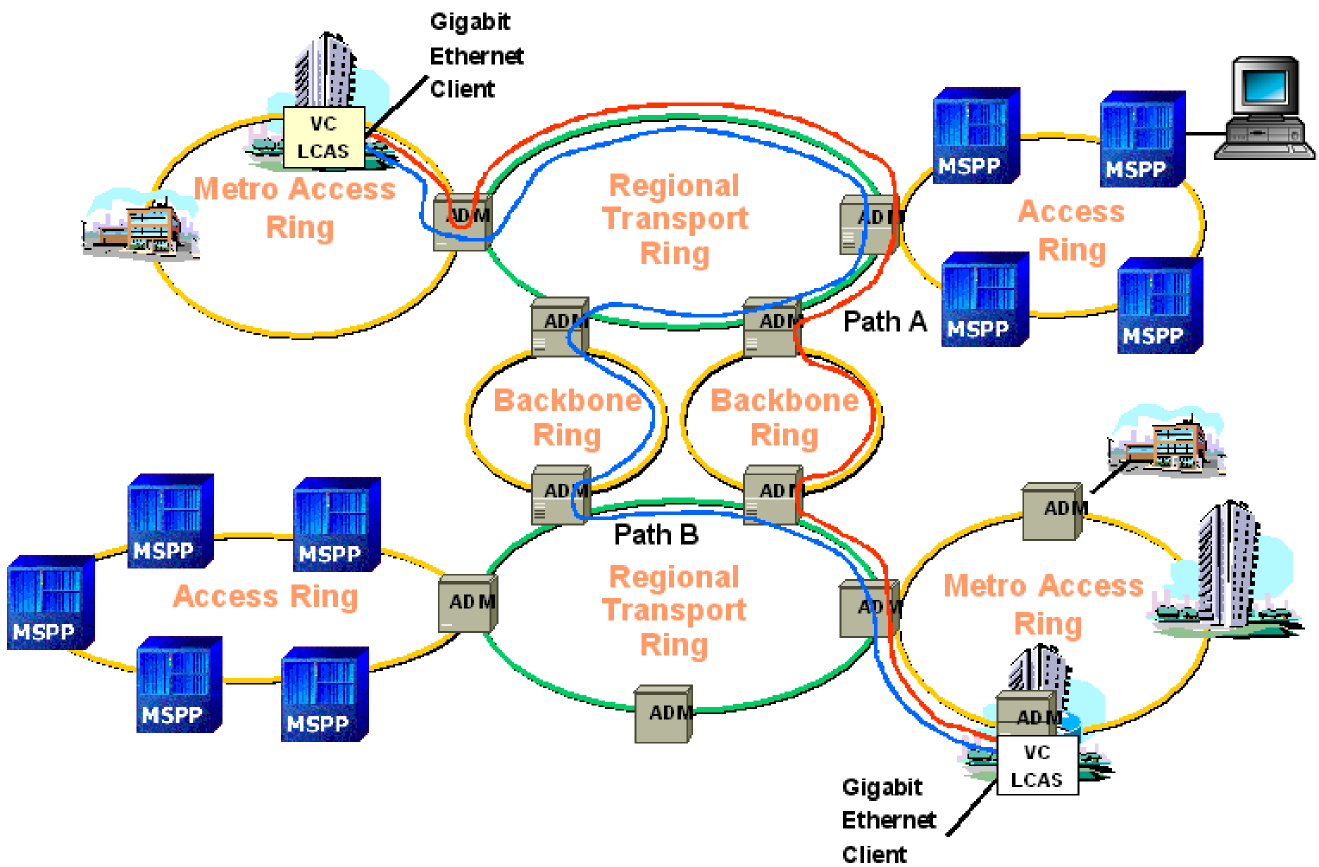

Figure 2– Network with VC and LCAS solution

Summary and Conclusions

Virtual concatenation and LCAS provide the following benefits:

- Enable a much closer alignment of native application data rates to SONET/SDH containers.
- Offer the flexibility to incrementally add and remove bandwidth capacity within a VCG, without affecting service or taking down the entire VCG service. This provides the additional capability of resizing VCG service capacity, during service time.
- LCAS load-sharing operations provide reduced-bandwidth service when a member fails, without affecting the total service.
- Provide transport layer independence. This solution can be implemented over any transport layer (e.g., SONET or OTN).
- Do not impose new requirements on intermediate NEs. Only the source and destination points of the required service need to support VC and/or LCAS.

In conclusion, Virtual concatenation combined with LCAS supplies an effective solution for migration from a TDM/voice-centric network toward a more convergent IP/Ethernet-oriented packet-based multi-service network, while allowing real time bandwidth allocation to different services and customers.

Abbreviations

CTRL	Control word sent from source to sink
GID	Group Identification
HO	High Order (path)
LCAS	Link Capacity Adjustment Scheme
LO	Low Order (path)
MFI	Multiframe Indicator
MST	Member Status
RS-Ack	Re-sequence acknowledge
Sk	Sink
So	Source
SQ	Sequence Indicator
VC	Virtual Concatenation
VCG	Virtual Concatenation Group. A logical link generated by virtual concatenation means.

References

ITU-T G.7042/Y.1305, Link Capacity Adjustment Scheme (LCAS) for Virtual Concatenated Signals

ITU-T G.707/Y.1322, Network Node Interface for Synchronous Digital Hierarchy (SDH)

About OptiX Networks

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OptiX designs and supplies very high-speed silicon semiconductor integrated circuit devices, which operate at 40 Gbps and 10 Gbps. These devices serve the SONET/SDH and OTN market and are offered to network systems equipment providers on an OEM basis, The first OptiX chipset is targeted to support the evolving worldwide markets for DWDM transport, optical switching systems, add/drop multiplexers, and routers—offering key systems to serve the worldwide telecommunications and data communications markets.

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