# VLAN tag-based cross-connection function in video network architecture

PÉTER SZEGEDI

*MATÁV PKI Telecommunications Development Institute*
*szegedi.peter3@ln.matav.hu*

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*Growing the magnitude of digital television techniques in studios as well as at the end users the solution of video communication over heterogeneous networks become more relevant. Broadcasters want to transport and exchange their digital streaming video and audio traffic between the studios in a packet-based manner. Innovative video communication services where new technologies enable additional opportunities are introduced in this paper. On the following pages the motivations and advantages of the integrated VLAN tag-based cross-connection function in Third-Generation SDH equipments are illustrated via hypothetical Hungarian video transport network architecture.*

## 1. Introduction and motivations

Nowadays, the most of the modern television studios are equipped by digital studio techniques. Digital camcorders, continuity desks, audio-mixers, content storage devices and many different hardware equipment are installed enabling to use special softwares and applications such as virtual 3D studios, special video editing and so on.

In studios there are Local Area Networks (LANs) to realize communication and inter-working between different applications running on these high-performance computers and professional digital devices. Since the LANs are using Ethernet technology it is obvious to handle video and audio stream in Ethernet format. However, Gigabit Ethernet is more than just transport, it is the basis of the Next-Generation Digital Video Network.

Representing the merging of synchronous audio/video (A/V) systems and asynchronous data networks in studios the leading players in the broadcast industry developed an open file format called MXF to transfer video and audio streams as files over Ethernet networks. The Material eXchange Format (MXF) is an open file format, targeted at the interchange of audio-visual materials with associated data and metadata. It has been designed and implemented with the aim of improving file-based interoperability between various applications used in the television production chain. The transportation of these different files is independent of contents (e.g. not compression scheme specific) and the applications of manufacturer specific equipment are not required [1].

Parallel with this trend the main brands (like SONY) improve their product line and announce new camcorders support Ethernet or wireless LAN interfaces and new professional decks support up to five times faster-than-real-time transfer of full-resolution video over Gigabit Ethernet interfaces, in addition to MXF file transfer over a 100-Base-T network connection. Testing of live streaming video systems the *Level 3 Connections'* engineers successfully transferred 50 and 30 Mbps broadcast-quality digital video segments across a local network [2].

The traditional and widespread MAN or WAN core network transport technology is the SDH with the underlying optical cable infrastructure or WDM systems. As the video transport solutions in studios are shifting to Ethernet and Gigabit Ethernet technology it is obvious to use Ethernet Private Line or Ethernet Virtual Private Line services [3] for video transport between studios over the MAN and WAN. Therefore the service providers and network operators have to offer Ethernet connectivity over the existing SDH and WDM technology (migrating to Next-Generation and Third-Generation SDH) to meet the broadcasters' new requirements detailed in the next section. The relevant network functions and the tag-based cross-connection solution are described in the third section. An application example and the proper network and node architecture are proposed in the fourth and fifth sections to model the next-generation network functions. Finally, in the sixth section the technical and economical advantages of the VLAN tag-based cross-connection are illustrated by a real case study.

## 2. New client requirements

The audio and video stream transport over the asynchronous data networks requires strict packet loss, latency and jitter constraints. The broadcasters want to transport their compressed or uncompressed video streams in Ethernet frames through the MAN or WAN network according to different SLAs. The main requirements are:

- Reliable video stream transport
- Guaranteed bandwidth service

- SLA-guaranteed interconnection.
- MXF data transport.
- Just in Time service provisioning.

The modern television applications (like regional news, nationwide interactive games, region-dependent advertising, and so on) require flexibility of the video connections. Mainly Just in Time services are required in a customer-driven connection-provisioning manner between studios.

The different SLAs allow the broadcasters to scale the transport services to their demands. For example stricter, and more expensive as well, protected Ethernet connections for the live streaming video transport are needed from the local studios to the main studio or the distribution points and non-protected Ethernet connections for the stored content exchange are needed between the studios.

## 3. Network functions and architecture

From the transport service provider point of view the native switched Ethernet core networks have well-known restrictions in fields of guaranteed bandwidth, QoS and fast (<50ms) protection/restoration mechanisms. But on the other hand the Ethernet technology's advantages (e.g. plug-and-play installation, good scalability and granularity, VLAN security, simplicity of operation, low cost, etc.) provide good economics of scale for the service providers. To eliminate the disadvantages of the native Ethernet and bring Ethernet economics with SLA guarantees to the existing SDH infrastructure Next-Generation SDH (NG-SDH) functions for the Ethernet services are implemented in the service providers' networks.

