

Migration to Next Generation SDH

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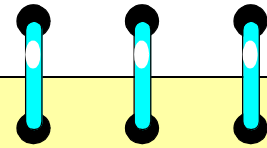
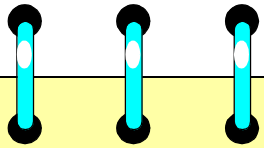
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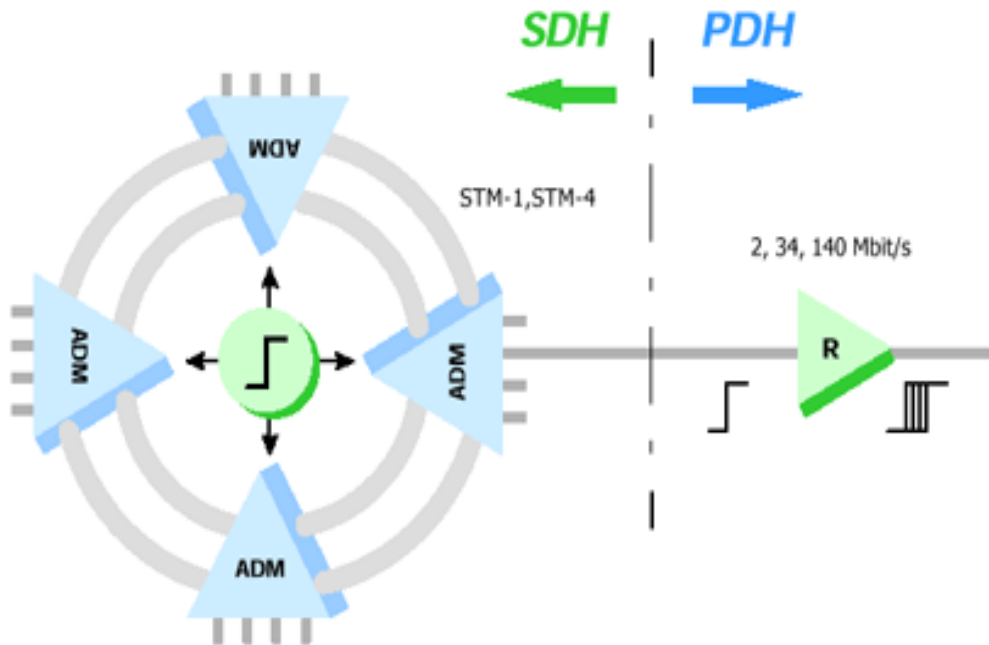


SDH classic



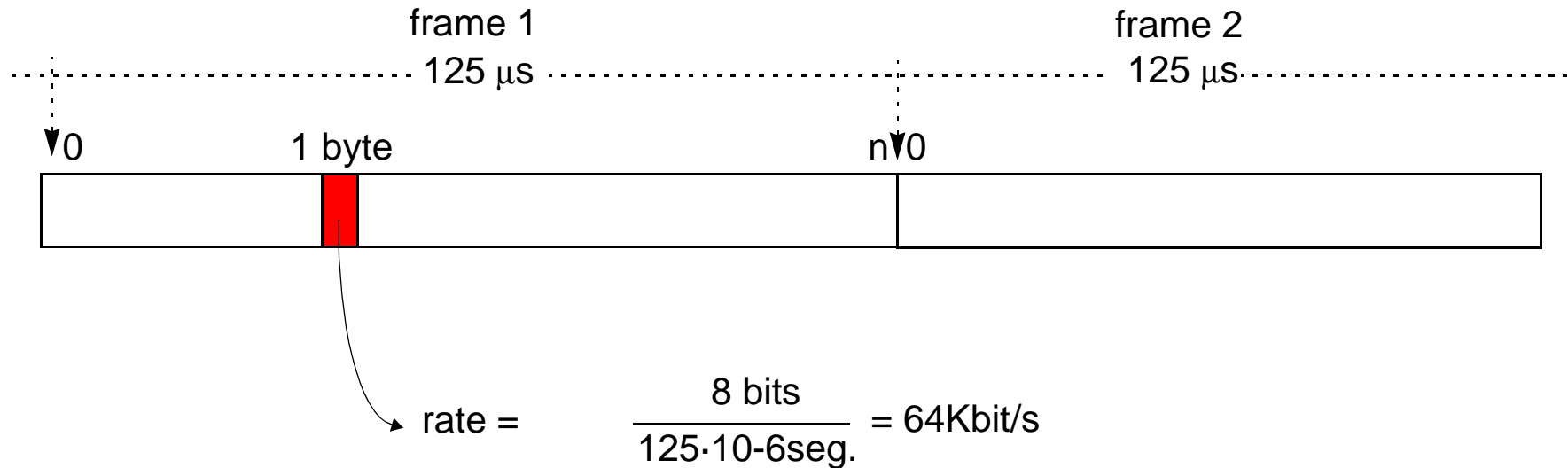
Section

Reasons to define SDH



- The Antitrust law in the US followed by Bell being broken into smaller companies
- It was necessary to interconnect new PTTs: SONET definition
- B-ISDN specification to integrate any traffic: SDH and ATM standardisation
- Advanced management needs: computers and telecom must work together
- Requirement for having new infrastructures manage any type traffic: data, voice, multimedia

bytes vs. bits



Standardised since 1988 when the G707, G708, G709 CCITT recommendations appeared

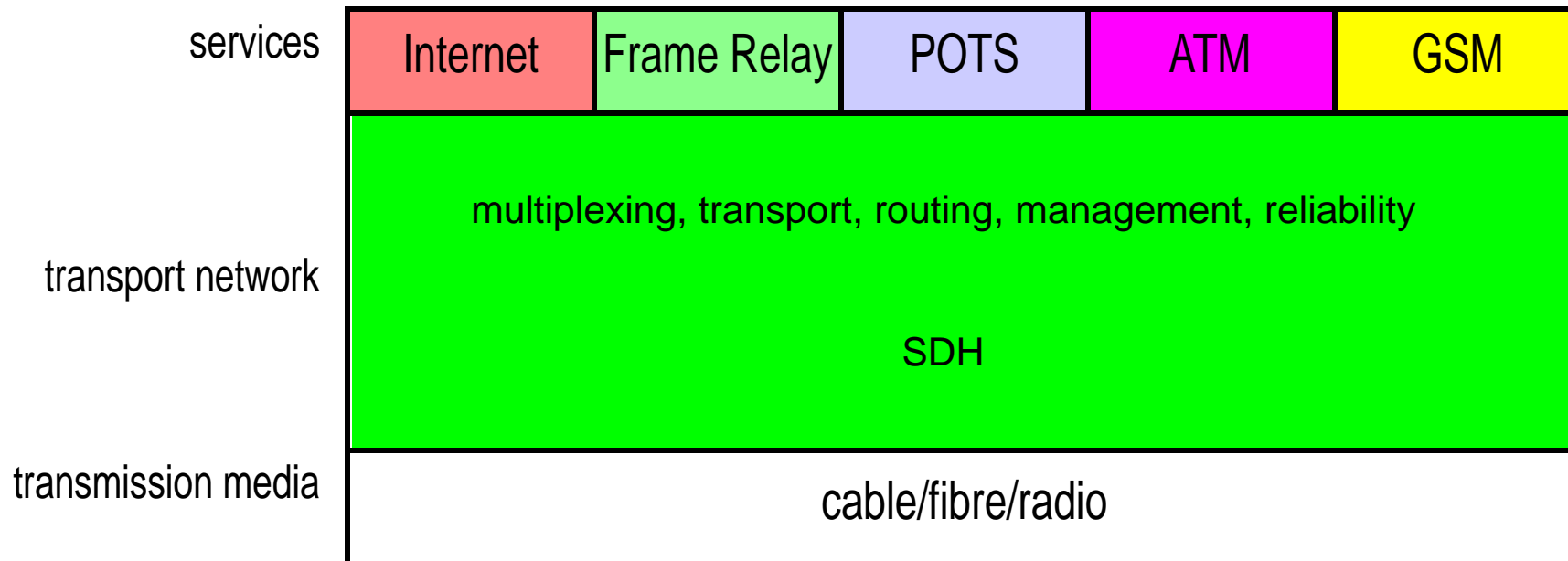
- SDH is byte oriented, it means that a byte is the unit for mapping and multiplexing
- STM-N is the name for the transport frames. They have always a period of 125 μ s
- An important consequence is that in SDH 1 byte represents a 64 Kbit/s channel

SDH is a flexible architecture

- *direct internet working* between equipment
- *scalability* up to 10 Gbit/s
- *direct add & drop* for low speed tributaries
- Rich in OAM functions
- *Support* to fit any application
- remote and centralised management
- Fault tolerance: fast traffic routing in case of faults
- SDH is highly compatible with SONET
- very efficient in managing circuits
- fast circuit definition from a centralised point
- advanced facilities for quality monitoring

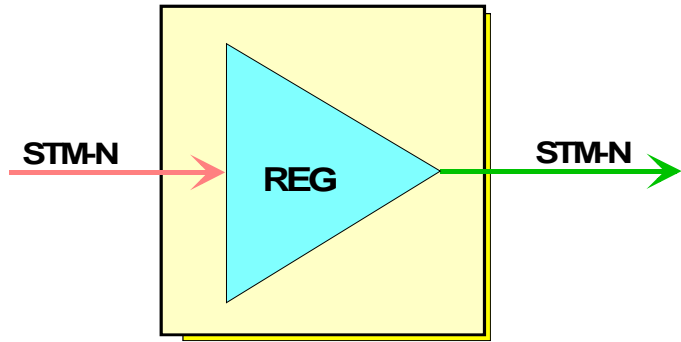


Classic SDH: Circuit provisioning

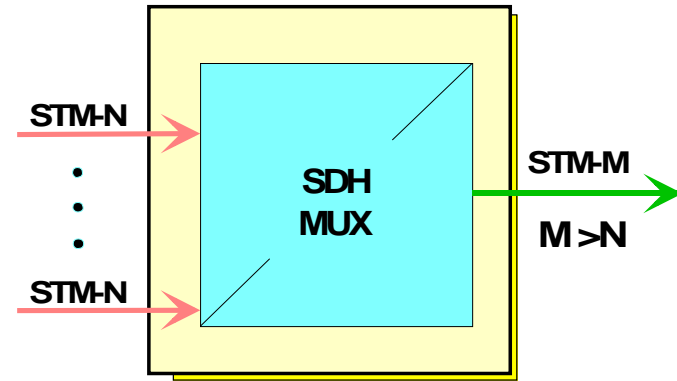


SDH provides efficient, reliable and flexible transport for circuits

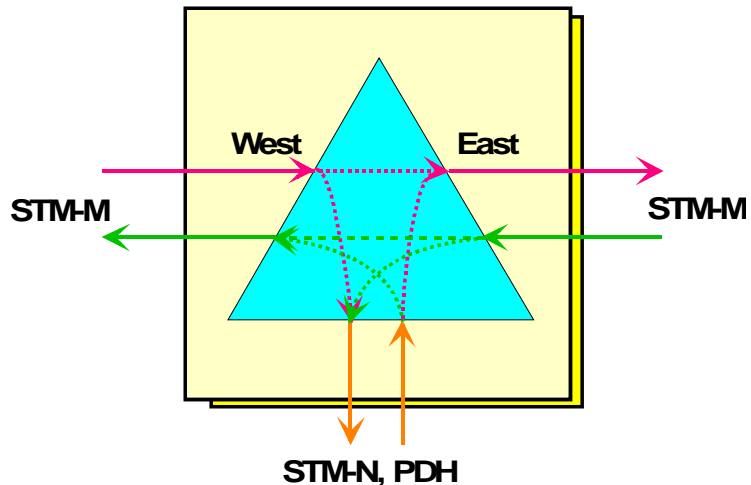
Classic SDH Network elements



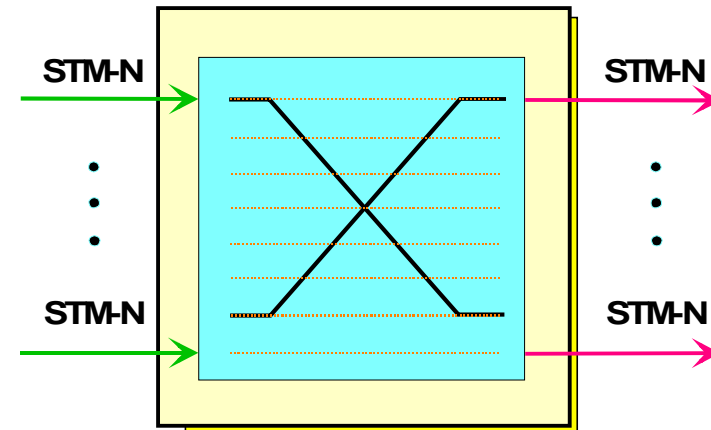
Regenerators



Multiplexers

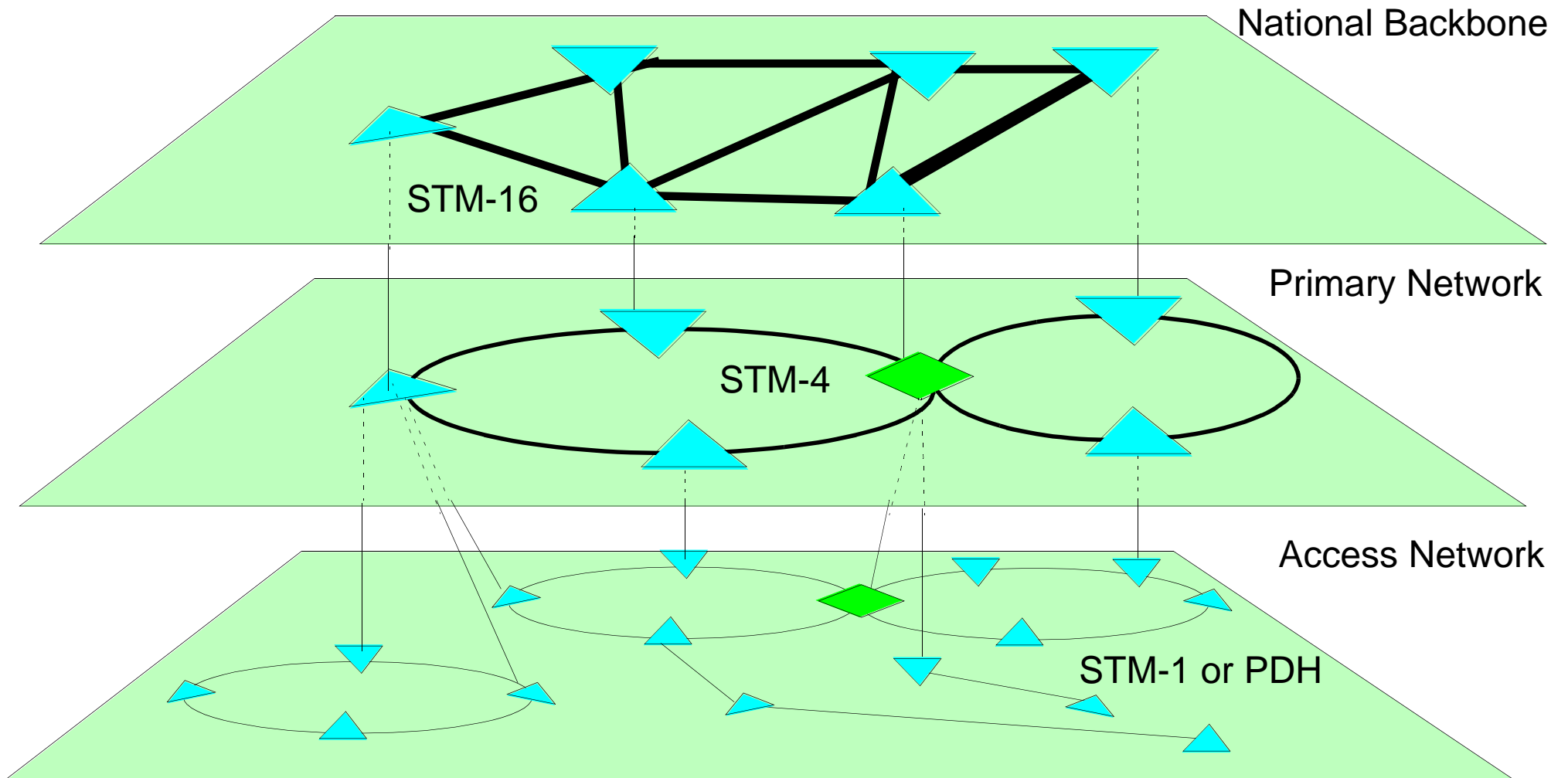


Add & Drop Multiplexer (ADM)

