Telecommunication Networks and Services

BMEVITMA310 in English

Tibor Cinkler (**1.**) March 31, 2016

Thursday 12:30 – 14:00 (I.B.144)

http://opti.tmit.bme.hu/~cinkler/TNS

Backbone / Transport Networks

Outline:

1.: PCM/PDH (http://www.hte.hu/hte2007/data/upload/File/online/THIS/2_en.pdf: 2.1.1.1, 2.1.1.2) (http://www.hte.hu/onlinebook)

2.: SDH/SONET(http://www.hte.hu/hte2007/data/upload/File/online/THIS/2_en.pdf: 2.1.1.3)

3.: ATM

4.: MPLS

5.: ngSDH/SONET (GFP, VCat, LCAS)

6.: OTN

7.: Optical Networks

Introduction

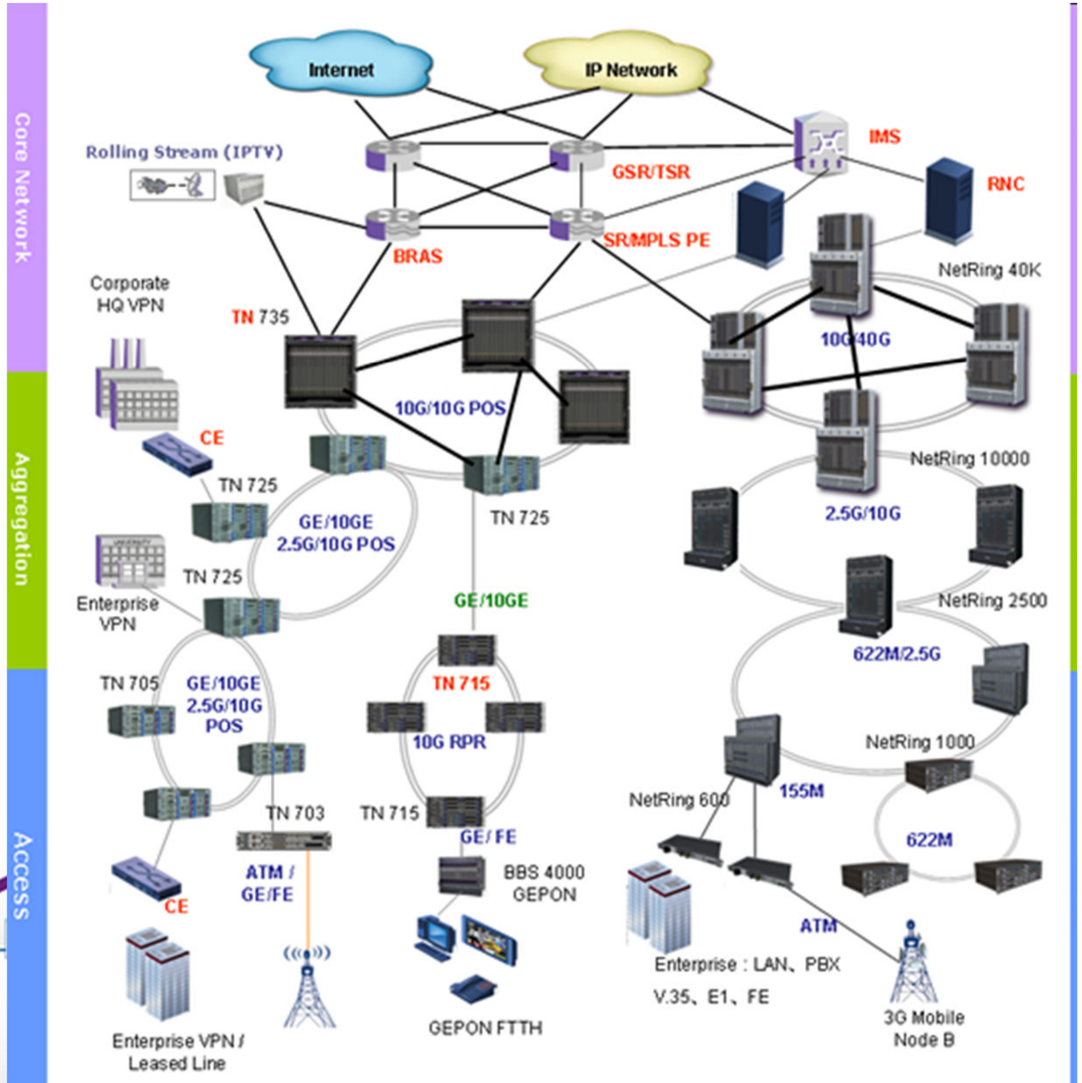
- Evolution of transmission techniques
  - 1915 New York - San Francisco telephony - copper/analog
  - 1936 coaxial cabel PSTN NY - Philadelphia
  - 1947 microwave links
  - 1962 telecom. satelite
  - 1980 fiber
  - 1988 SONET (ANSI) and SDH (CCITT → ITU) standard