The Ethernet Private Line and Ethernet Virtual Private Line services [3] over the NG-SDH network provide such performance as traditional private line services. With the GFP, VCAT and LCAS techniques [6] the Ethernet over NG-SDH network architecture has great performance to meet clients' specific requirements.

Traditionally the NG-SDH equipment provides a time-slot cross-connect that allows time-slots from one physical interface to be cross-connected to a different physical interface. As the amount of the Ethernet services in the SDH network is growing, it is worth to integrate frame-based cross-connect into the SDH equipment [4].

Each Ethernet service is identified and segregated by tagging the Ethernet frames, using VLAN tags. Benefits of this integrated frame cross-connect include:

- Multiple Ethernet services can be presented on a single physical interface *(Fig. 1.)*, thus the client's Ethernet equipment can be connected to the VLAN tag-based cross-connect cloud in more economical way.
- Multiple Ethernet services can share the given SDH bandwidth, namely point-point VLAN connections can be multiplexed into virtually concatenated SDH payloads.
- Statistical gain can be achieved to overbook the SDH bandwidth, i.e. in some cases the individual peak bit rates could be higher than average.

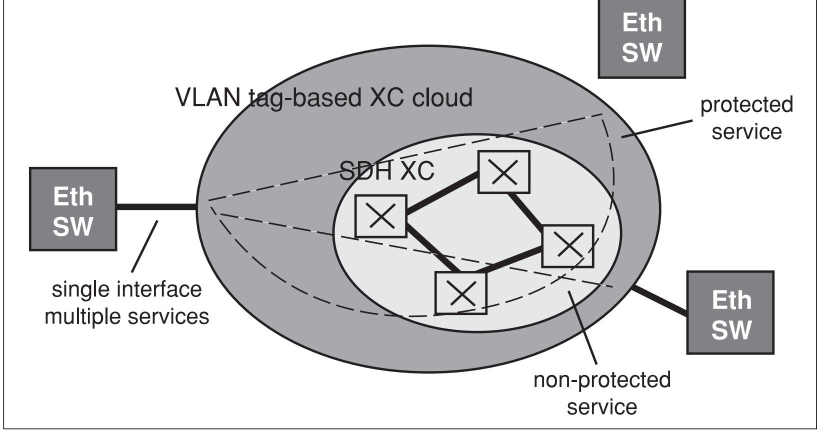
The physical integration of the frame cross-connect into the SDH equipment reduces the number of interfaces by an order of magnitude or more. In addition to reducing the cost of physical interfaces, provisioning of multiple services on a single Ethernet interface increases the traffic density and reduces operation costs. Based on the ability to provide multiple, SLA-guaranteed services per Ethernet interface, carriers can now grow the revenue per customer without incremental investment in access infrastructure.

The service provider prefers to provide guaranteed bandwidth point-point VLAN connection over the NG-SDH network. The automatic provisioning of VLAN connections gives flexibility to the network. The management of the VLAN tags in the Ethernet layer is the main issue form the feasible network operation point of view. The connection set up and the valid VLAN tag administration is supported by the GVRP (Generic VLAN Registration Protocol). GVRP remove the burden of manually installing and managing VLANs from the network administrator's hands, provides a mechanism for dynamic maintenance of VLAN Active Filtering Database and for propagating the information they contain to other VLAN-aware switches. GVRP was namely never designed to set up point-point VLANs (the VLAN topologies would rather resemble a sub-tree of the Spanning Tree topology). The required GVRP modifications [7] can be done correctly, but these are out of this paper's scope.

## 4. Application example

To illustrate the advantages of the integrated VLAN tag-based cross-connects in the networks, typical Hungarian video transport architecture among the main re-

*Fig. 1. Network architecture*



gional studios (located in the capital and in largest country towns) is proposed. The network architecture contains an Ethernet and a NG-SDH layer. The regional studios are connected to the redundant Ethernet switches. Between the switches the dual star logical topology provides redundant paths against the failures in the Ethernet layer. The logical loops are avoided by the STP algorithm.