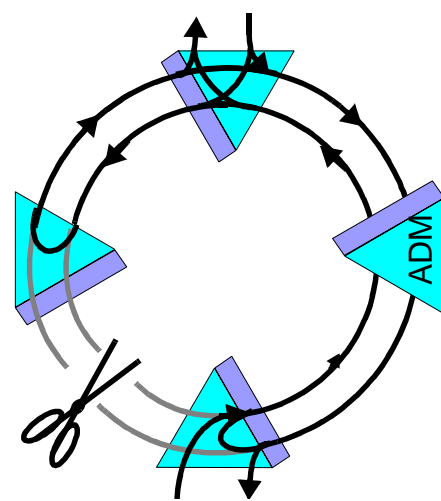
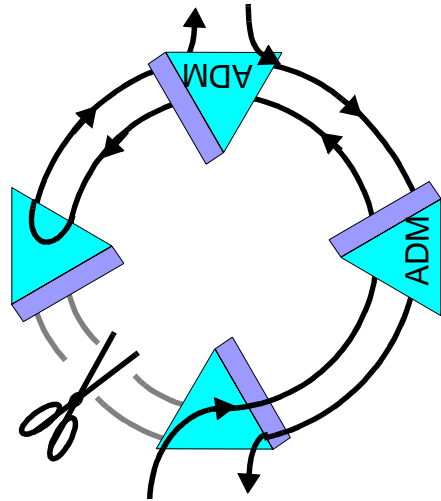
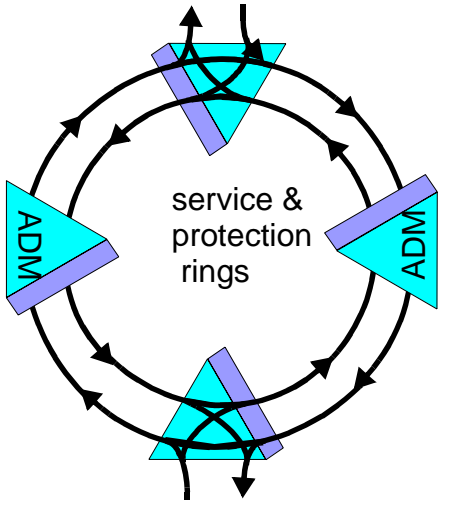
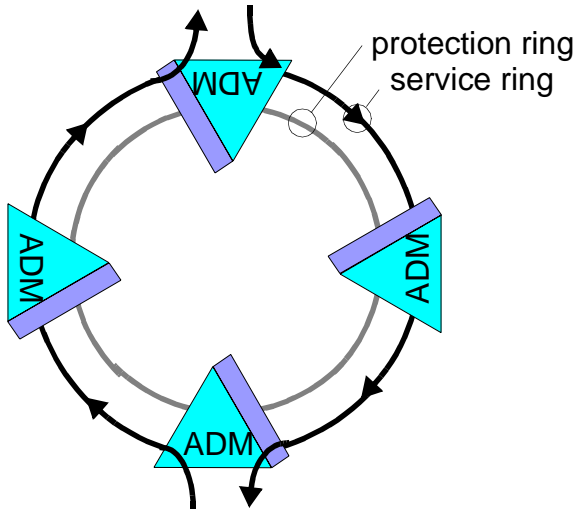
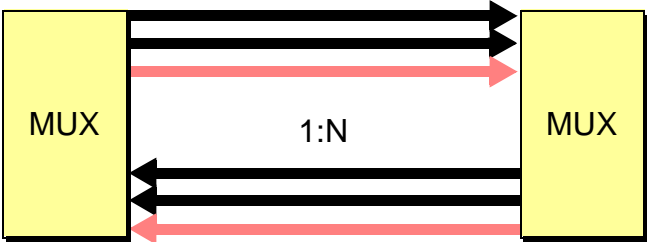
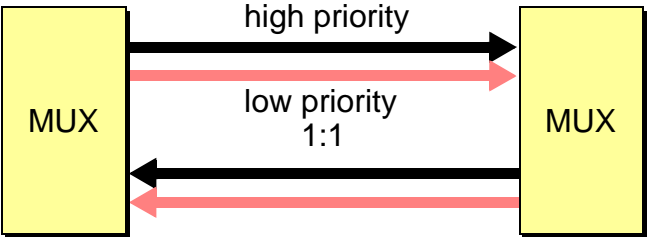
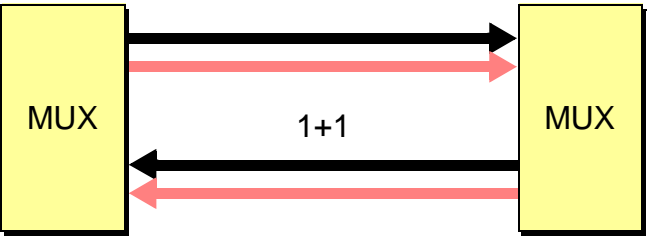


Digital Cross-Connect (DXC)

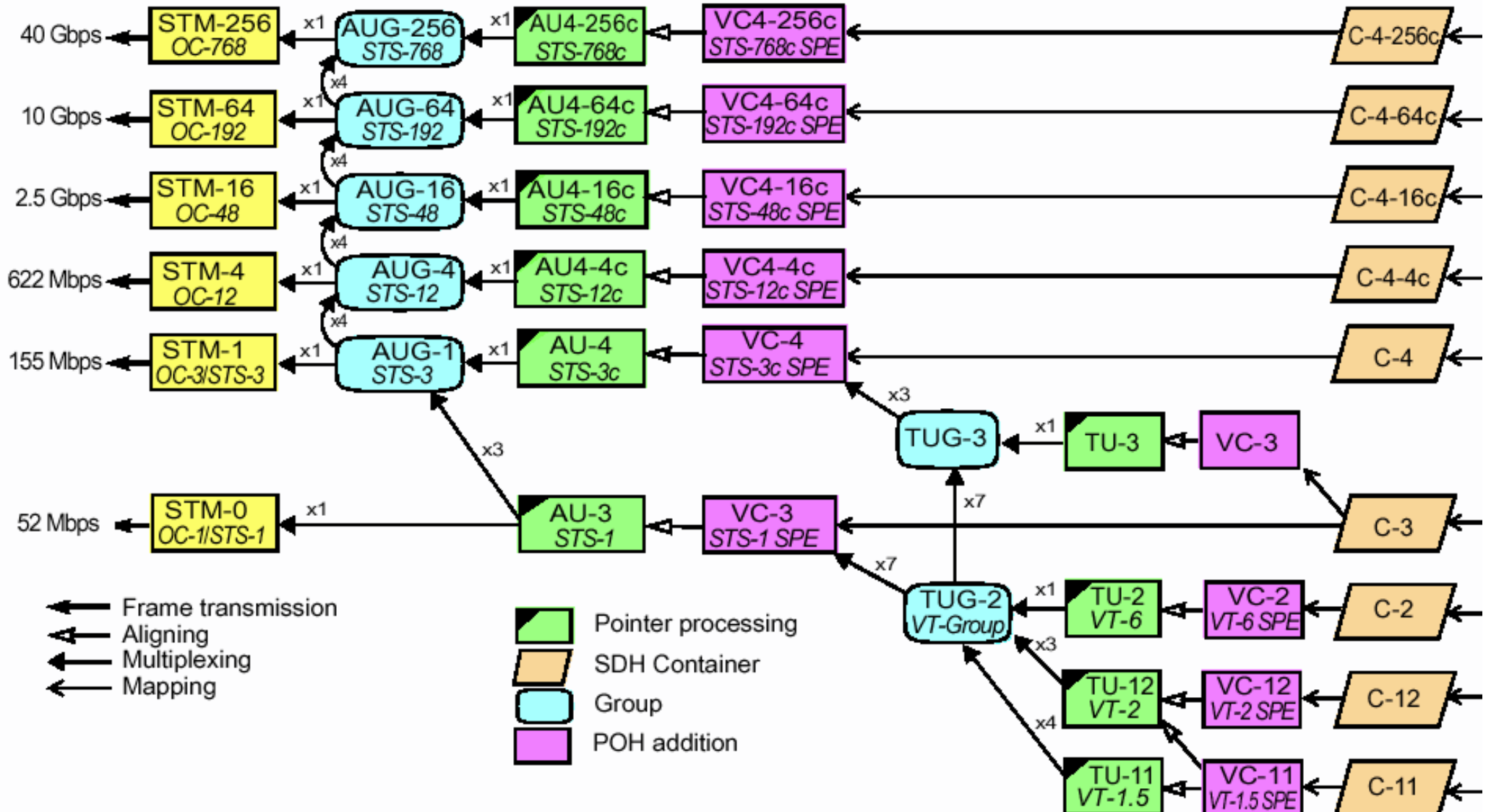
Transport design



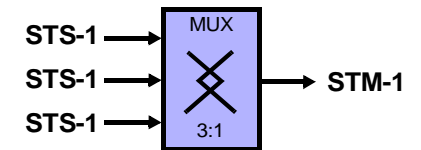
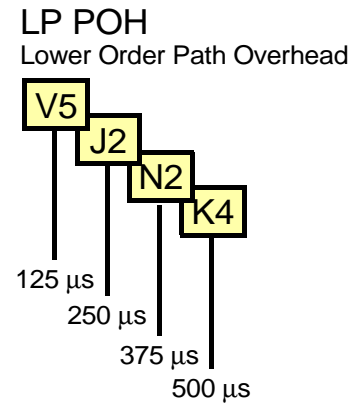
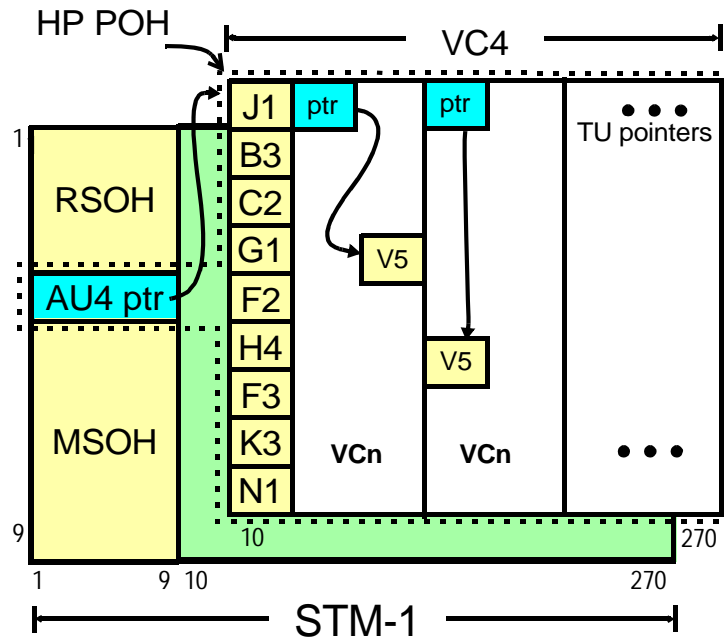
Nothing compares with SDH resilience



The SDH multiplexing map

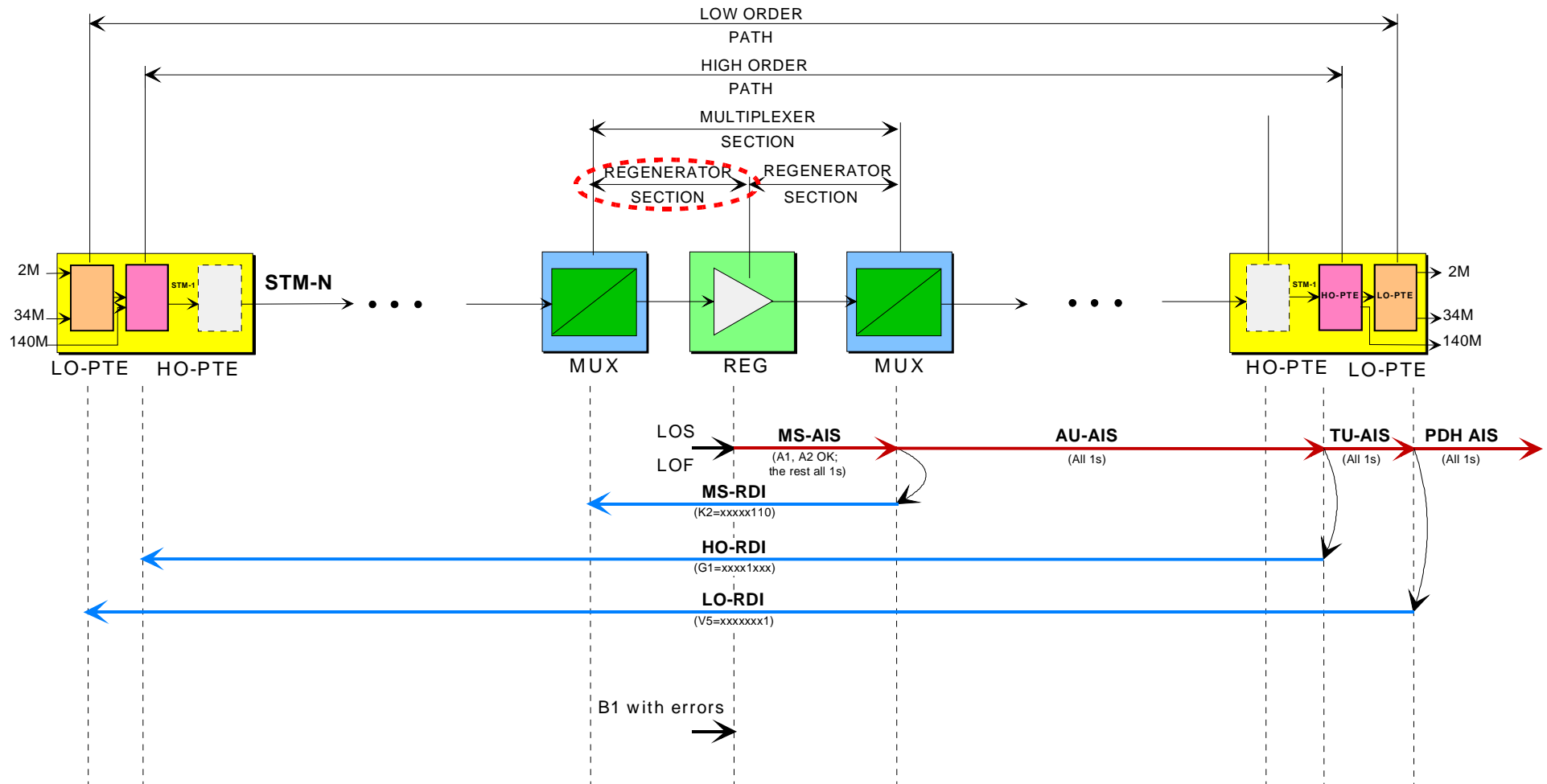


The STM-1 frame



- STM-1 = AUG + RSOH + MSOH
- RSOH and MSOH sections allow the traffic management
- The VC4 is floating inside the STM-1: VC4 is asynchronous STM1 is synchronous
- The AU pointer always points to the position where the VC4 starts and follows possible fluctuations

OAM: Detected events at the end of a RS



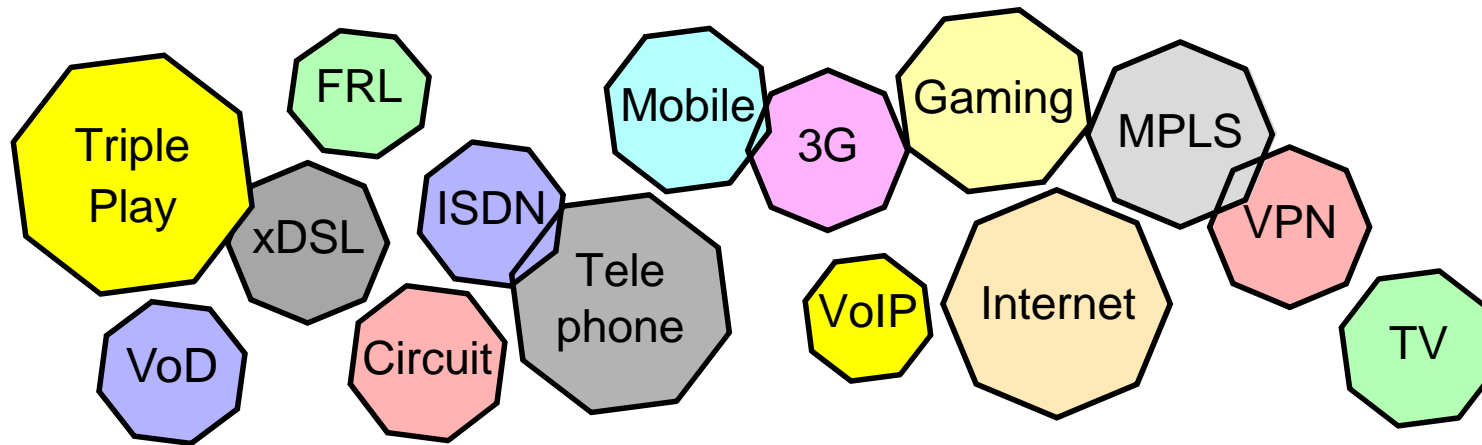
Next Generation SDH



NG SDH = classic SDH + [GFP+VCAT+LCAS]

Section

Streaming forces

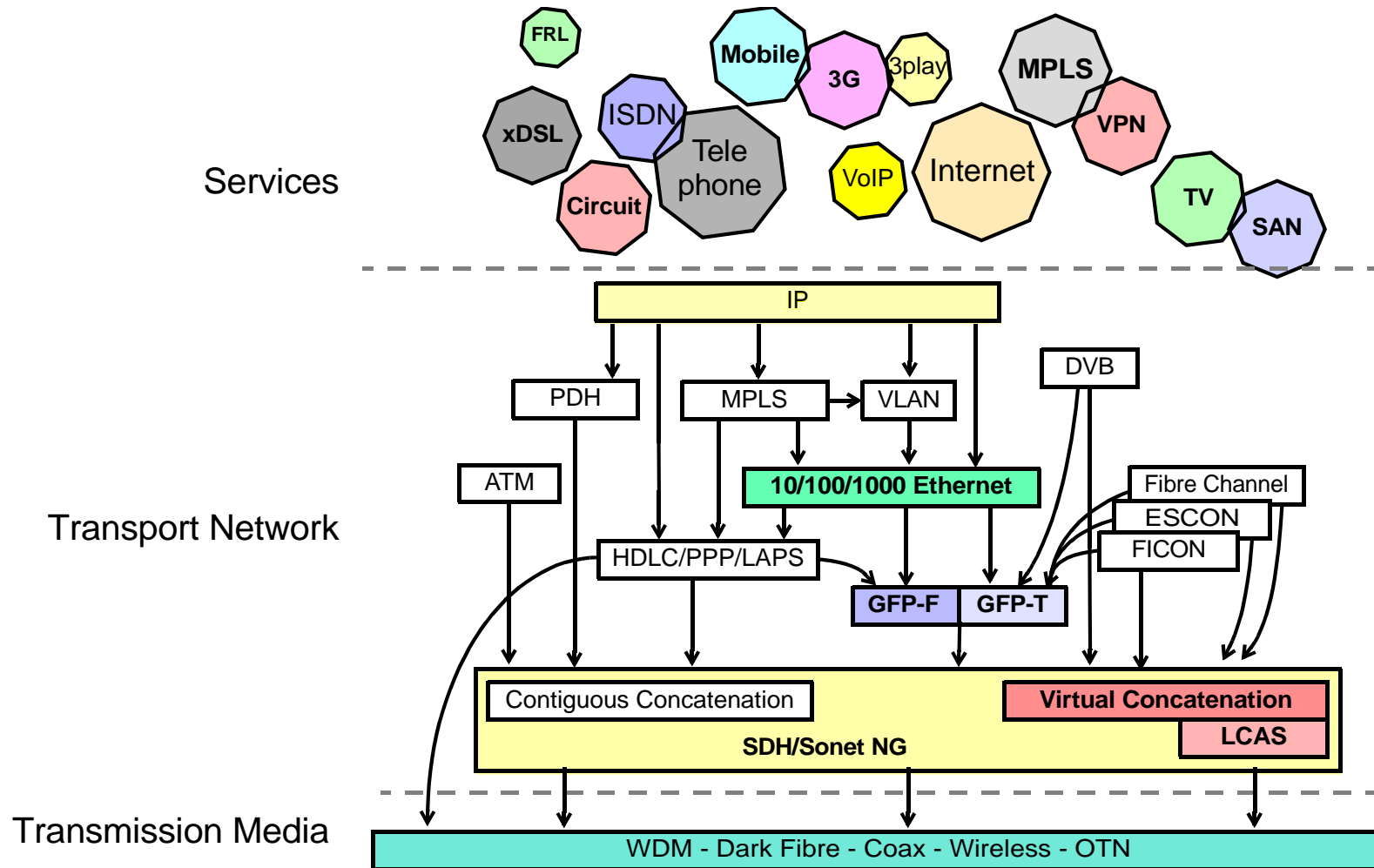


New services and applications based on internet, mobile, multimedia, DVB, SAN, Ethernet or VPN, are demanding long haul transport. State of the art:

1. Ethernet, are in an early stage of development for efficient optical transport
2. Most have their transport infrastructure entirely based on SDH/SONET.
3. There is a lot of experience in managing SDH/SONET.