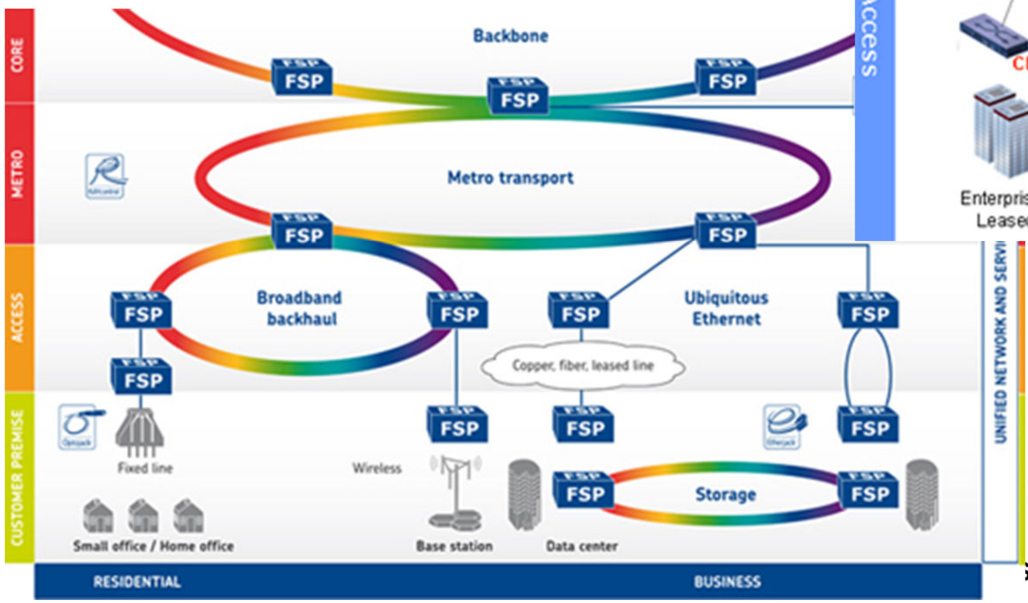
Analog -> Digital

PDH -> SDH

- Today
  - PCM/PDH, ISDN
  - SDH/ngSDH
  - ATM/MPLS
  - IP/Ethernet
  - DWDM
  - GMPLS
  - MPLS-TP

Access
Metro
Core





1.: PCM/PDH

- PCM: Pulse Coded Modulation
- PDH: Plesyochronous Digital Hierarchy
- Digital transmission of analog voice signals
- TDM: Time Division Multiplexing
- 2-3 different systems/solutions

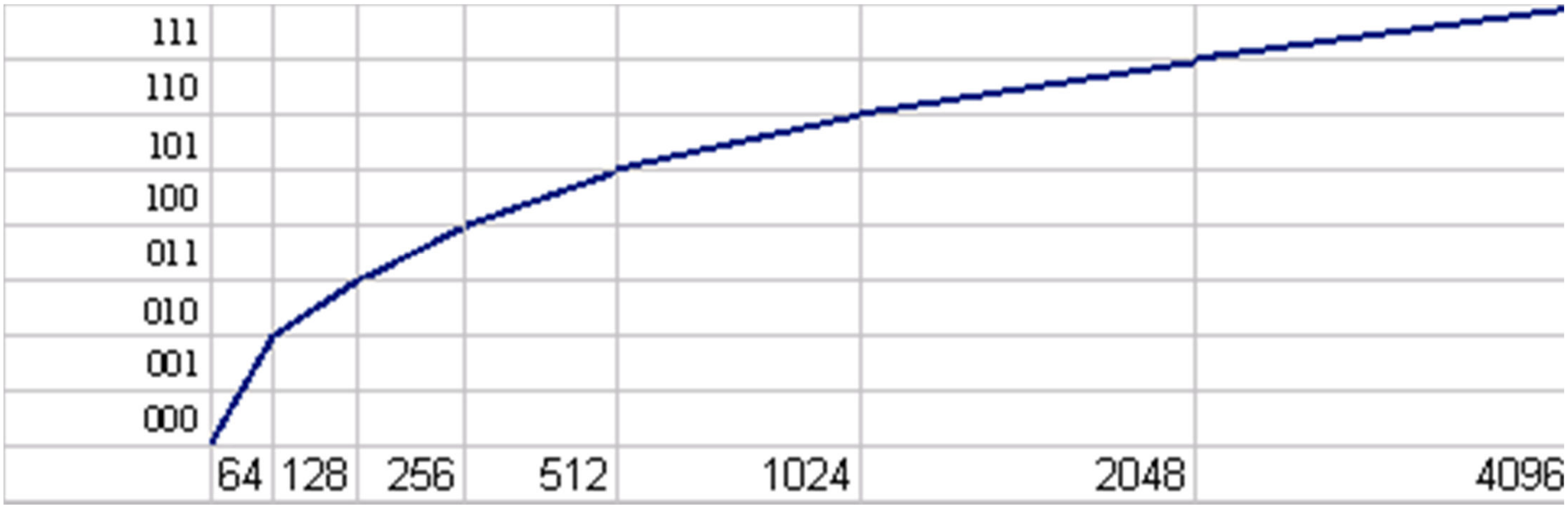
PCM: voice → 8000 samples/s

- 300–3400 analog voice
- Nyquist-Shannon theorem: 8 kHz sampling
- compander (non-linear)
  - Europe: *A-law*
  - Compressor-function: *A*=87,6