*Fig. 2. Ethernet logical topology*

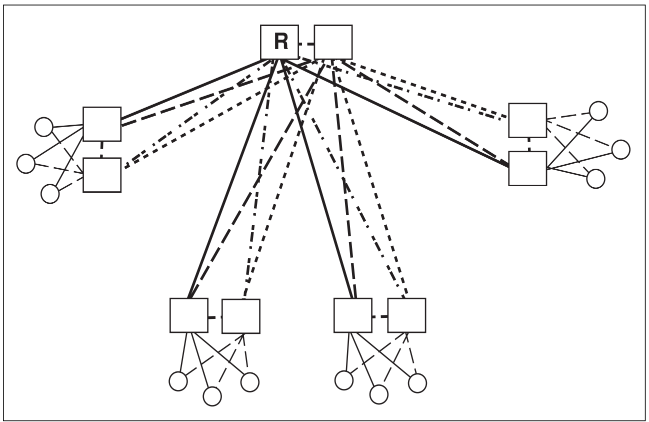
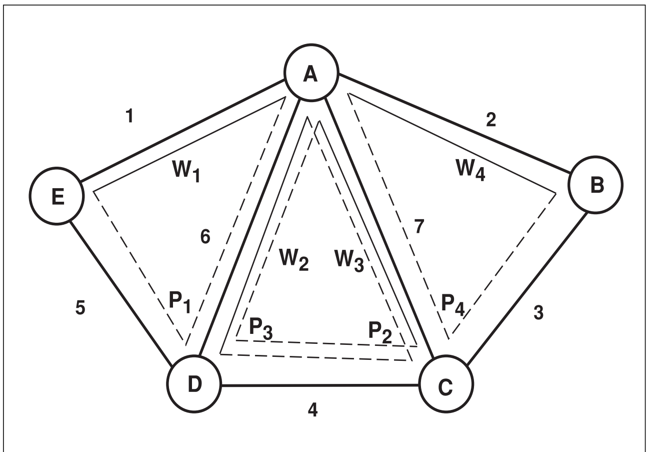



*Fig. 3. SDH physical topology*




The underlying SDH layer has more connected physical topology, this provides to establish link-independent physical connectivity for the Ethernet services. The Ethernet layer provides protection only against the failure of the Ethernet layer. The physical link failures are protected by the SDH layer's 1+1 path protection because the convergence time of the STP algorithm is not feasible for the clients' requirements. The physical link failures are hided from the Ethernet by the SDH protection.

In the regional studios the streaming video connection demands are separated into different VLANs by the customer Ethernet equipment's GVRP protocol, than the VLANs are mapped into the right sized virtually concatenated VC-4 payloads of the SDH to the desired direction. According to the different SLAs there are protected VLAN demands and non-protected VLAN demands on the customer side. Because of the optimal SDH bandwidth utilization the service provider wants to protect only the protected VLAN demands in the transport SDH layer. So the VLANs can be identified and grouped by the service provider equipment. In case of no VLAN tag-based cross-connecting function, the different VLANs should be identified by tributary ports, but if there is frame cross-connection in the SDH layer the different VLANs are identified by the VLAN tags on the single tributary port.

## 5. Network and node models

To illustrate the benefits of the application of integrated frame cross-connects detailed node models are introduced in this paper. The main functions are both identified in case of Next-Generation SDH and so called Third-Generation SDH [5] equipments with VLAN tag-based cross-connecting function.