No other technology than SDH/SONET has this maturity grade at the optical physical layer.

Next Generation SDH: Packet Friendly



SDH/SONET has also evolved to more efficiently adapt statistical multiplexing traffic based on data packets.

Legacy and Next Generation SDH

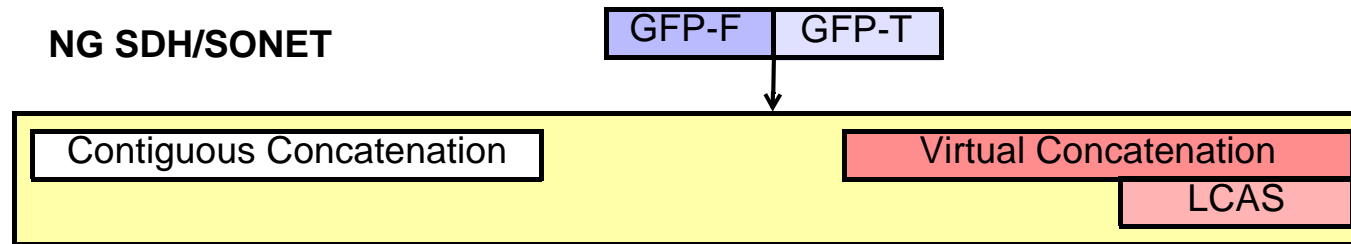
The Next Generation of SDH/SONET is offering:

- data-packet interfaces
- TDM interfaces
- new functionalities

The objective is:

- to support efficiently any type of traffic (including of data packets)
- get the best of Legacy SDH including:
 - resiliency,
 - reliability,
 - scalability,
 - centralised management
 - rerouting

Key NG SDH/SONET



GFP (Generic Framing Protocol)

is robust and standardized encapsulation procedure for the transport of packetised data on SDH/SONET. In principal, GFP performs bit rate adaptation managing features such as priorities, discard eligibility, transport channels selection, and submultiplexing.

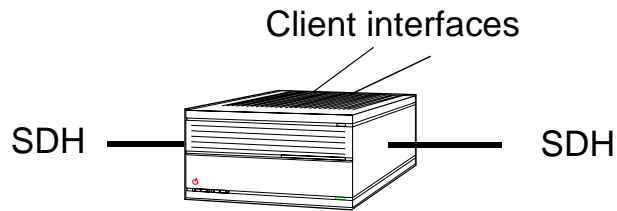
VCAT (Virtual Concatenation)

is a mechanism which assigns granular bandwidth sizes rather than the exponential provision of the Contiguous Concatenation. Therefore VCAT is more flexible and efficient.

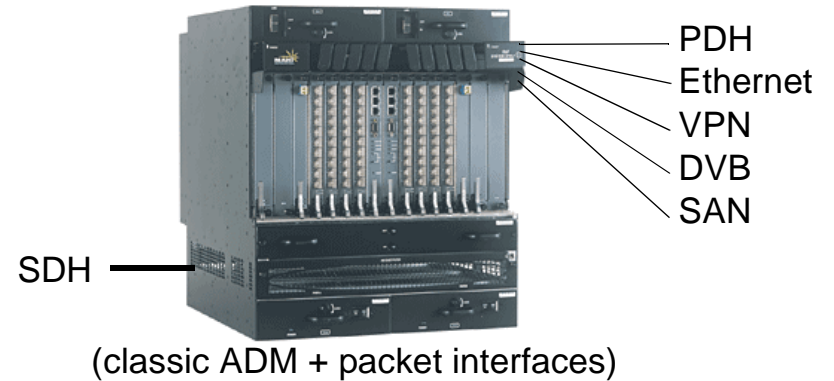
LCAS (Link Capacity Adjustment Scheme)

LCAS can modify dynamically the allocated VCAT bandwidth by adding/removing members of a pipe in use. LCAS is being used also to implement diversity for traffic resilience.

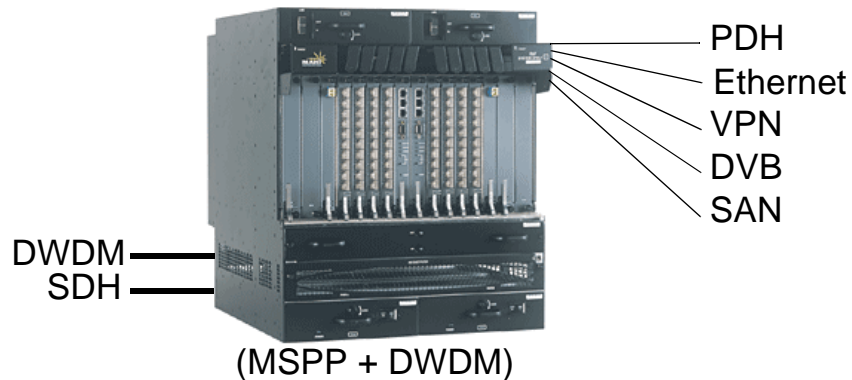
Next Gen. SDH Network elements



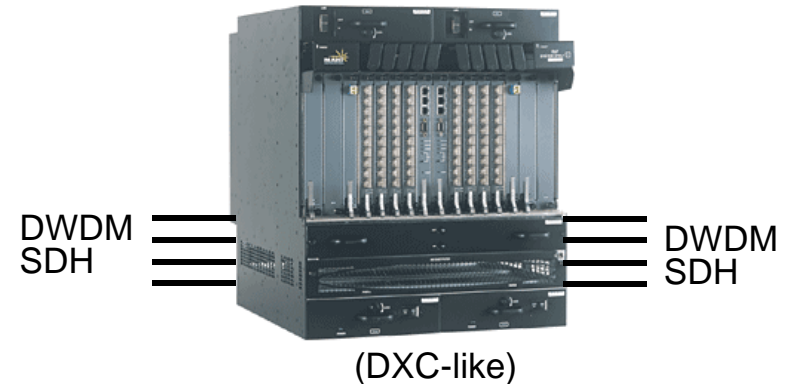
Legacy NE: Reg, Mux, ADM, DXC



Multiservice Provisioning Platform (MSPP)

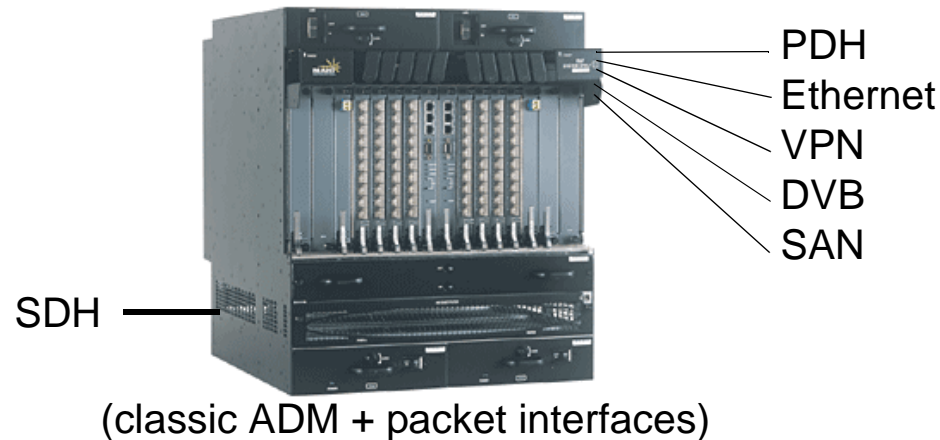


Multiservice Transport Platform (MSTP)



Multiservice Switching Platform (MSSP)

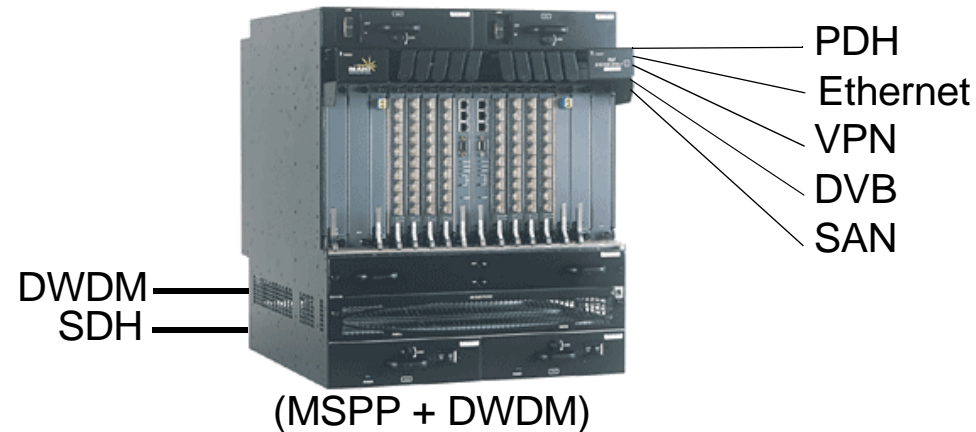
Multiservice Provisioning Platform (MSPP)



A Multiservice Provisioning Platform (MSPP) is basically the result of the evolution of legacy ADM and TDM interfaces and optical interfaces, to a type of access node that includes a set of:

- legacy TDM interfaces
- data interfaces, such as Ethernet, GigE, Fiber Channel, or DVB
- NG SDH/SONET functionalities such as GFP, VCAT and LCAS
- optical interfaces from STM-0/STS-1 to STM-64/OC-192

Multiservice Transport Platform (MSTP)

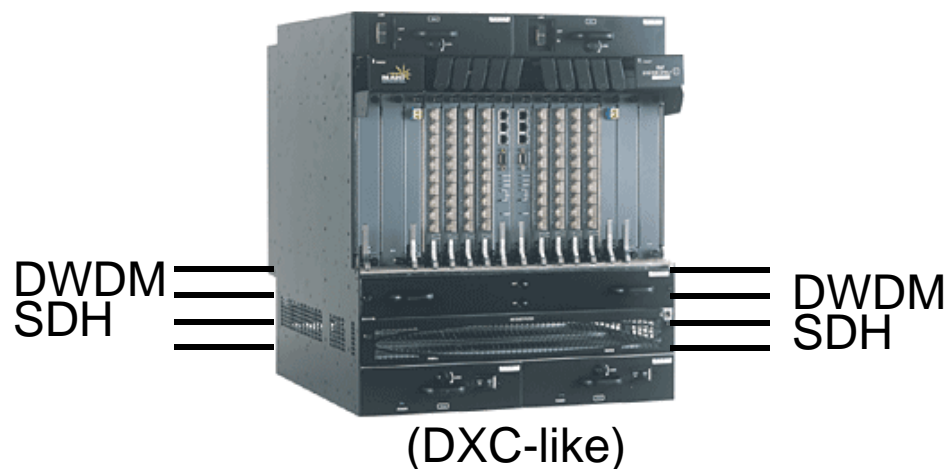


A Multiservice Transport Platform (MSTP) basically is a MSPP with DWDM functions to drop selected wavelengths at a site that will provide higher aggregated capacity to multiplex and to transport client signals.

MSTP allows to integrate SDH/SONET, TDM and data services, with efficient WDM transport and wavelength switching.

Typically, MSTPs are installed in the metro core network.

Multiservice Switching Platform

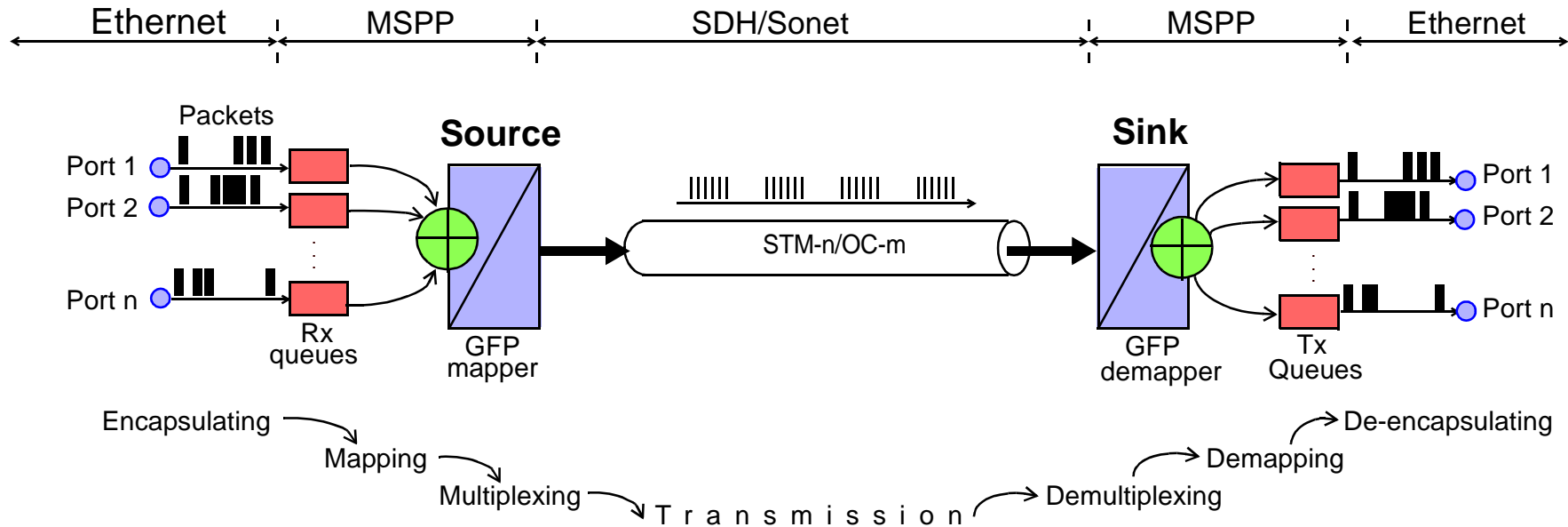


A Multiservice Switching Platform (MSSP) is the NG equivalent for cross-connect, performing efficient traffic grooming and switching at STM-N/OC-M levels but also at VC level.

MSSPs should support more than just data service mapping, namely true data services multiplexing and switching.

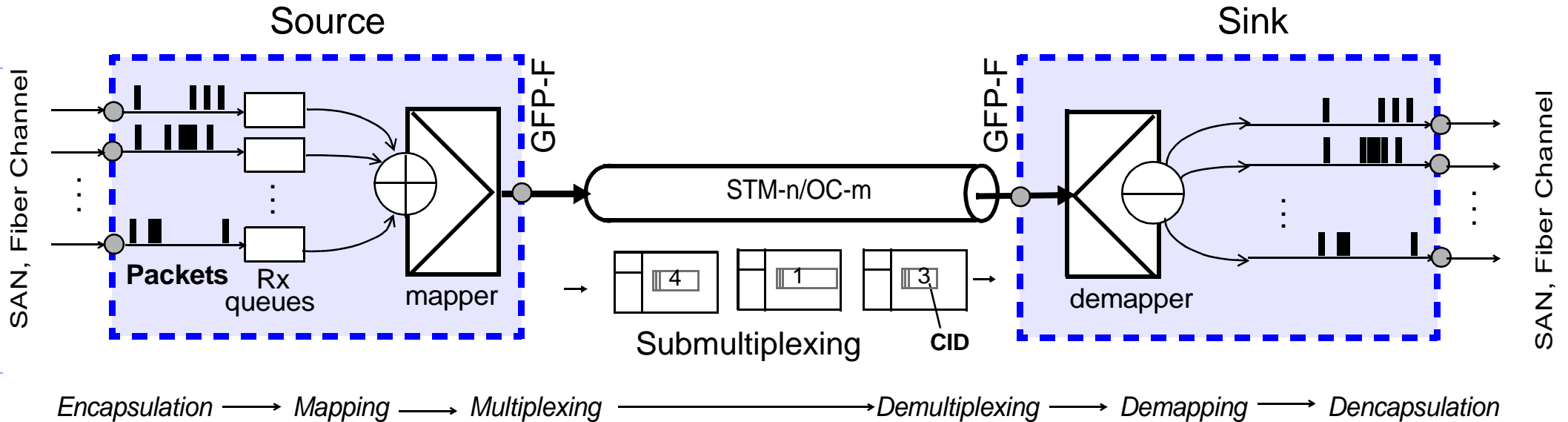
MSSP is still emerging as a NG Network element, while MSPP and MSTP are quite mature.

Generic Framing Protocol (GFP)



- GFP, defined in ITU-T G.7041, provides data rate adaption and frame delineation
- There are two mapping service for data protocols:
 1. **GFP-T** (Transparent) is a layer 1 encapsulation in constant sized frames. Optimised for traf-
fic based on 8B/10B codification such as 1000BASE-T, Fibre Channel, and ESCON.
 2. **GFP-F** (Framed) is a layer 2 encapsulation in variable sized frames. Optimised for data
packet protocols such as DVD, PPP and Ethernet.