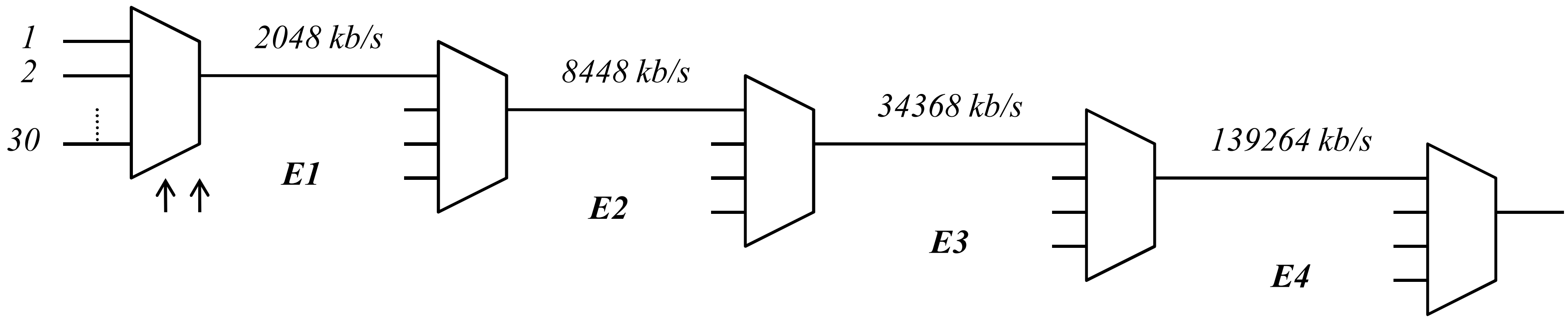
$$y = \begin{cases} \dfrac{Ax}{1+\ln A}, \text{if } |x| < 1 \\ \dfrac{1+\ln Ax}{1+\ln A}, \text{if } |x| \geq 1 \end{cases}$$