Only one direction of one connection is shown on the next figures *(Fig. 4.)*

*Fig. 4.*
*Ethernet – NG-SDH node models (a, b)*

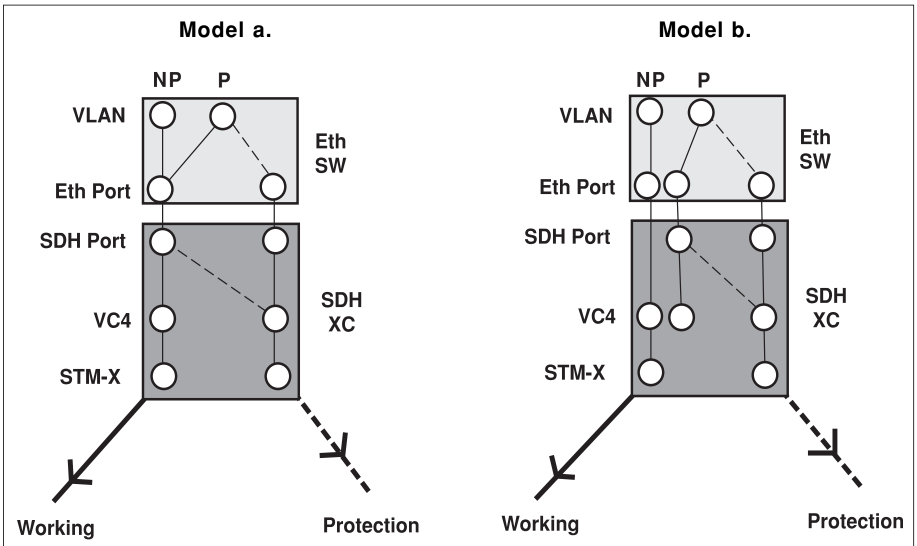
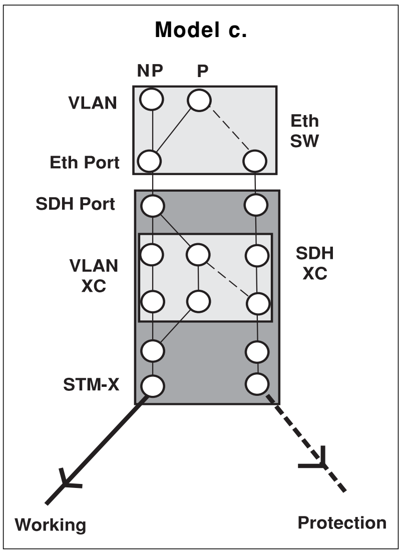



*Fig. 5.*
*Ethernet – TG-SDH node model (c)*



In case of NG-SDH transport architecture without selective protection all type of services are presented on a single Ethernet-SDH interface *(Fig. 4/a).*

The Ethernet switch (Eth SW) provides protection only against the interface failure and the SDH cross-connect (SDH XC) provides protection against the link failure. In case of selective protection the protected (P) and the non-protected (NP) services had to be separated into different interfaces *(Fig. 4/b.)*, thus more ports are required. But based on the SDH tributary ports the SDH cross-connect can provide protection only for the protected services, so fewer SDH capacity is required.

If the bandwidth of the protected and non-protected VLANs (VLAN), the Ethernet port capacities (GbE) and the SDH concatenation unit size (VC4) are known the following formulas describe the number of required ports (#port) and SDH working and protection transport capacities (#W_VC4, #P_VC4).

**Model a – No selective protection**

$$\# port_{1a} = \left\lceil \frac{\sum VLAN_P + \sum VLAN_{NP}}{GbE} \right\rceil + \left\lceil \frac{\sum VLAN_P}{GbE} \right\rceil$$

$$\# \ddot{U}\_VC4_{1a} = \left\lceil \frac{\sum VLAN_P + \sum VLAN_{NP}}{VC4} \right\rceil$$

$$\# V\_VC4_{1a} = \left\lceil \frac{\sum VLAN_P + \sum VLAN_{NP}}{VC4} \right\rceil$$

**Model b – Port-based selective protection**

$$\# port_{1b} = 2 \times \left\lceil \frac{\sum VLAN_P}{GbE} \right\rceil + \left\lceil \frac{\sum VLAN_{NP}}{GbE} \right\rceil$$

$$\# \ddot{U}\_VC4_{1b} = \left\lceil \frac{\sum VLAN_P}{VC4} \right\rceil + \left\lceil \frac{\sum VLAN_{NP}}{VC4} \right\rceil$$

$$\# V\_VC4_{1b} = \left\lceil \frac{\sum VLAN_P}{VC4} \right\rceil$$

In case of Third-Generation SDH with selective protection based on the VLAN tag-based cross-connection function the all type of services are presented on a single Ethernet-SDH interface *(Fig. 5* – Model c).

Thanks to the frame cross-connection capability in SDH (VLAN XC) the protected and non-protected services can be identified by VLAN tags on a single interface as well. Thus, the SDH can provide selective protection for the protected VLANs against the link failures. This solution requires fewer ports and fewer SDH capacities than the NG-SDH selective protection solution (Model b).

The following formulas describe the needed port numbers (#port) and SDH transport capacities (#VC4).