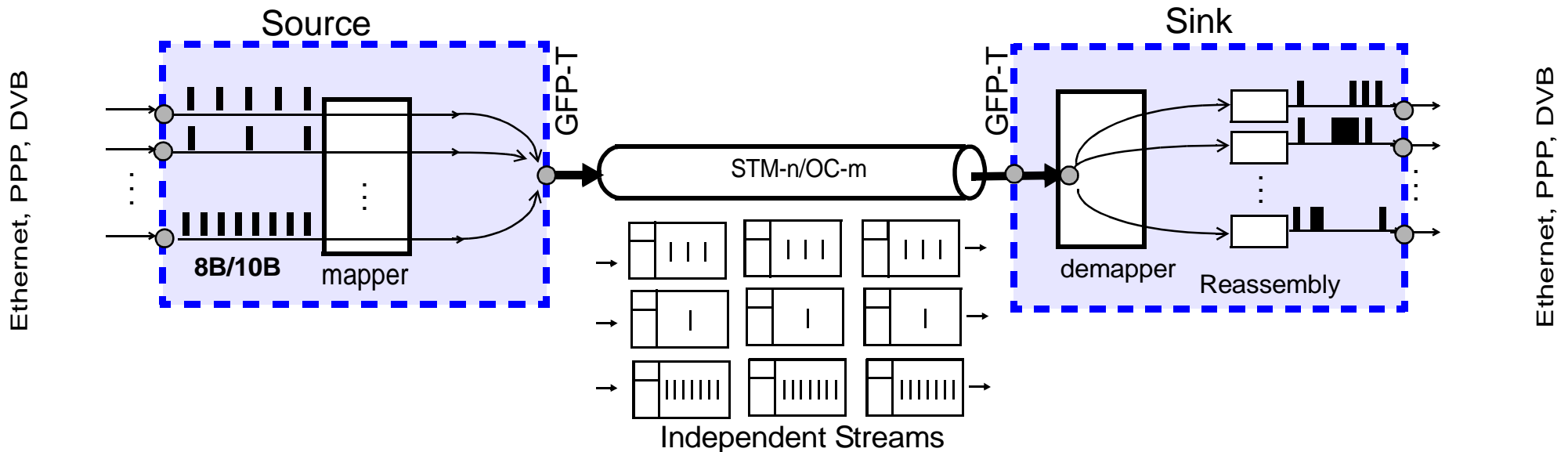
Frame-Mapped GFP (GFP-F)



- The entire client packet is dropped into a GFP frame
- Data Client signals such as Ethernet, PPP and DVB are queued waiting to be mapped
- Some codes can be removed to minimize the transmission size
- GFP-F supports submultiplexing onto a single channel for low-rate sources

GFP-F results in a more efficient transport, however, the encapsulation processes described above increase latency, making GFP-F inappropriate for time-sensitive protocols.

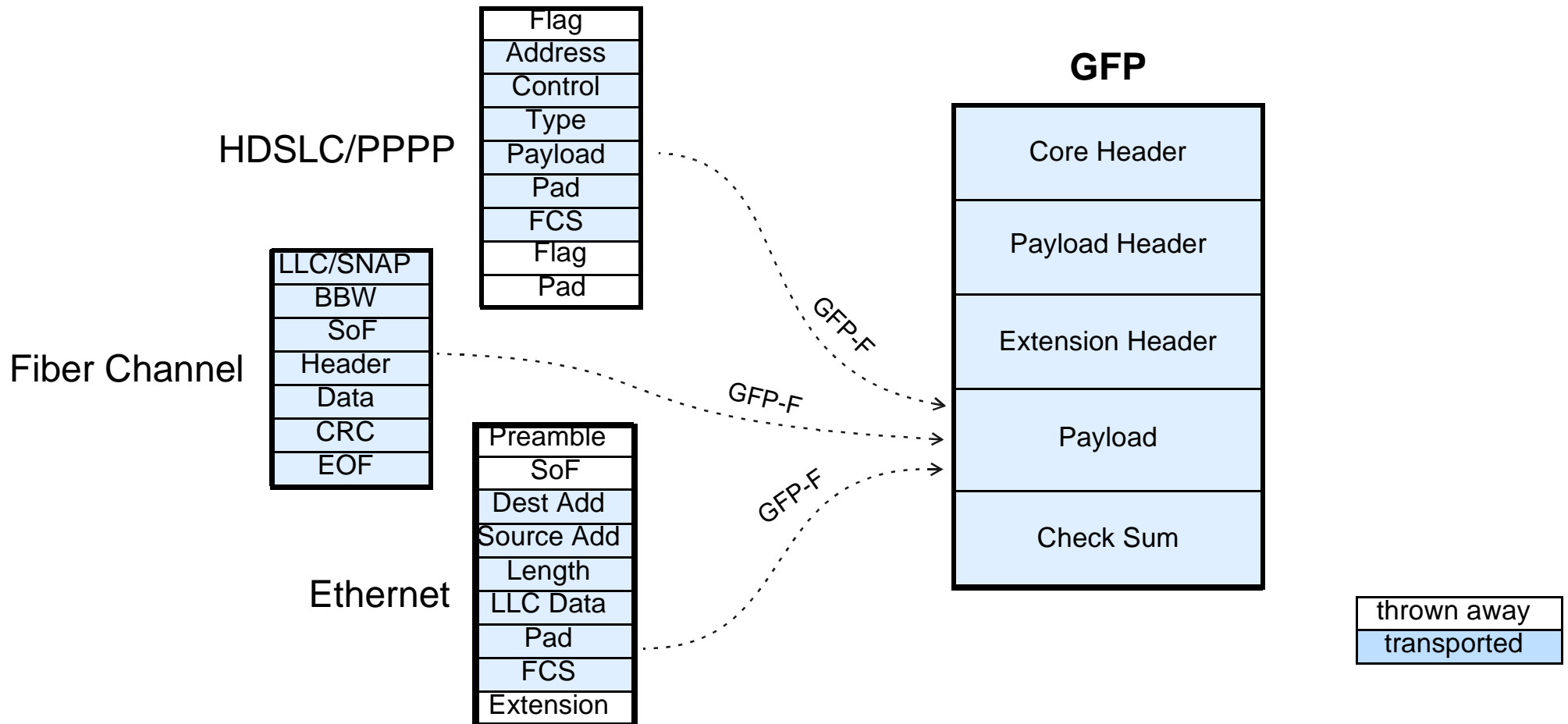
Transparent GFP (GFP-T)



Encapsulation → *Mapping* → *Multiplexing* → *Demultiplexing* → *Demapping* → *Decapsulation*

- GFP-T client signals are mapped into fixed-length GFP frames and transmitted immediately without waiting for the entire client data packet to be received.
- GFP-T encapsulates any protocol as long as they are based on 8B/10B line coding, which is why it is often called protocol-agnostic.
- ALL the client characters, without exception, are transported to the far end.
- GFP-T is very good for isocronic protocols and SAN, such as ESCON or FICON. This is because it is not necessary to process client frames or to wait for arrival of the complete frame

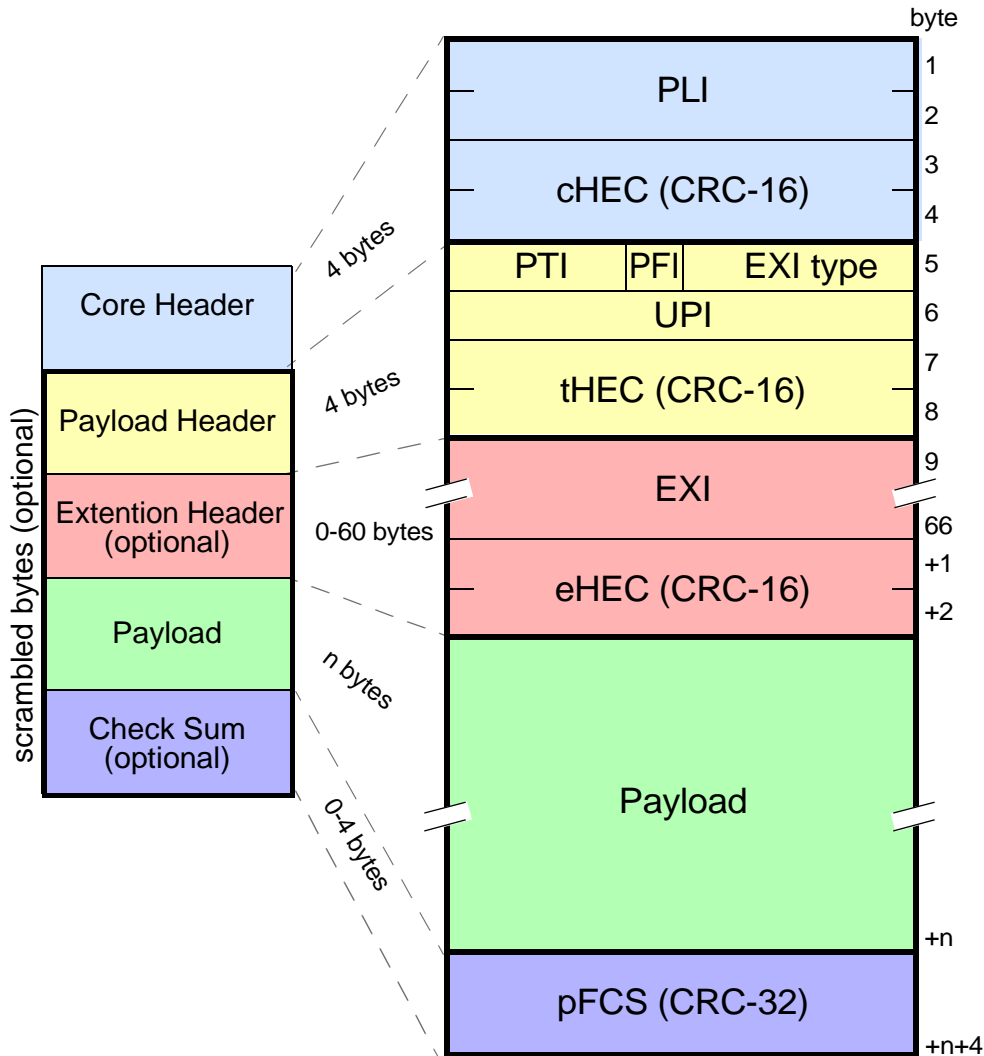
GFP mapping of client signals



Depending on the type of GFP in question, the mapping function can drop the whole signal (in the case of GFP-T), or can throw away certain delineation fields (GFP-F).

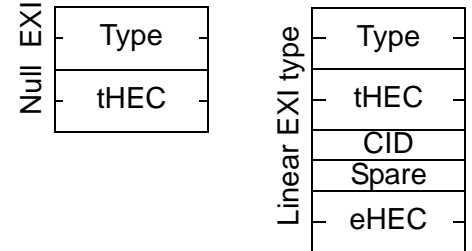
GFP frame formats and protocols

GFP frame



- PLI**: PDU Length Indicator
- cHEC**: Core HEC protection
- PTI**: Payload type Identifier
 - 000: client data
 - 100: client management
- PFI**: Payload FCS Indicator
 - 1: presence of FCS
 - 0: absence
- EXI type**: Extension Header Identifier
 - 0000: Null
 - 0001: Linear
 - 0010: Ring
- UPI**: User Payload Identifier (PTI=0)
 - 01x: Ethernet (GFP-F)
 - 02x: PPP (GFP-F)
 - 03x: Fiber Channel (GFP-T)
 - 04x: FICON (GFP-T)
 - 05x: ESCON (GFP-T)
 - 06x: Gigabit Ethernet (GFP-T)
 - 08x: MAPOS (GFP-F)
 - 09x: DVB (GFP-T)
 - 0Ax: RPR (GFP-F)
 - 0Bx: Fiber Channel (GFP-F)
 - 0Cx: Async Fiber Channel (GFP-T)

tHEC: Type HEC protection
EXI: Extension Header Identifier



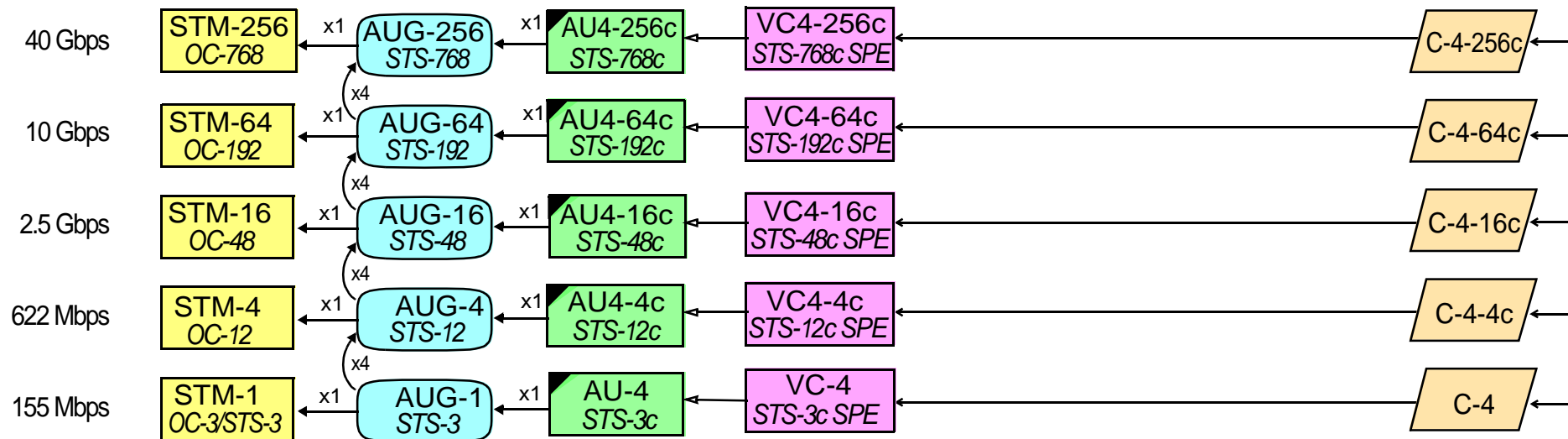
tHEC: Type HEC protection
CID: Channel ID for submultiple

eHEC: Extension HEC protection
Payload: Space for the framed PDU
pFCS: Payload FCS

GFP-F vs. GFP-T

<i>Feature</i>	<i>GFP-F</i>	<i>GFP-T</i>
Protocol transparency	low	high
Efficiency	high	low
Isocronic protocols	no	yes
Encapsulation protocol level	Layer 2 (Frames)	Layer 1 (Physical)
Optimized for	Ethernet	SAN, DVB
LCAS protection	likely	poor
Statistical submultiplexing	yes	no
SAN transport	no	yes
Ethernet transport	optimum	possible

Concatenation

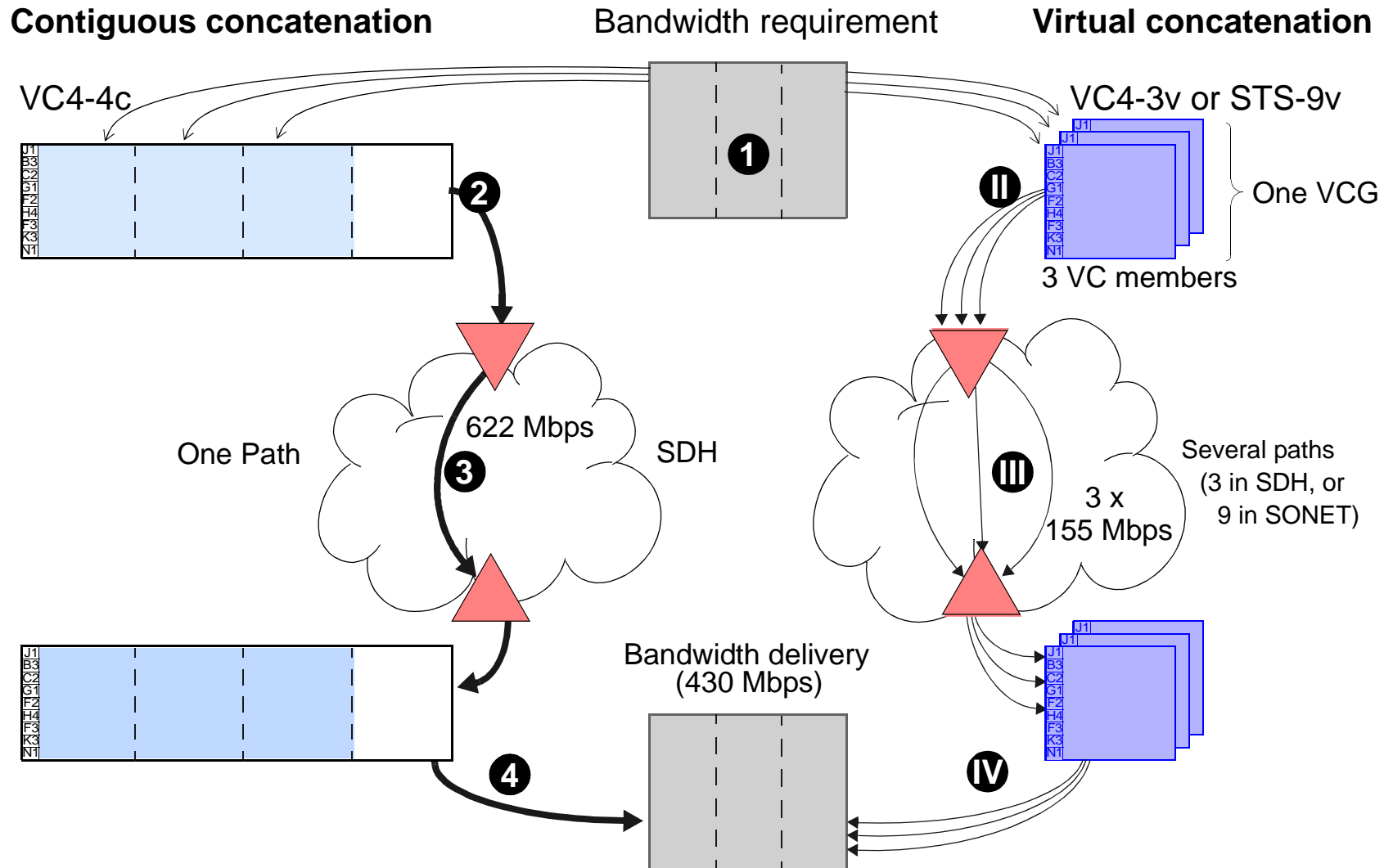


Concatenation is the process of summing the bandwidth of X containers of the same type into a larger container.