Piecewise approximation of the A-characteristic → 8 bits/sample

	Polarity	Segment			Linear coding within a segment			
1970 mV	1	1	1	0	1	1	1	0



PDH: The Hierarchy

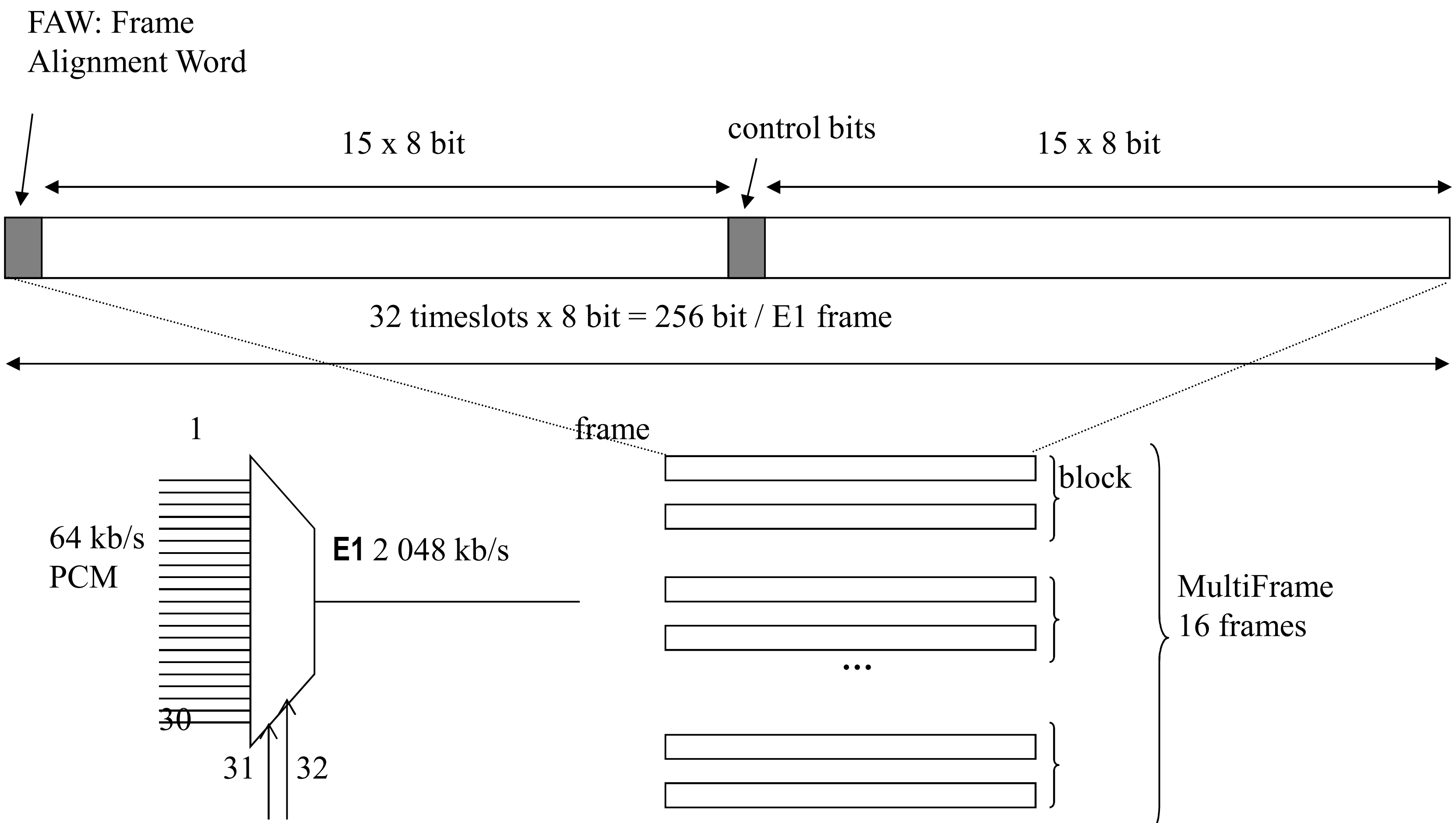


	Nominal bit rate [kb/s]	Tolerance [ppm[1]]	Line coding	Half-peak voltage (V)	a (dB/km)	Frame size [bit]	Bits from one input in the output frame
E1	2 048	±50	HDB3[2]	2,37 vagy[3] 3	6	32×8=256	8
E2	8 448	±30	HDB3	2,37	6	848	205(+1)
E3	34 368	±20	HDB3	1	12	1536	377(+1)
E4	139 264	±15	CMI[4]	1	12	2928	722(+1)

[1] ppm: parts per million
[2] HDB3: High Density Bipolar Coding, limited to 3 zeros
[3] 2,37 V assimetric (e.g., coaxial cabel), and 3 V simmetric (e.g., wisted pair)
[4] CMI: Coded Mark Inversion.

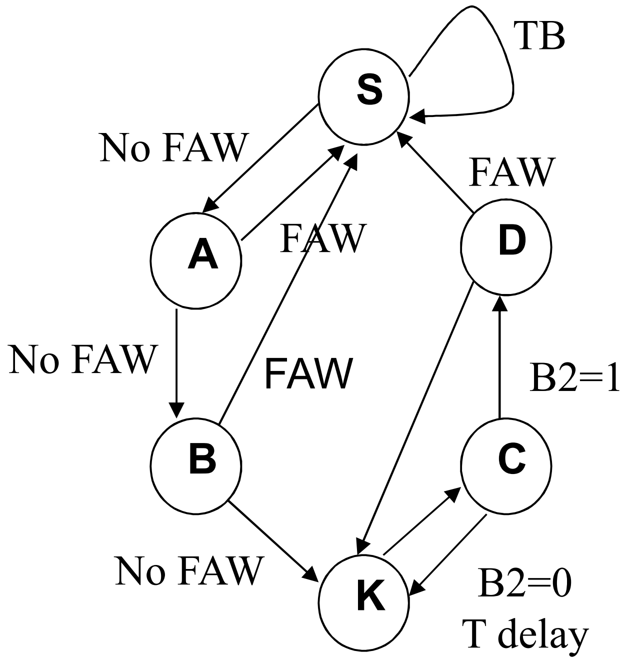
E1: (30 + 2) * 64 kbit/s = 2048 kbit/s

0.	1.	2.	3.	4.	5.	6.	7.
x	**0**	**0**	**1**	**1**	**0**	**1**	**1**

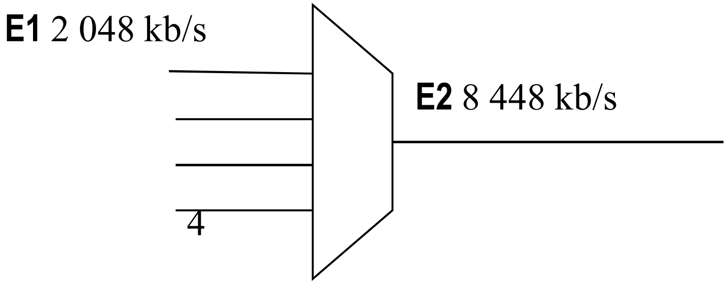


Frame Alignment

- δ=2 if a sequence equal to the FAW is found exidentally
- *If tehre was a bit error* (α=3).