**Model c – VLAN tag-based selective protection**

$$\# port_2 = \left\lceil \frac{\sum VLAN_P + \sum VLAN_{NP}}{GbE} \right\rceil + \left\lceil \frac{\sum VLAN_P}{GbE} \right\rceil$$

$$\# W\_VC4_2 = \left\lceil \frac{\sum VLAN_P + \sum VLAN_{NP}}{VC4} \right\rceil$$

$$\# P\_VC4_2 = \left\lceil \frac{\sum VLAN_P}{VC4} \right\rceil$$

## 6. Case studies

Above the network architecture and topology described in Section 4., assuming a given traffic matrix witch contains the number of point-point VLAN demands between regional studios. The bandwidth of this broadcast-quality, uncompressed connection demands is 165 Mbps (IEC-601). The higher-order SDH virtual concatenation unit is one VC-4 (139,264 Mbps), because the maximum number of virtually concatenated lower-order containers (e.g. VC-12) is 64, so this is not enough for the VLAN's bandwidth [6].

In normal cases one VLAN requires one VC-4-2v payload and two different VLANs require a VC-4-4v payload (2xVC-4-2v). In case of VLAN tag-based cross-connection one VLAN requires one VC-4-2v payload as well but two VLANs requires only a VC-4-3v payload because the connections are identified by the VLAN tags.

The detailed network and node models enable to analyze many of technical and economical case studies. Based on the simple example above it is easy to understand that the VLAN tag-based solution requires fewer SDH protection capacities and lower number of interfaces to satisfy the client's requirements.

On the network level, instead of the total number of required network resources in the service provider point of view the most interesting question is the number of unused resources and the possible points of the capacity upgrades. Based on the proposed models in this paper, assuming given link capacities the following figures show the unused resources and the capacity upgrade points in function of the relative traffic load *(Fig. 6).*

As it is shown, it is obvious the port-based selective protection (Model b) enables to extend the capacity upgrade point compared to the no selective protection case (Model a) because of the fewer protection capacity needs. The proposed architecture with VLAN tag-based cross-connection (Model c) enables to provide more VC-4s and more VLANs *(Fig. 7.)* in the same network, so enables to more extend the capacity upgrade point as the relative traffic load is increasing.

In connection with this, the required interface card numbers by the VLAN tag-based cross-connection case

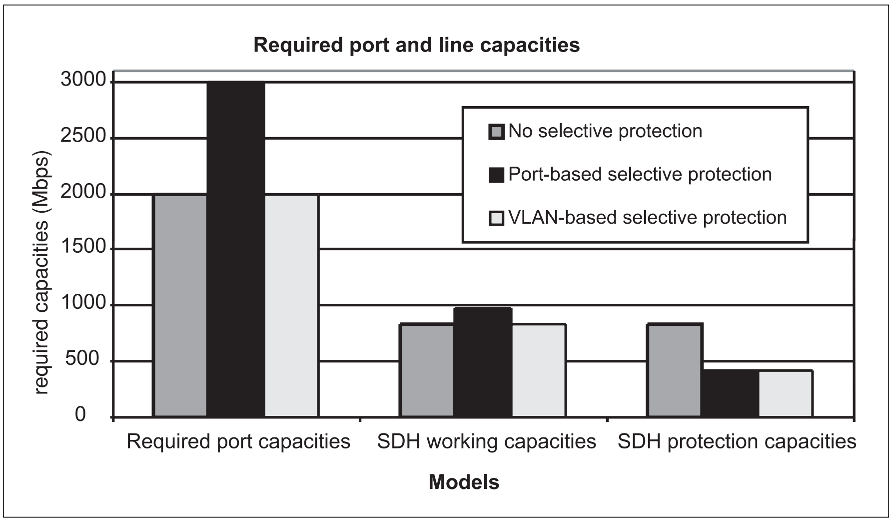



*Fig. 6. Capacity requirements*

(Model c) are the same as the case of no selective protection (Model a), so beside better network performance the total network cost can be lower than in port-based selective protection case.

## 7. Conclusions

Broadcasters want to transport and exchange their digital streaming video and audio traffic between the studios in a packet-based manner. The Next-Generation SDH equipments and the integrated VLAN tag-based cross-connecting function (e.g. Third-Generation SDH) enable to flexibly establish guaranteed bandwidth VLAN connections over the transport network.

Based on the proposed models the advantages of the integrated frame cross-connection function are manifested in the network resources, the network utilization, the interface cost and the total network cost as well.

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*Fig. 7. Capacity upgrade points*