There are two concatenation methods:

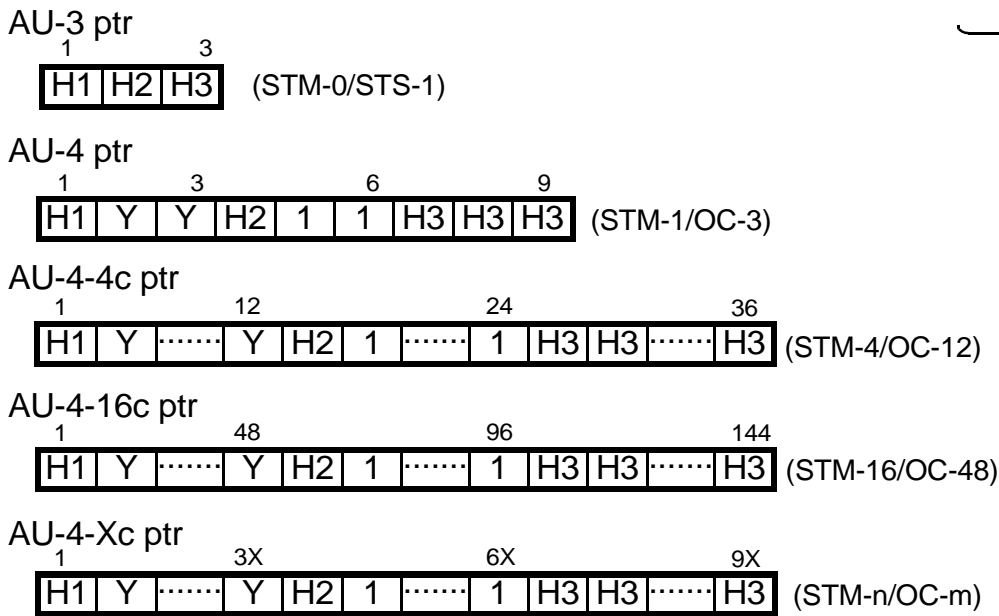
- **Contiguous concatenation**, which creates big containers that cannot split into smaller pieces during transmission. For this, each NE must have a concatenation functionality.
- **Virtual concatenation**, which transports the individual VCs and aggregates them at the end point of the transmission path. For this, concatenation functionality is only needed at the path termination equipment.

Contiguous and Virtual Concatenation



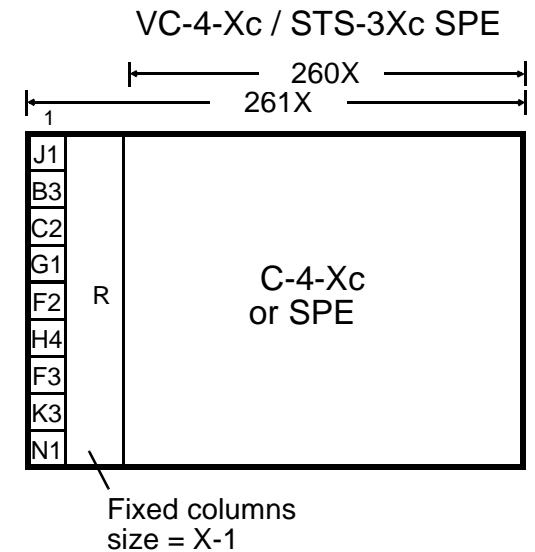
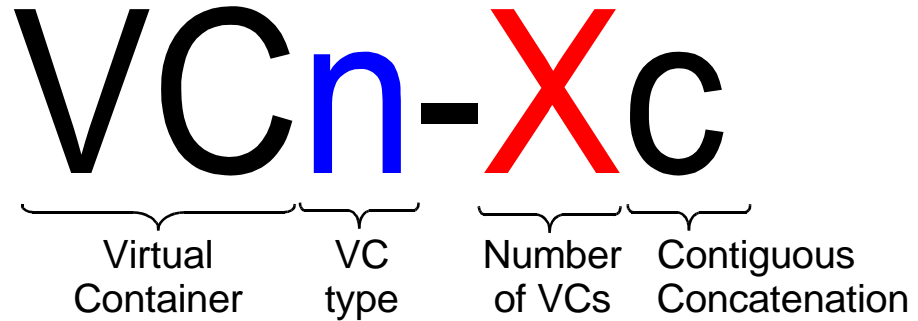
Contiguous Concatenation (VCAT)

STM / STS pointers



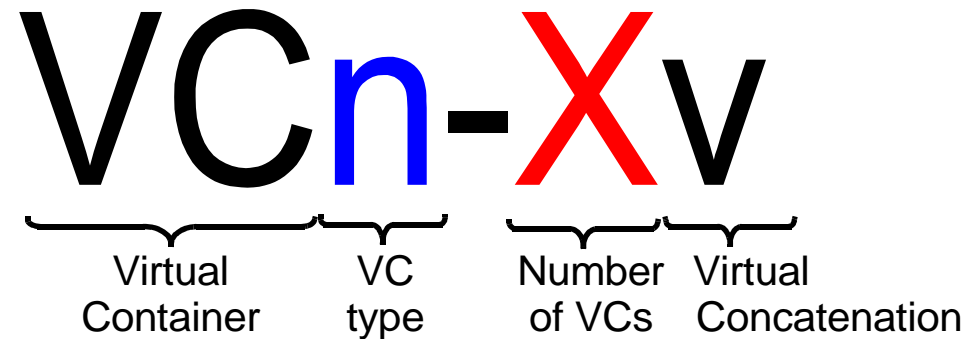
Y: 1001SS11

1: All 1s byte Justification unit = 3 X bytes



Contiguous concatenation: Pointers and containers. A VC-4-Xc (X = 1, 4, 16, 64, 256) structure, where X represents the level. The increment/decrement unit (justification) is 3 X, as it depends on the level: AU-4=3 bytes, AU-4-256c=768 bytes.

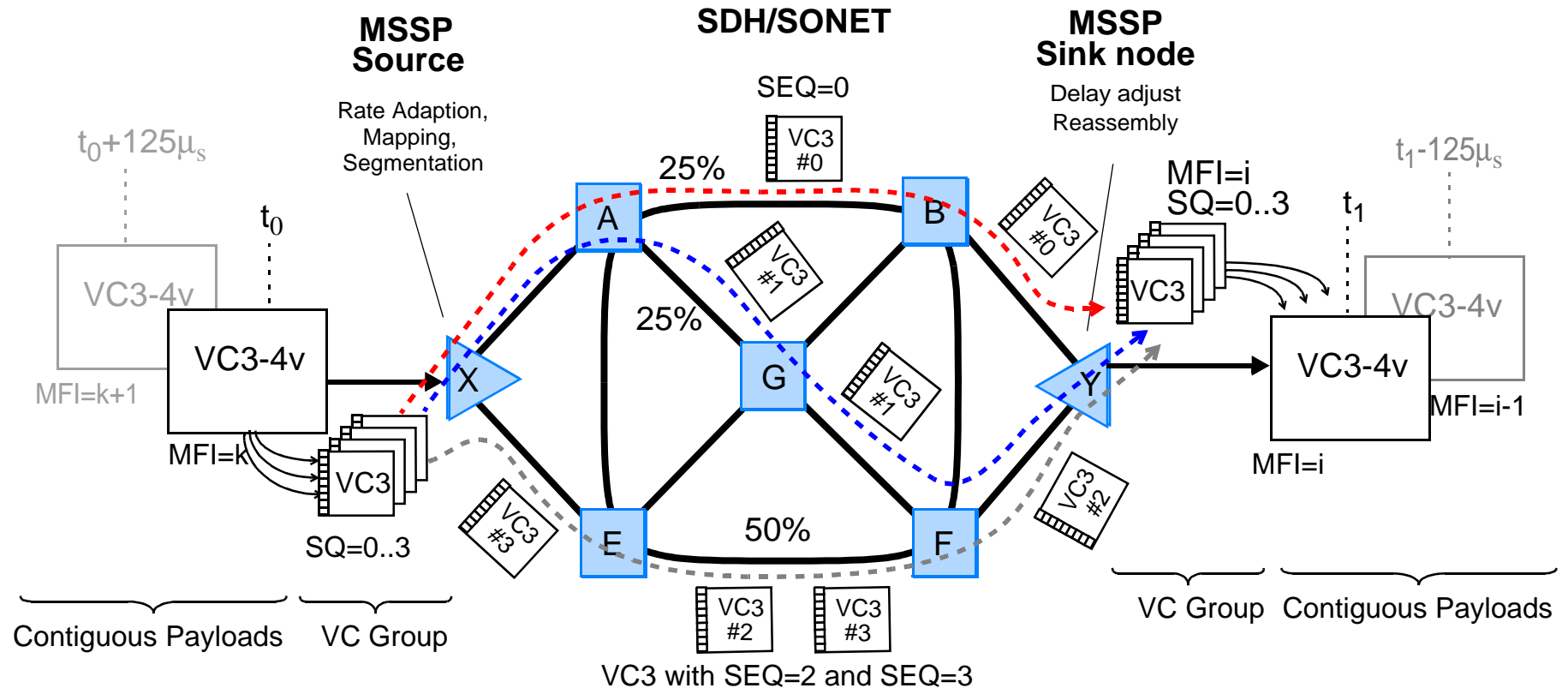
Virtual Concatenation (VCAT)



Packet-oriented, statistically multiplexed technologies, such as IP or Ethernet, do not match well the bandwidth granularity provided by contiguous concatenation.

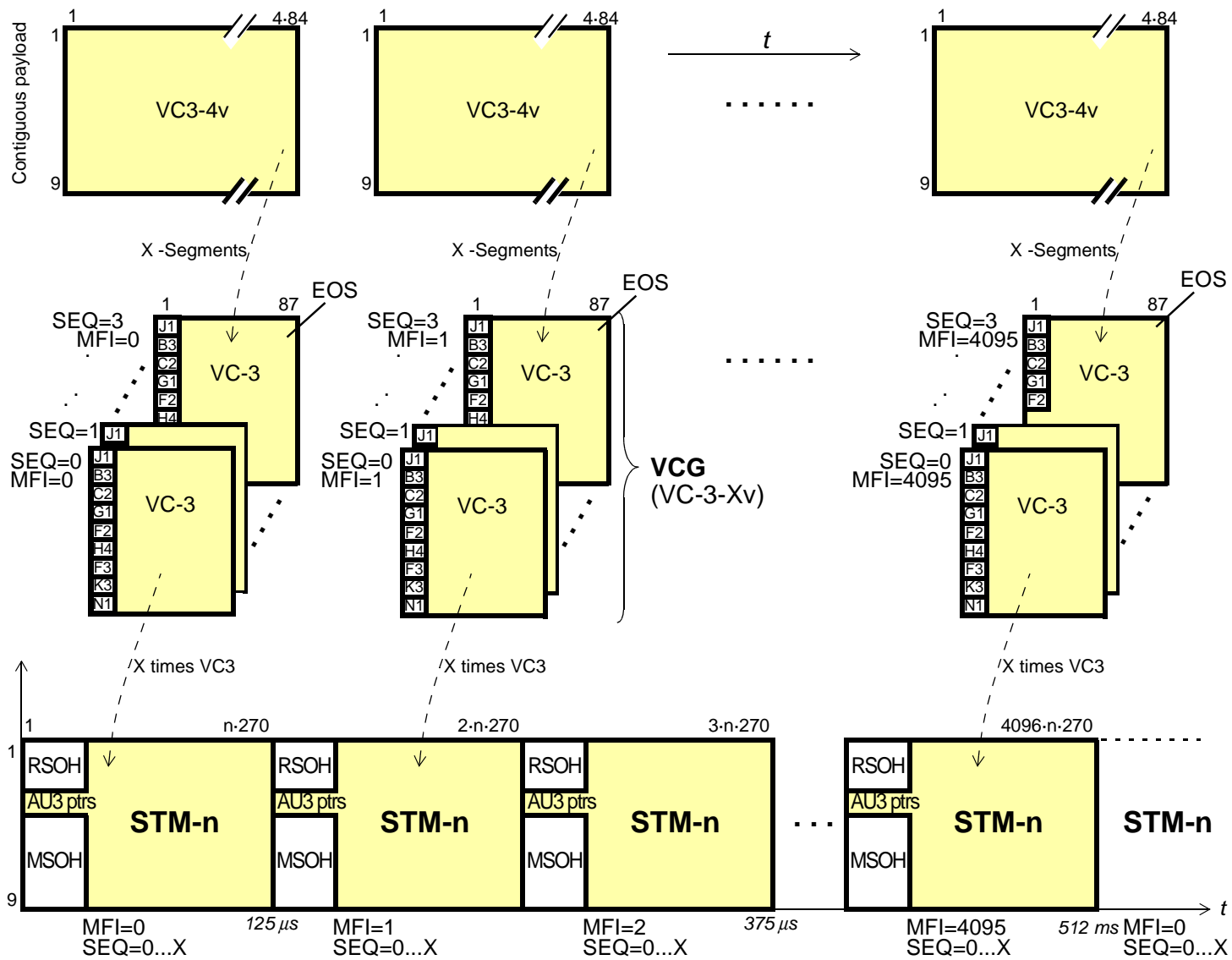
- VCAT is an inverse multiplexing technique that allows granular increments of bandwidth in single VC-n units.
- At the source node VCAT creates a continuous payload equivalent to X times the VC-n
- The set of X containers is known as a Virtual Container Group (VCG), and each individual VC is a member of the VCG.
- Lower-Order Virtual Concatenation (LO-VCAT) uses X times VC11, VC12, or VC2 containers (VC11/12/2-Xv, X = 1... 64).
- Higher-Order Virtual Concatenation (HO-VCAT) uses X times VC3 or VC4 containers (VC3/4-Xv, X = 1... 256), providing a payload capacity of X times 48 384 or 149 760 kbit/s.

Virtual Concatenation Operation



- MFI: Multiframe Indicator, VCG: Virtual Container group, SEQ: Sequence Number
- Virtual concatenation is required only at edge nodes
- Sink node must compensate for the different delays

Virtual Concatenation Graphically



Virtual vs. Contiguous Concatenation

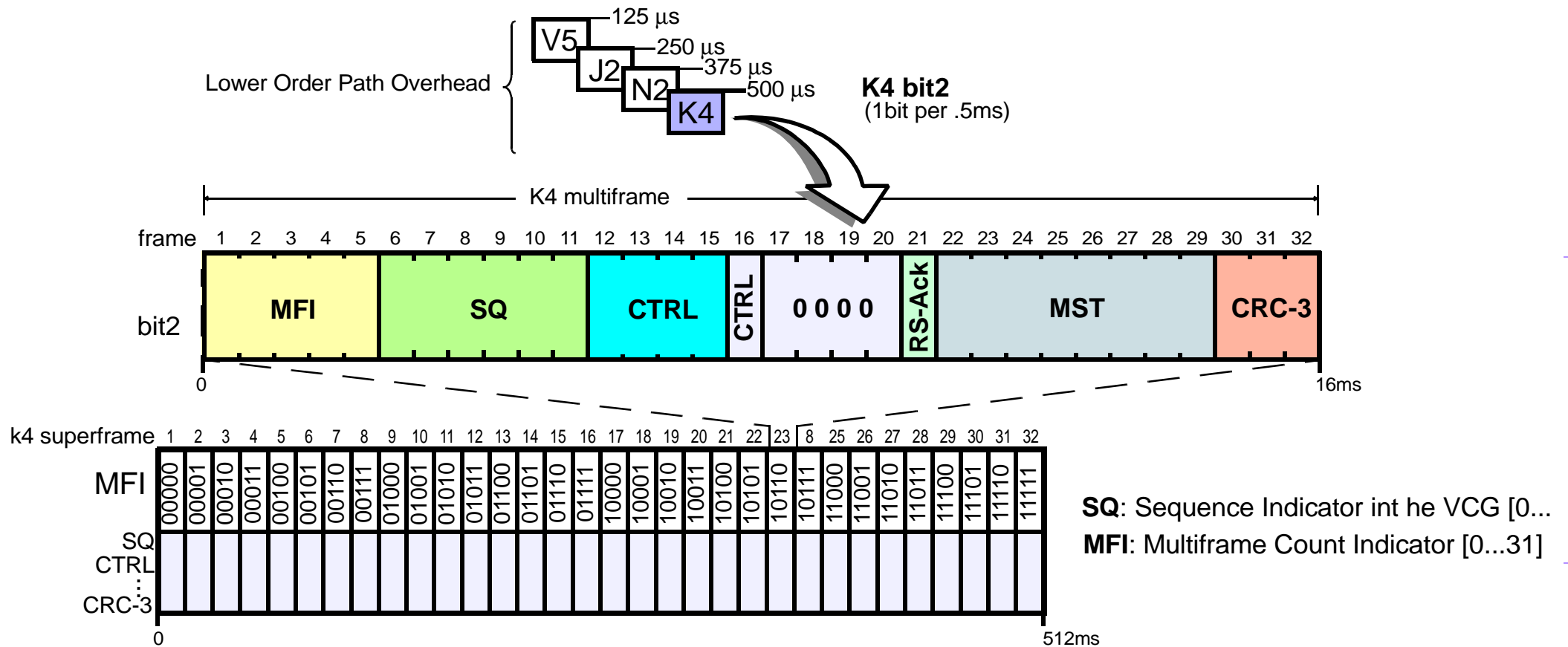
<i>SDH</i>	<i>SONET</i>	<i>X times</i>	<i>Capacity</i>	<i>Justification</i>	<i>Transport</i>
VC-4	STS3c-SPE	1	149,760 Kbps	3 bytes	STM-1/OC-3
VC-4-4c	STS12c-SPE	4	599,040 Kbps	12 bytes	STM-4/OC-12
VC-4-16c	STS48c-SPE	16	2,396,160 Kbps	48 bytes	STM-16/OC-48
VC-4-64c	STS192c-SPE	64	9,584,640 Kbps	192 bytes	STM-64/OC-192
VC-4-256c	STS768c-SPE	256	38,338,560 Kbps	768 bytes	STM-256/OC-768

<i>SDH</i>	<i>SONET</i>	<i>X times</i>	<i>Capacity</i>	<i>Virtual Capacity</i>
VC-11-Xv	VT.15-Xv	1 to 64	1,600 Kbps	1,600 to 102,400 Kbps
VC-12-Xv	VT2-Xv	1 to 64	2,176 Kbps	2,176 to 139,264 Kbps
VC-2-Xv	VT6-Xv	1 to 64	6,784 Kbps	6,784 to 434,176 Kbps
VC-3-Xv	STS-1-Xv	1 to 256	48,384 Kbps	48,384 to 12,386 Kbps
VC-4-Xv	STS-3c-Xv	1 to 256	149,760 Kbps	149,760 to 38,338,560 Kbps