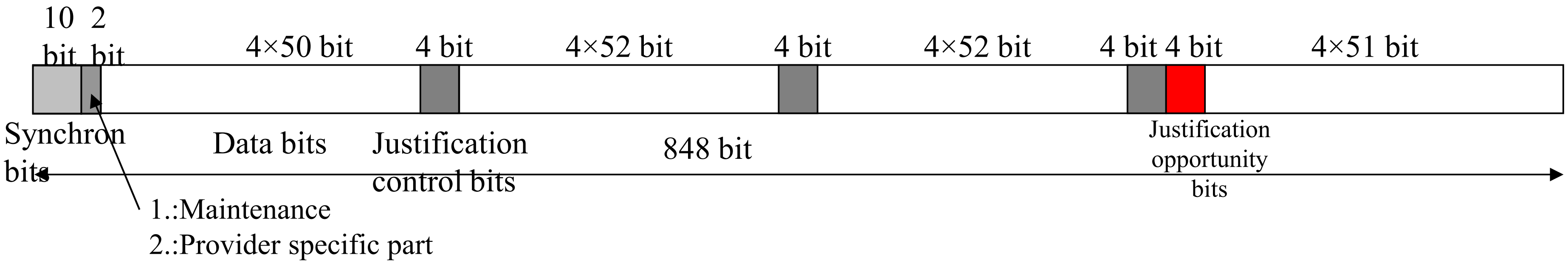
E2



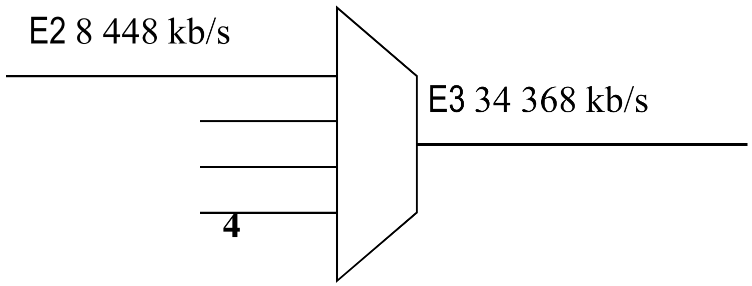
- Insertion rate η=0,58
- For nominal E1 and E2
- Average 205,5762 bit/frame

$$f_{\min}^{E1} = 205\,\text{bit} \cdot f_k^{E2} = 205\,\text{bit} \cdot \frac{8448 \cdot 10^3\,\text{bit/s}}{848\,\text{bit}} = 2042{,}26\,\text{kb/s}$$

$$f_{\max}^{E1} = 206\,\text{bit} \cdot f_k^{E2} = 206\,\text{bit} \cdot \frac{8448 \cdot 10^3\,\text{bit/s}}{848\,\text{bit}} = 2052{,}22\,\text{kb/s}$$

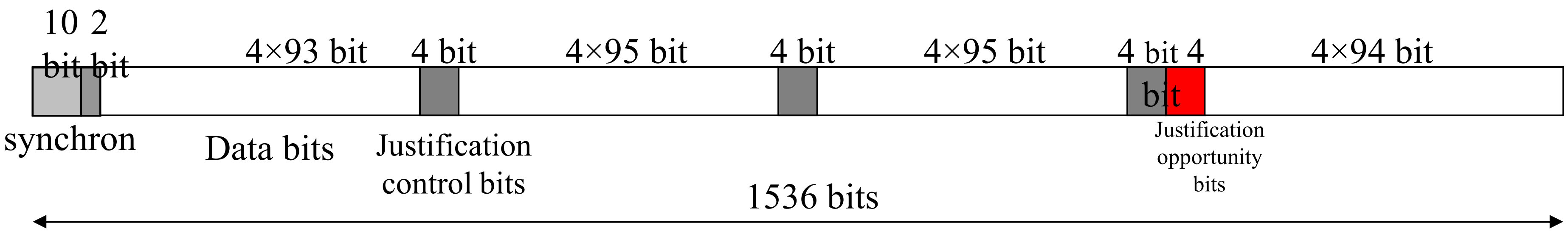


E3



$$f_{min}^{E2} = 377\text{ bit} \cdot f_k^{E3} = 377\text{ bit} \cdot \frac{34378 \cdot 10^3\text{ bit/s}}{1536\text{ bit}} = 8435{,}375\text{ kb/s}$$

$$f_{max}^{E2} = 378\text{ bit} \cdot f_k^{E3} = 378\text{ bit} \cdot \frac{34378 \cdot 10^3\text{ bit/s}}{1536\text{ bit}} = 8457{,}75\text{ kb/s}$$



Telecommunication Networks and Services

BMEVITMA310 in English

Tibor Cinkler (**2.**) April 7, 2016

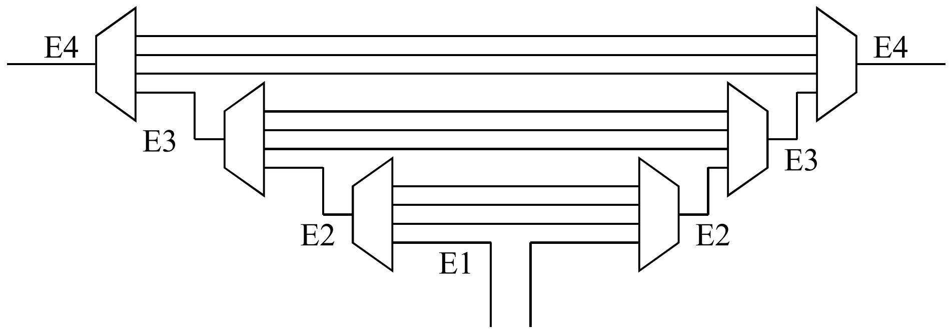
Thursday 12:30 – 14:00 (I.B.144)

http://opti.tmit.bme.hu/~cinkler/TNS

- Tomorrow 12:00-13:30
- Laboratory: MPLS
  – next week – explanations
  – Tuesday afternoon 14:00 – (16:00) – 18:00

PDH “pro and con”

- bit-by-bit multiplexing
- Different solution for Europe, Japan and USA.
+ Even if clocks deviate from nominal the system works well
+ No need for network synchronisation (that time not really possible)
- New framing at each level. An example:



- Not enough space for management and OAM information
- Resilience not considered
- With voiceband modems max 56 kbit/s on 64 kbit/s channels

Backbone / Transport Networks

Outline:

1.: PCM/PDH (http://www.hte.hu/ob/2.pdf: 2.1.1.1, 2.1.1.2)

2.: SDH/SONET (http://www.hte.hu/ob/2.pdf: 2.1.1.3)

3.: ATM

4.: MPLS

5.: ngSDH/SONET (GFP, VCat, LCAS)

6.: OTN

7.: Optical Networks

2. SDH/SONET

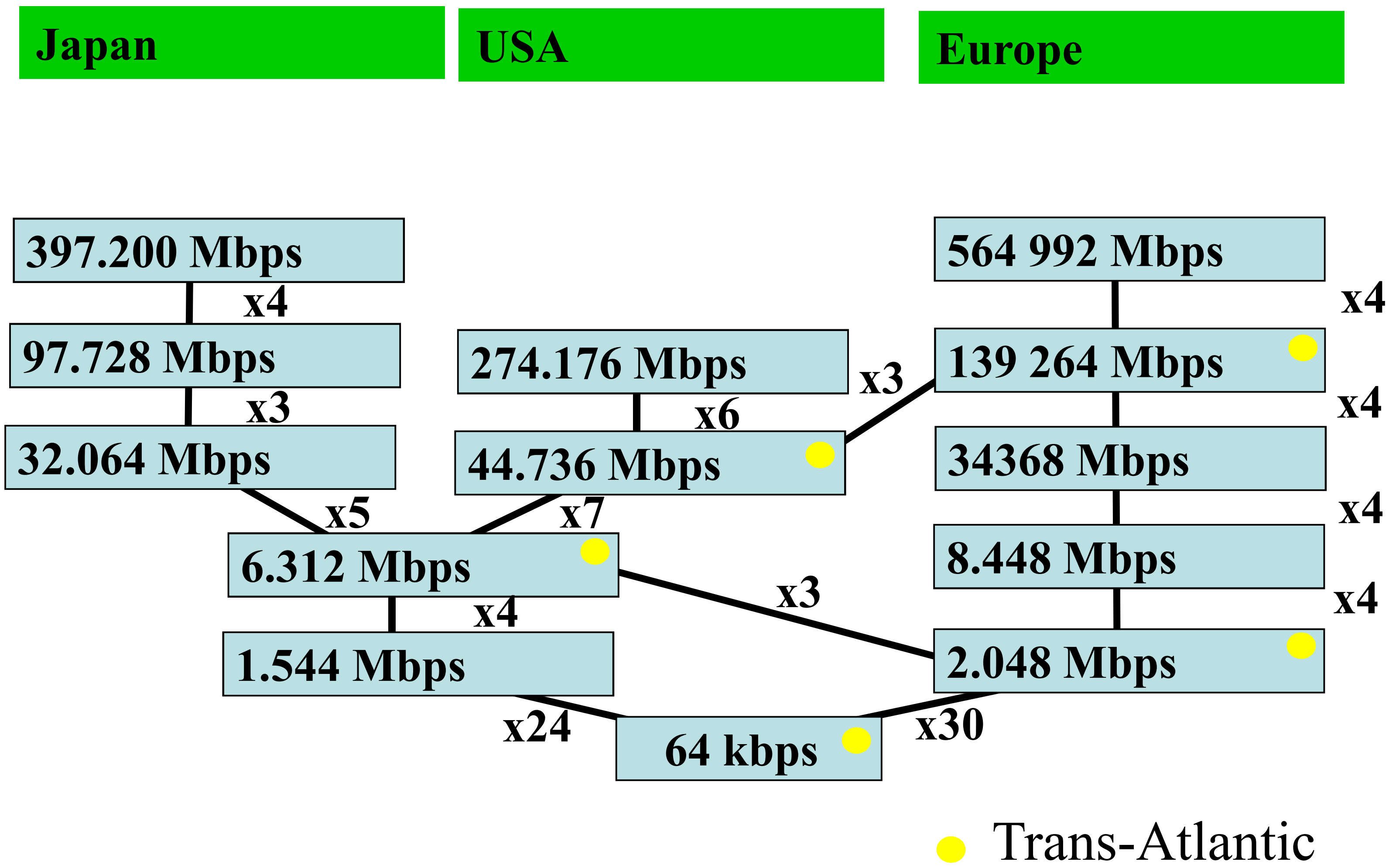
- Metro and backbone transport solution
- Private and public
- Standards
  - SONET (ANSI) 1988
  - SDH (ETSI)
  - SDH (CCITT -> ITU-T)

SONET: Synchronous Optical NETwork

SDH: Synchronous Digital Hierarchy

http://www.jdsu.com/productliterature/sdh_pg_opt_tm_ae.pdf

Japan, USA, Europe



What is SDH suitable for?