Virtual vs. Contiguous Concatenation

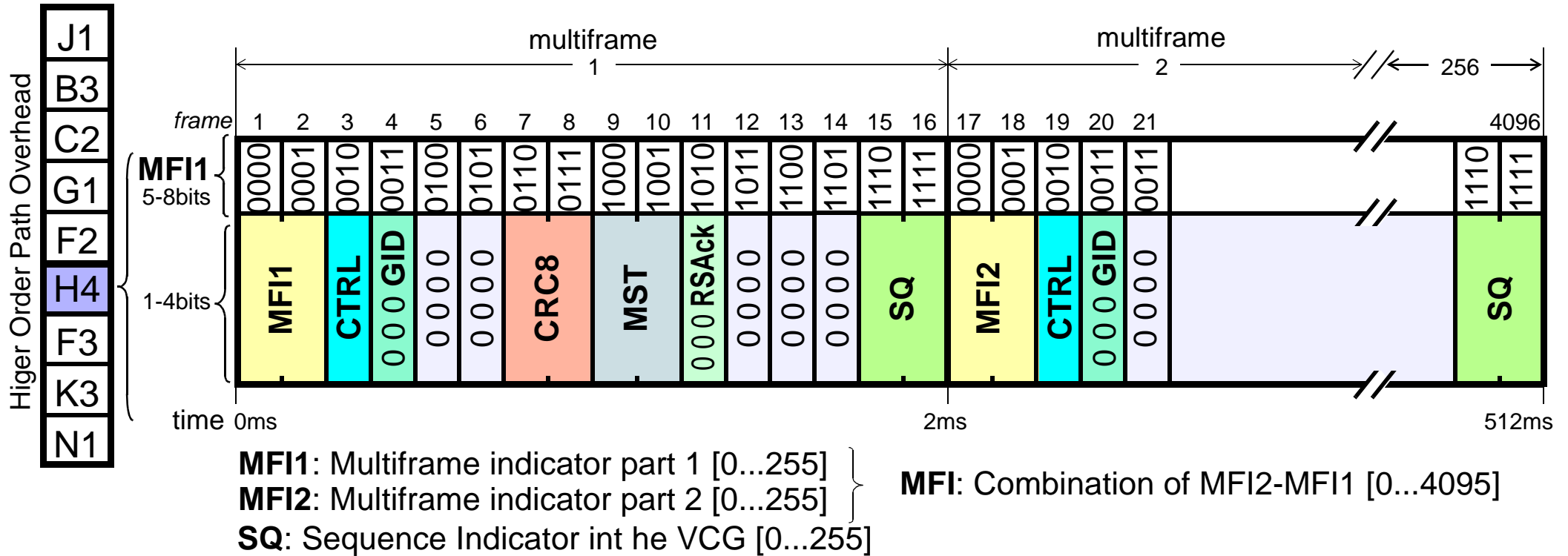
<i>Service</i>	<i>Bit Rate</i>	<i>Contiguous Concat.</i>	<i>Virtual Concatenation</i>
Ethernet	10 Mbit/s	VC-3 (20%)	VC-11-7v (89%)
Fast Ethernet	100 Mbit/s	VC-4 (67%)	VC-3-2v (99%)
Gigabit Ethernet	1000 Mbit/s	VC-4-16c (42%)	VC-4-7v (95%)
Fiber Channel	1700 Mbit/s	VC-4-16c (42%)	VC-4-12v (90%)
ATM	25 Mbit/s	VC-3 (50%)	VC-11-16c (98%)
DVB	270 Mbit/s	VC-4-4c (37%)	VC-3-6v (93%)
ESCON	160 Mbit/s	VC-4-4c (26%)	VC-3-4v (83%)

K4 multiframe (VCAT & LCAS codification)



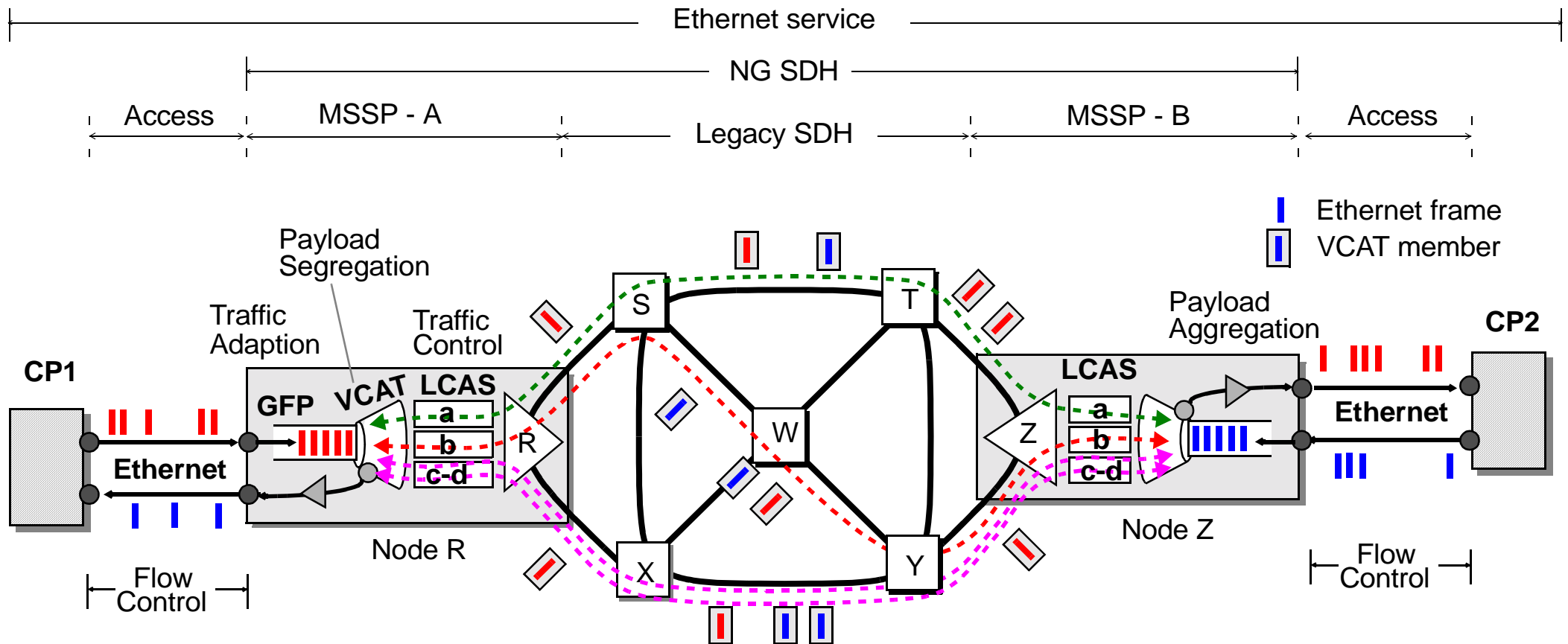
- K4 is part of the LO-PO overhead and is repeated every 500 ms
- 32 bits are sent in a complete multiframe which takes 16ms to repeat. (500 x 32=16 ms)
- The bit-2 superframe is made up of 32 multiframes and takes 512 ms to repeat.

H4 multiframe (VCAT & LCAS codification)



- H4 is part of the HO-PO overhead
- H4 is repeated every 125 ms
- 16-byte multiframes takes 16 ms
- A complete multiframe of 4096 bytes takes 512 ms to repeat (125x4096=512 ms)

Ethernet service provided by VCAT/LCAS



The link between node A and node Z transports Ethernet frames using a Virtual Concatenation Group of three members. Three separate LCAS protocols constantly monitor each peer connection: LCAS-a of node R talks with LCAS-a of node Z, LCAS-b(R) with LCAS-b(Z), ... LCAS-n (R) with LCAS-n (Z)

Link Capacity Adjustment Scheme (LCAS)

ITU-T as G.7042, designed to manage the bandwidth allocation of a VCAT path. LCAS can add and remove members of a VCG that control a VCAT channel. LCAS cannot adapt the size of the VCAT channel according to the traffic pattern.

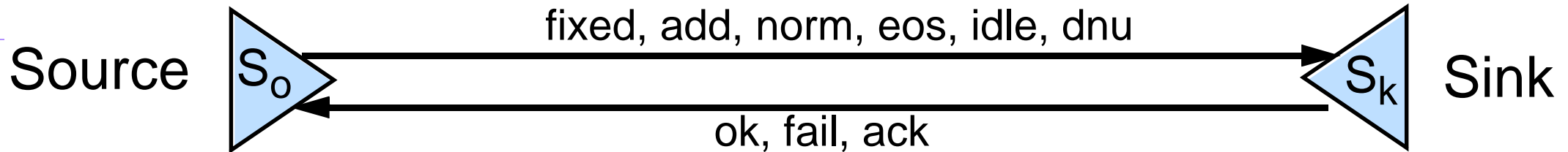
Source to Sink messages:

- *Multi-Frame Indicator* (MFI) keeps the multiframe sequence.
- *Sequence Indicator* (SQ) indicates member's sequence to reassemble correctly the client signal that was split and sent through several paths.
- *Control* (CTRL) protocol messages which can be fixed, add, norm, eos, idle, and dnu.
- *Group Identification* (GID) is a constant value for all members of a VCG.

Sink to Source include:

- *Member Status* (MST), which indicates to source each member status: fail or OK.
- *Re-Sequence Acknowledge* (RS-Ack) is an ack of renumbering after a new **eos** member.

LCAS protocol



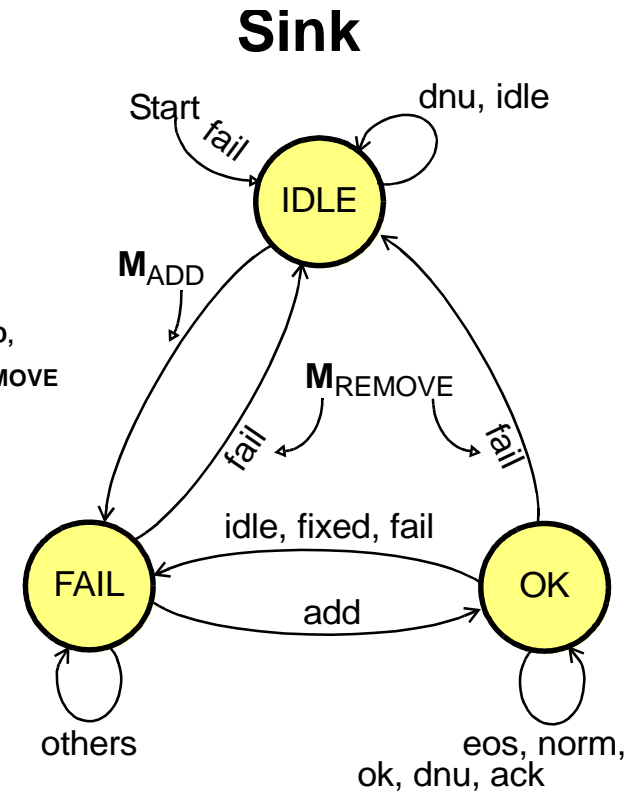
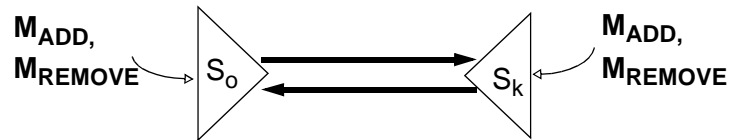
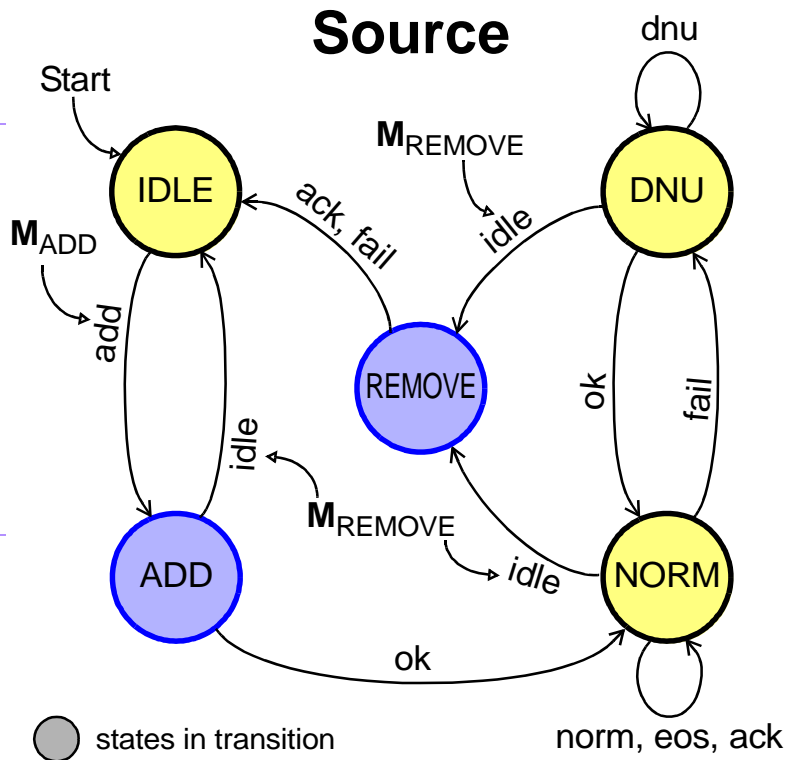
Source to Sink
(CNTRL message)

fixed: Indicates fixed bandwidth and no LCAS support
add: Member to be added to the VCG
norm: Normal transmission
eos: End of sequence, the member has the highest VCG seq number, Normal transmission
idle: Member is part of the VCG or to be removed
dnu: Do Not Use, receive side reported MST FAIL status

Sink to Source
(MST & RS messages)

ok: active member, no failure condition detected (MST msg)
fail: failure condition detected in member (MST msg)
ack: Re-Sequence Acknowledge after eos msg (RS-Ack msg)

Simplified LCAS Source and Sink State Machine



Source States

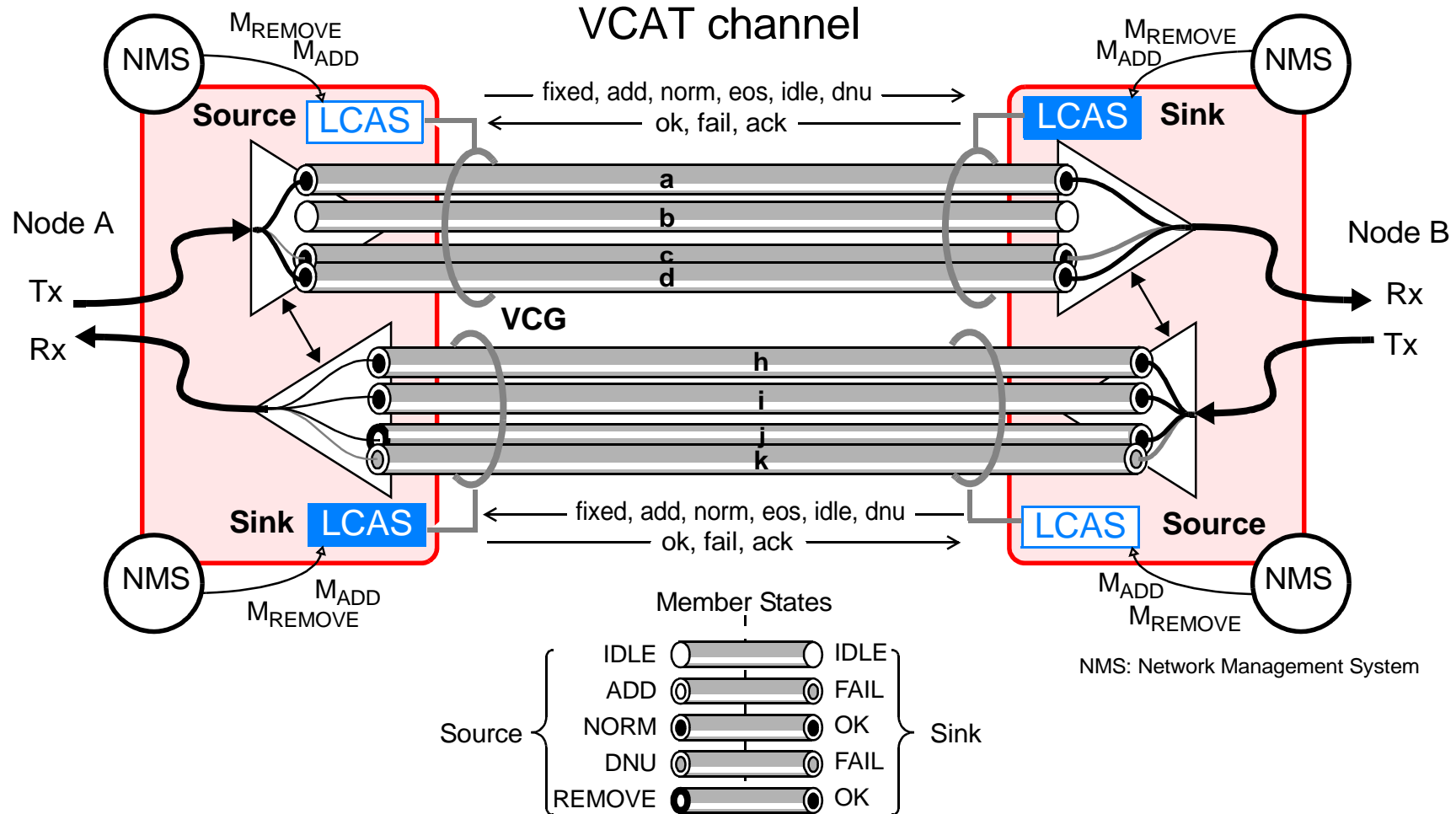
- IDLE:** Not provisioned member
- ADD:** In process of being added to the VCG
- NORM:** Active and provisioned member, good path
- DNU (Do Not Use):** Provisioned but its path has failed
- REMOVE:** In process of being removed of the VCG

- M_{ADD} : add one or more members of the VCG
- M_{REMOVE} : remove one member of the VCG