- Voice and Data
- Small delay --- significant bandwidth

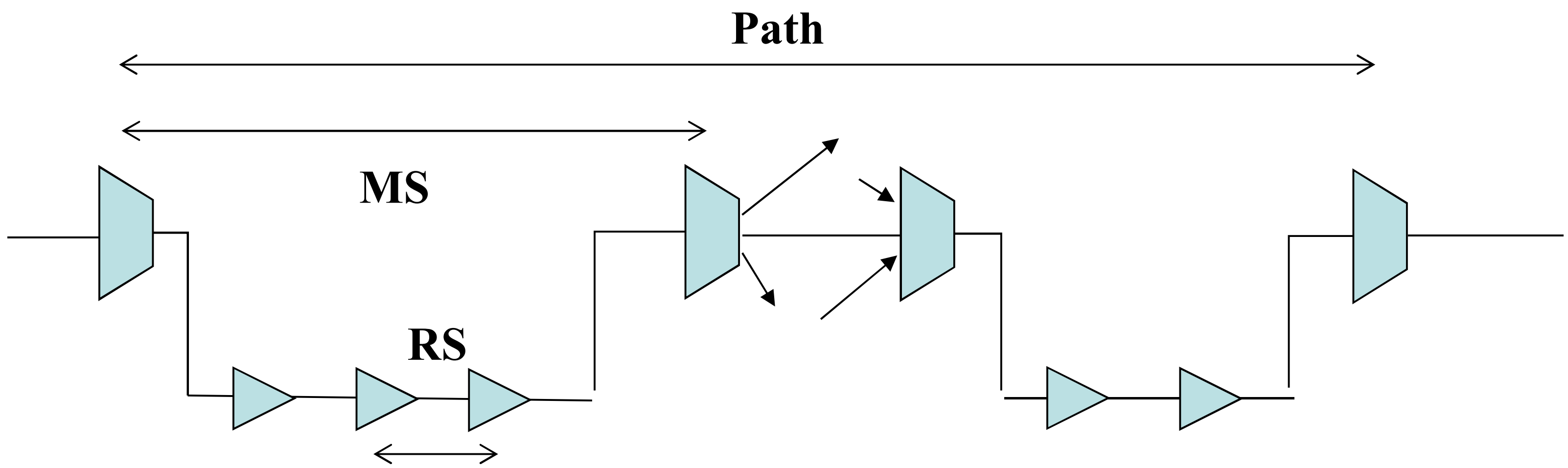
- PDH
- ISDN
- ATM
- FR
- IP
- Ethernet
- Leased line
- etc.

SDH Synchronous?

- Synchronous - Pleziochronous - Asynchronous
- SDH synchronous because:
  - All clocks synchronised
  - All hierarchy layers synchronised
  - Synchronous transfer mode because data units "synchronised" to frames, i.e., their position does matter

"Layers"

- RS: regenerator section (section)
- MS: multiplexer section (line)
- Path: from end to end (path)