Sink States

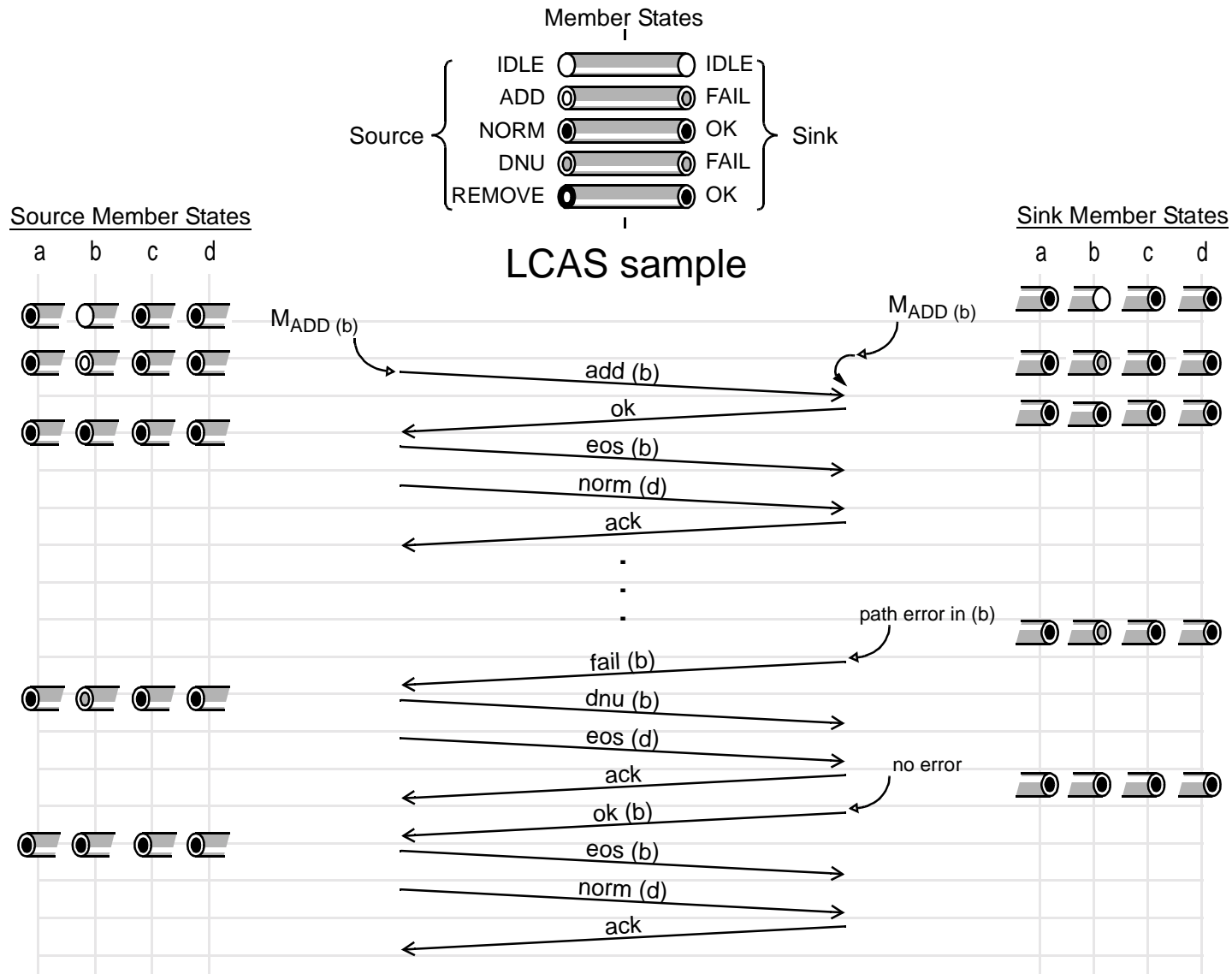
- IDLE:** Not provisioned member
- OK:** Provisioned and active member
- FAIL:** Provisioned member, failed path

VCAT Channel managed with LCAS

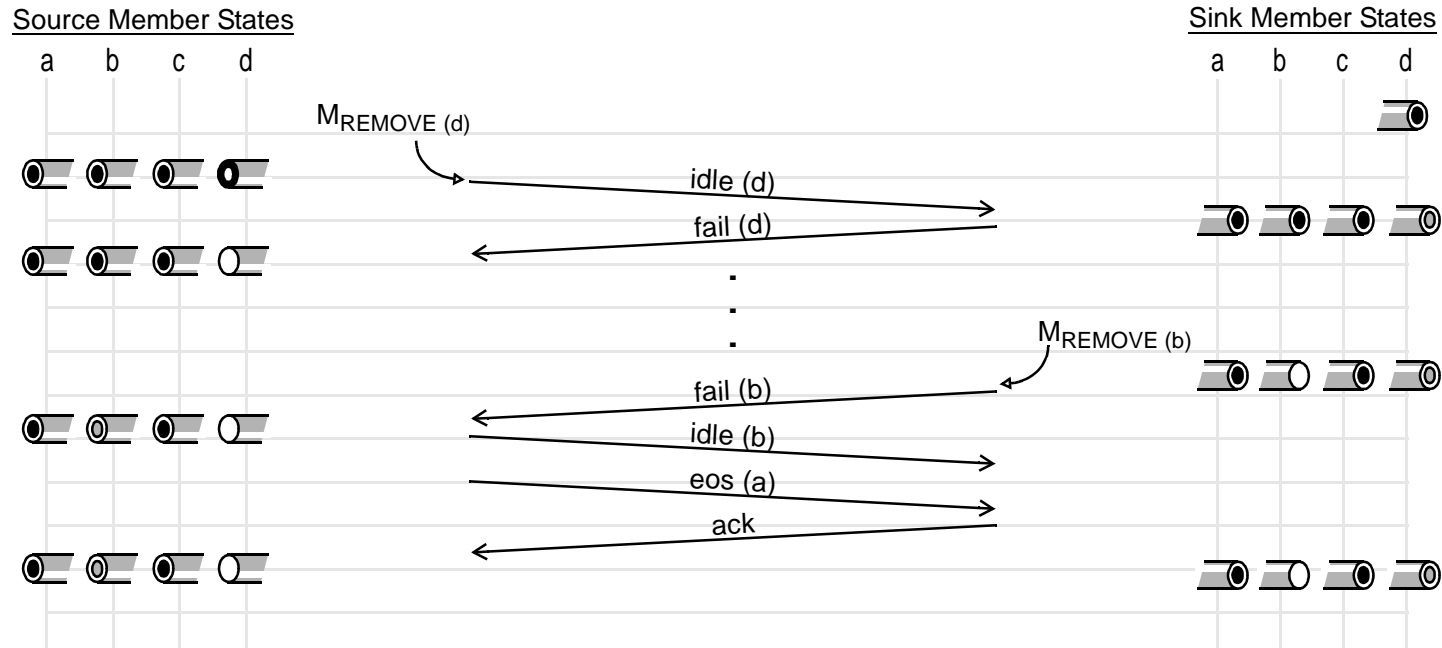
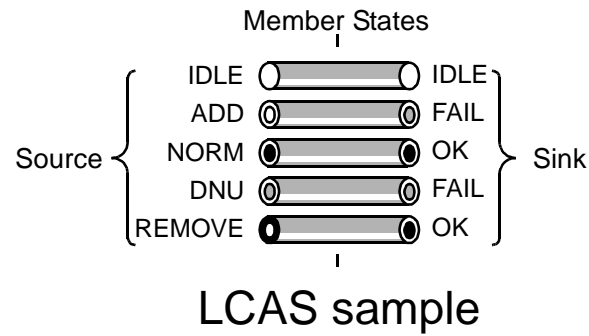


LCAS helps network operators to efficiently control NG SDH connections established at VCAT sites. The use of LCAS is not compulsory, but improves VCAT management

LCAS protocol: M_{ADD} and Path error

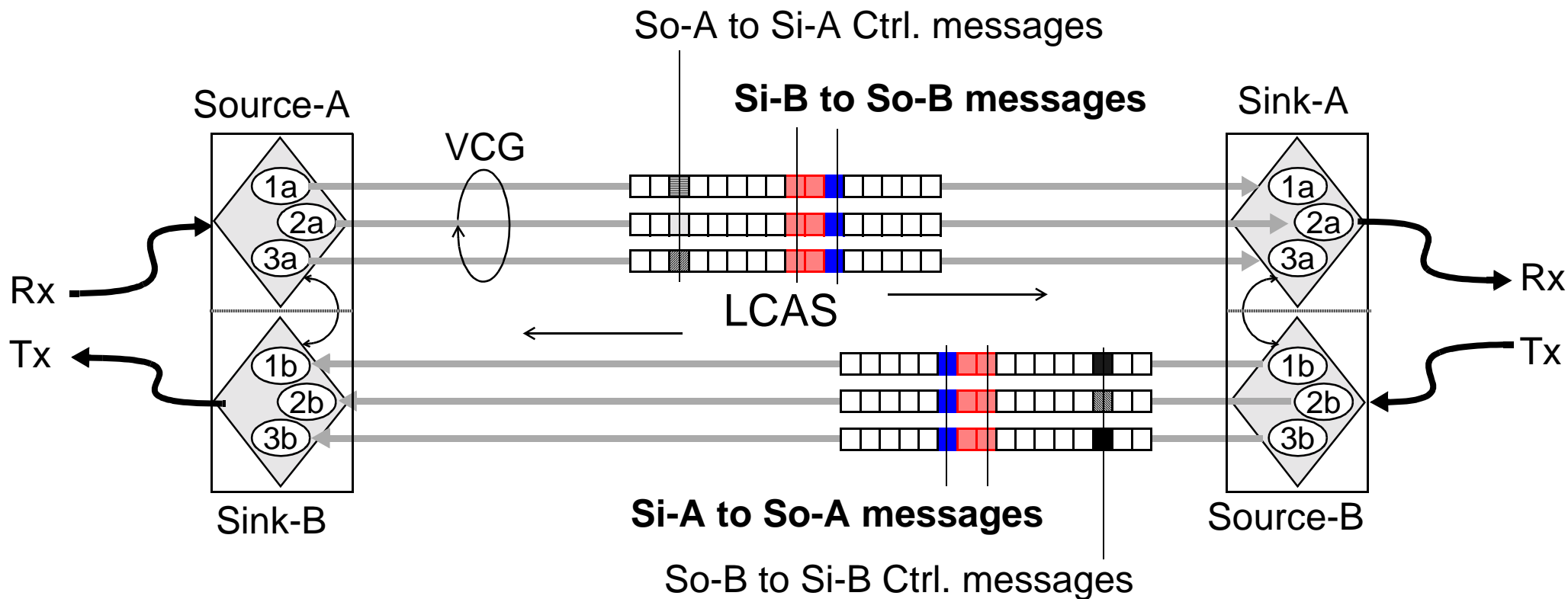


LCAS protocol: M_{REMOVE}



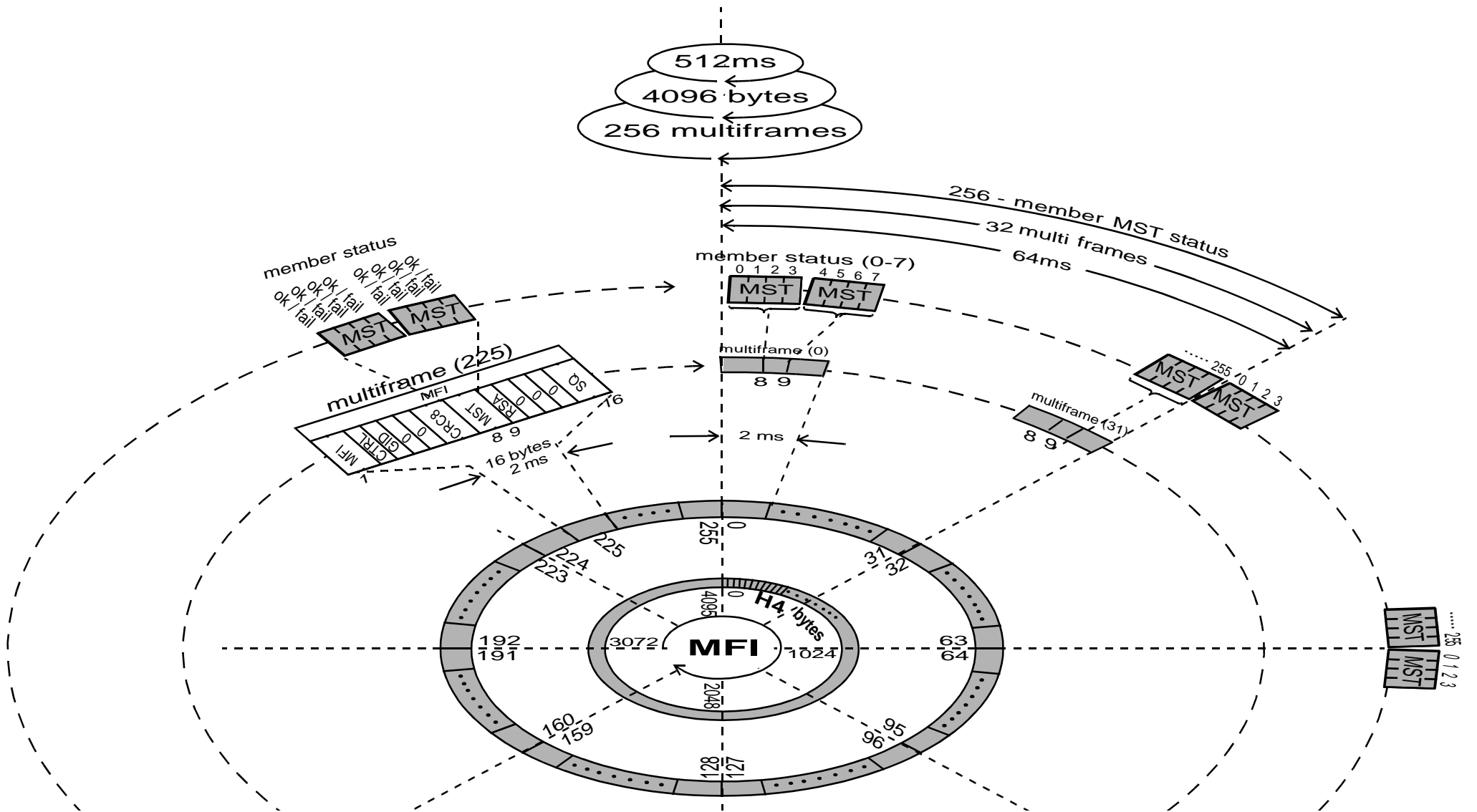
LCAS is a two-way handshake protocol resident in H4 and K4 and executed permanently between source and sink as many times as VCAT members.

Sink messages are fault tolerant

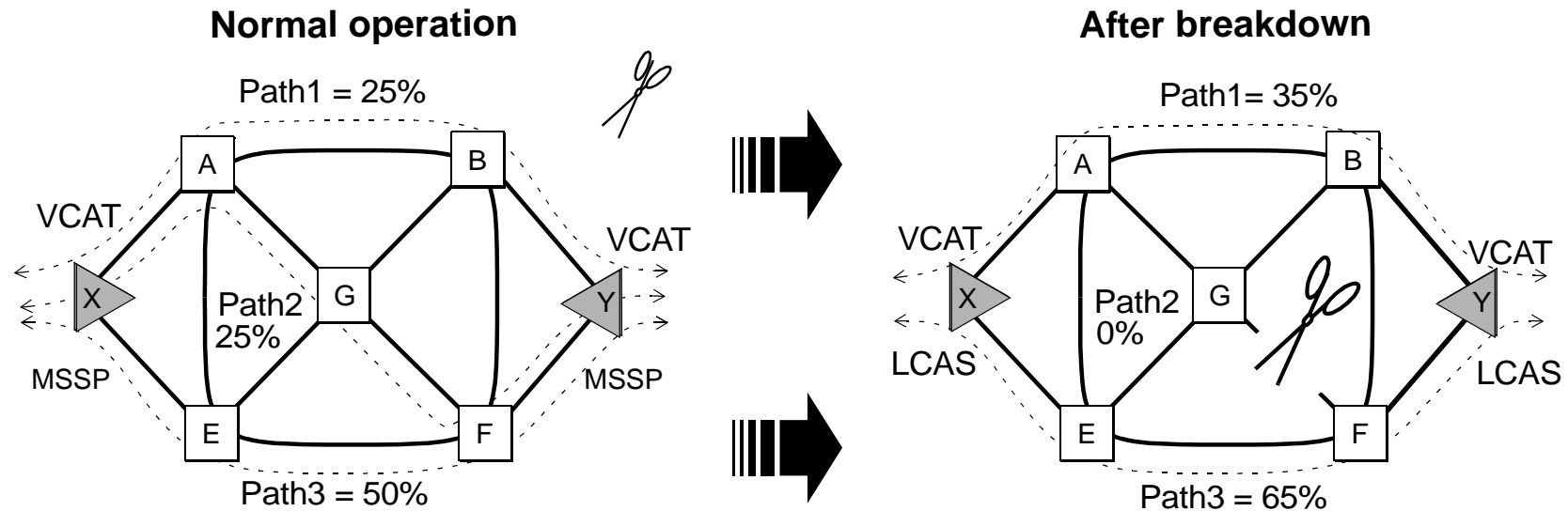


Sink to Source messages (MST, RS-Ack) are redundant while Source to Sink are specific to each member. This means that Sink messages are repeated as many times as members in the group. It also means that the origin of sink messages is irrelevant, because all the members are sending the same information in a multiframe.

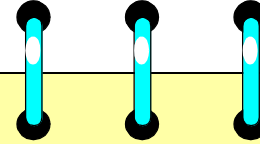
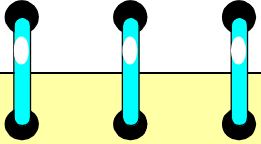
H4 multiframe sequence



LCAS applications



- **VCAT bandwidth allocation**, LCAS enables the resizing of the VCAT pipe in use when it receives an order from the NMS to increase or decrease the size.
- **Network Resilience**, In the case of a partial failure of one path, LCAS reconfigures the connection using the members still up and able to continue carrying traffic.
- **Asymmetric Configurations**, LCAS is a unidirectional protocol allowing the provision of asymmetric bandwidth between two MSSP nodes to configure asymmetric links
- **Cross-Domain Operation**, because LCAS resides only at edge nodes it is not necessary to coordinate more than one configuration centre



Conclusions

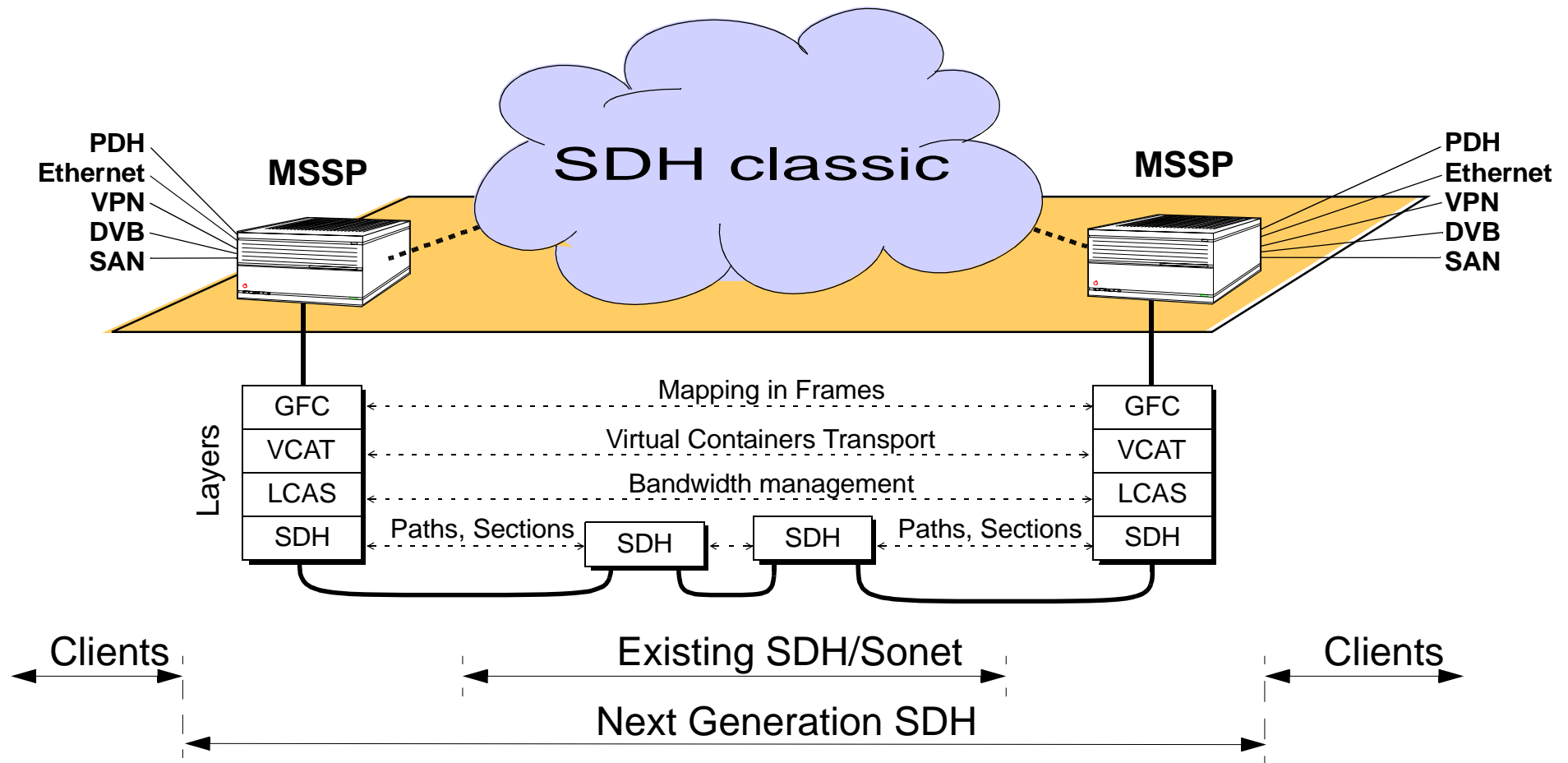
Section

SDH is future proof



- SDH cannot be considered anymore as a “legacy technology”
- The evolution to Next Generation SDH is the future
- Future proof at least for the next 10 years
- NG SDH can deliver packet and TDM services
- Carriers are already migration from static, circuit-oriented SDH to multiservice packet-friendly NG SDH

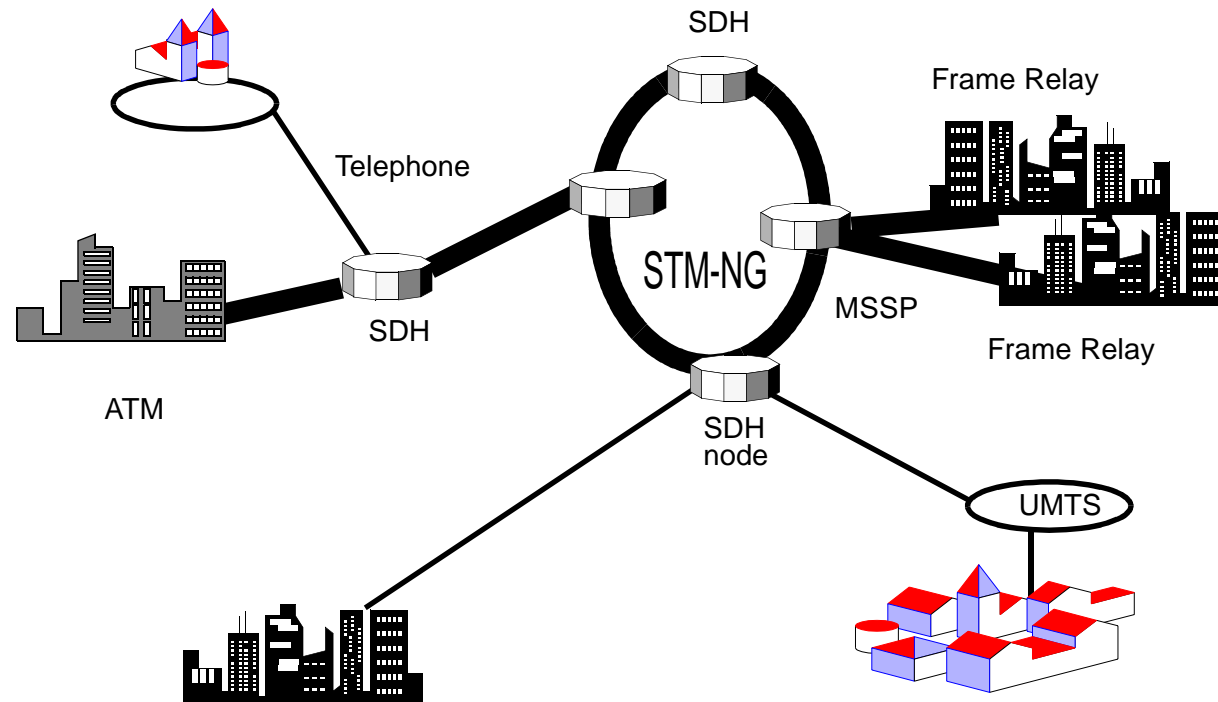
Migration to Next Generation



It is only necessary to migrate the edges to get a full Next Generation SDH network

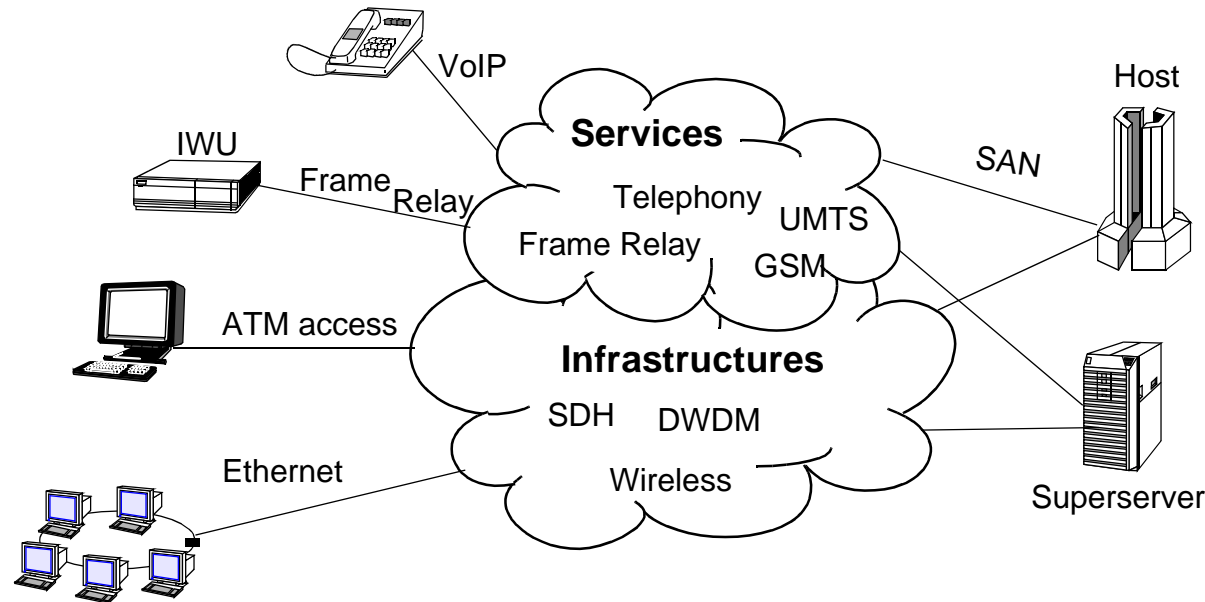
IT IS TODAY'S BEST COMBINATION FOR DATA AND CIRCUIT TRANSPORT

NG SDH means unification and standardisation



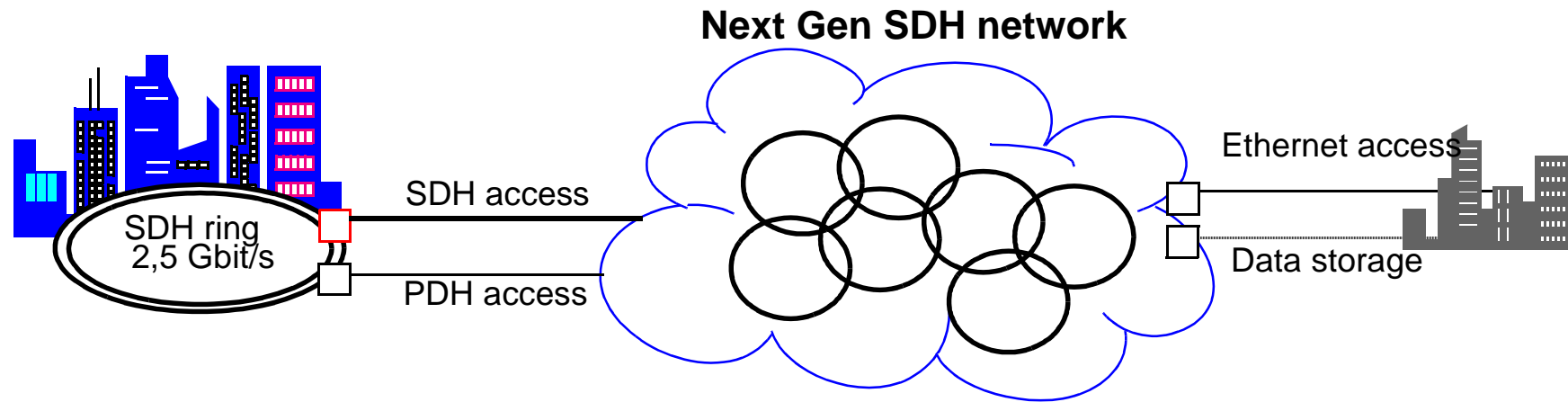
Next Generation SDH unifies and standardises transport infrastructure for any type of client network packet or circuit oriented network such as Ethernet, PDH, Frame Relay, UMTS, SAN...

Old and New services as well



- NG SDH helps to provide the right SLA to Ethernet services
- Transport for high definition audio and video
- High speed data for Internet or other networks
- Fast bandwidth management to satisfy requirements
- Integration under the same architecture circuit and packet networks

Cost effective



- Universal standard: multivendor
- Unifies infrastructures under a central architecture avoiding a new overlap network
- Reduces the number of network elements needed to provide advanced services
- New technologies are making NG SDH more competitive and cheaper
- With just a few network elements is possible to configure a network
- Simplifies the management because of centralised configurations

Telecom basis in the next 10 years?

Broadband Networks

- “SDH will be the dominant technology in the next 10 years” Pioneers Optical Edge Networks Boston (MA) June 2000
- “SDH is being used in wireless, we think there is a market at least for the next 10 years” Eli Lotan Global Telephony March 01
- “Ethernet demand lights up but SDH will remain at the core network” Ken Weiland Telecommunications International April 03
- “Ethernet and Optic networks have to match SDH resilience and management to challenge SDH at the metro and core network” JM Caballero Mundo Electr. April 04
- “Installed base is huge to simply walk away from” S. Clavena Heaving Reading Nov. 03
- “Ethernet, of course, but over SDH” Network Planning and Operations US

Broadband Networks

Ethernet challenge or SDH complement?



- Just a few carriers and operators around the world are setting up Core Networks removing SDH and relying only on Ethernet and/or DWDM
- It has always been difficult to justify in economic, technical and management terms a completely new separate network. And that is still the case.
- Ethernet reduces leased access costs while NG SDH enhances QoS
- Native Ethernet services, and best effort technologies in general, do not scale well
- SDH resilience is critical to deliver 24/365 Ethernet services
- Ethernet is by nature a best effort technology, carrier-class is already under way
- Ethernet does not match today the OEM functions provided by SDH
- A pure packet network, i.e. Ethernet + MPLS, has to emulate circuits: *it's a risky solution!*

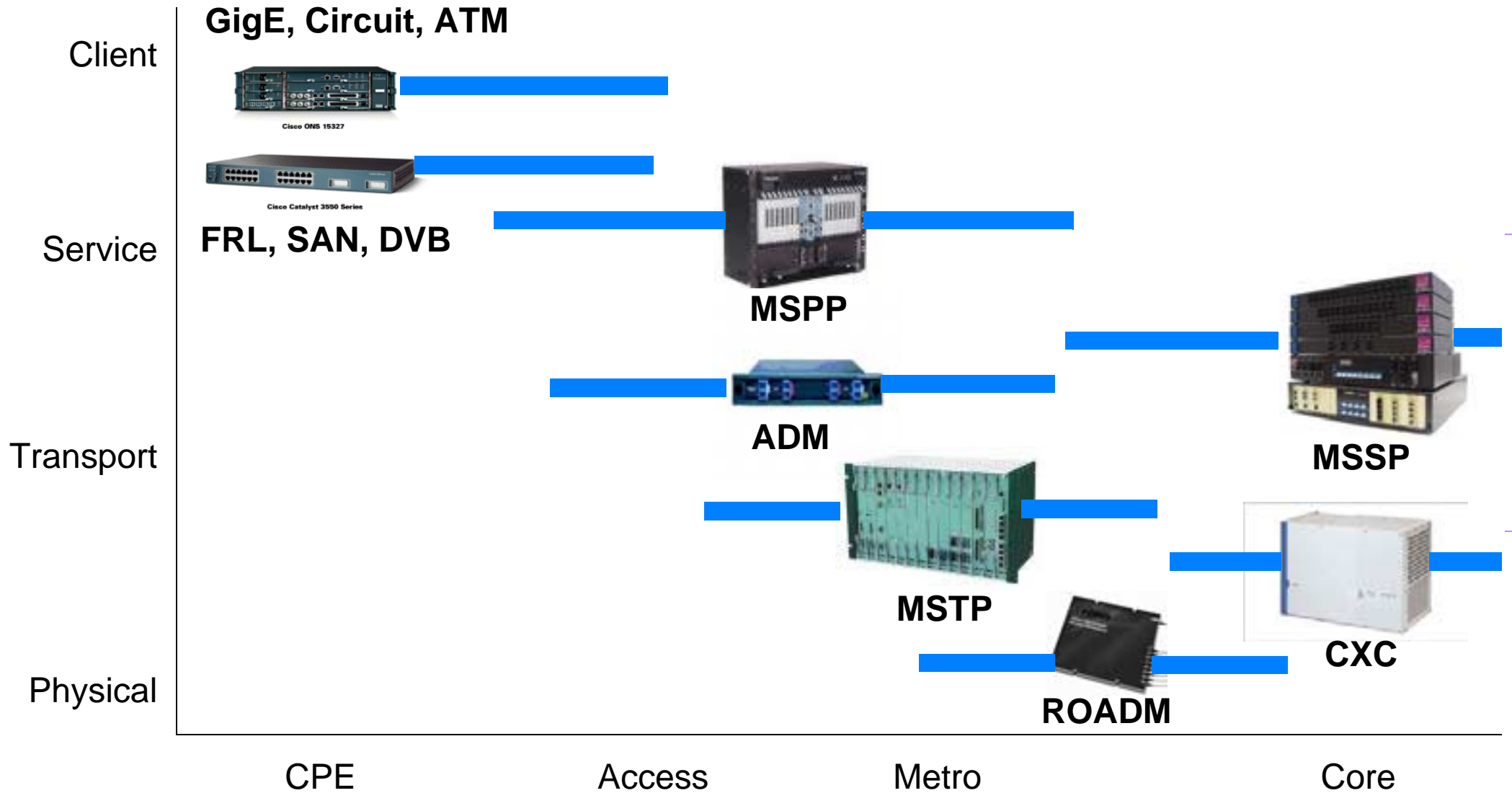
All-optical challenge or SDH complement?



- DWDM alone does not have the diversity or management functions of NG SDH
- The new MSTP nodes combines reconfigurable OADM with NG SDH features
- Provides new interfaces (packet + circuit oriented) while offering wider managing services
- Automate wavelength provisioning and lower wavelength delivery costs
- Ability to reduce network elements in the circuit path

Conclusion: Optical layer integration is a must for NG SDH using MSPP that will provide higher flexibility and Lower Capital Expense (Capex) operational expense (Opex)

New data services



NG SDH is S·T·R·A·T·E·G·I·C

- Is being adopted not only by incumbent operators and carriers but also by new ones.
- It is interesting to consider the adoption of RPR and/or MPLS to enhance the feature of the Ethernet + NG SDH tandem to layer 2 protection, QoS and multipoint access.
- Video transport and Storage over NG SDH is just starting to impact in today's networking
- Automatic layer 1 reconfiguration complements Layer 2 RPR reconfiguration
- High reliability equivalent similar in core and metro
- Centralised management of events, bandwidth provisioning
- Next Generation network (such as MSPP, MSSP) elements will be as fundamental to telecom networks in the coming decade as routers were to the Internet of the 90s