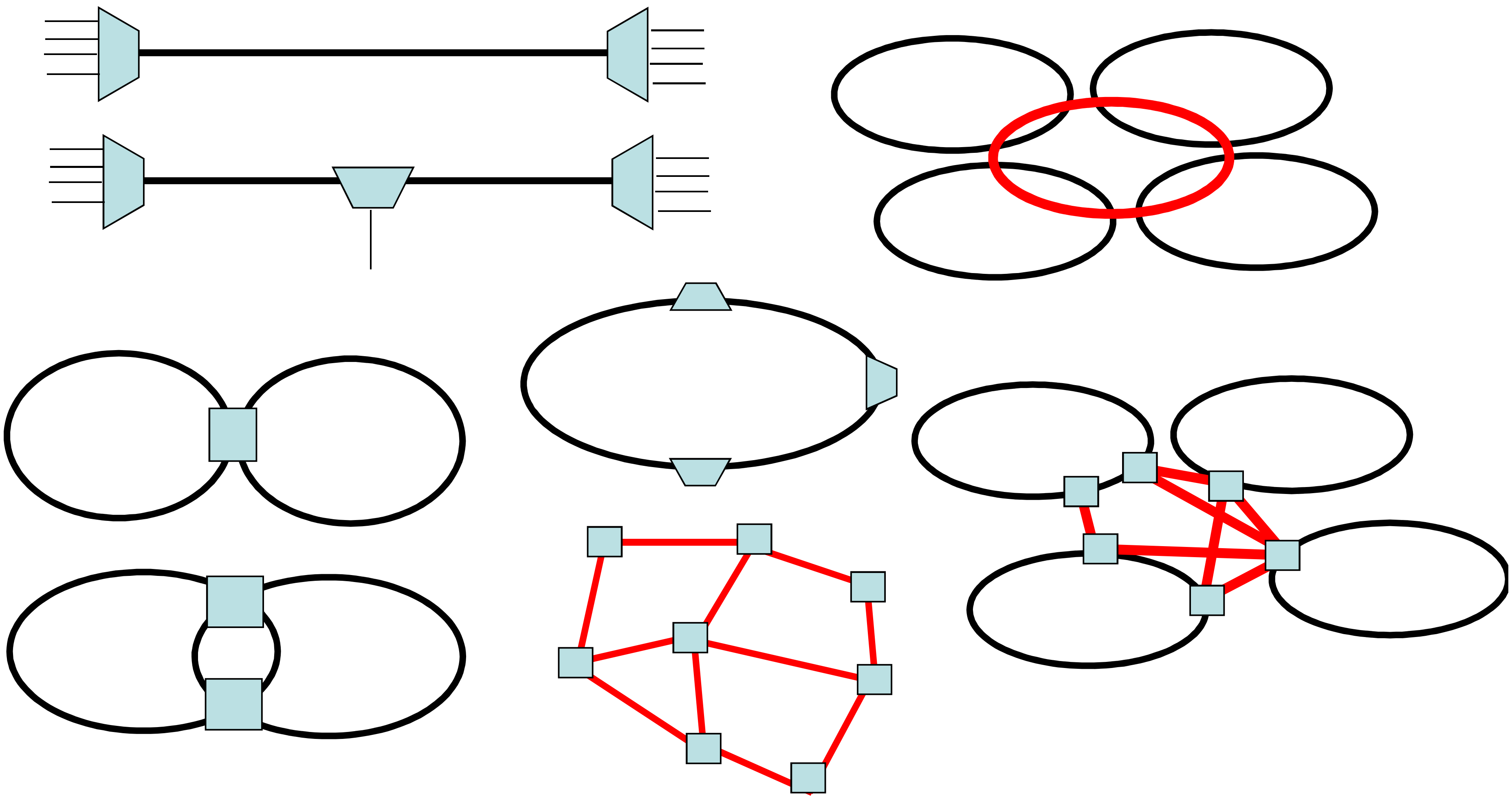


SDH network elements

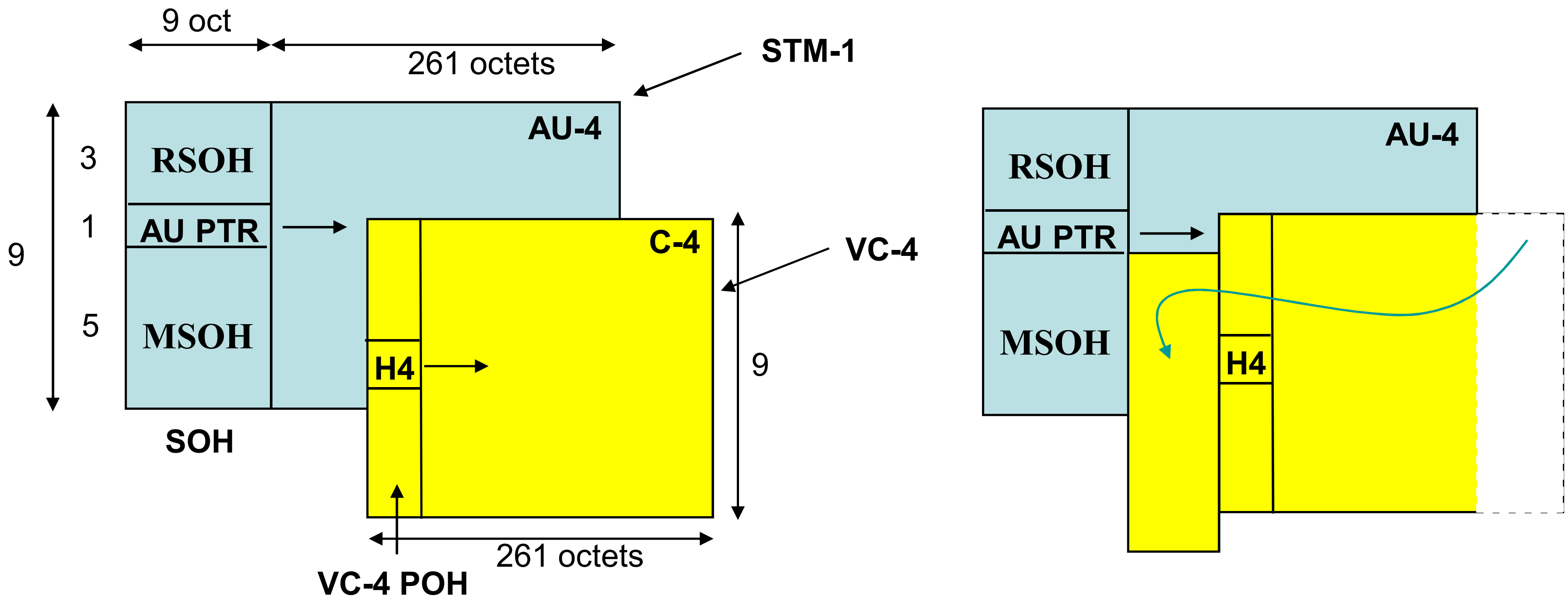
- Transmission sections with different media:
  - Fiber (SMF, MMF)
  - Copper (Coax, UTP/STP)
  - μ-wave links, ...
- regenerators (O/E/O)

- Multiplexer
  - ADM: Add/Drop Multiplexer
  - Terminating MUX
- DXC/DCC: Digital Cross-Connect
- Transmitters, receivers, Line Terminals…

Network topologies



SDH frameing (G.707)



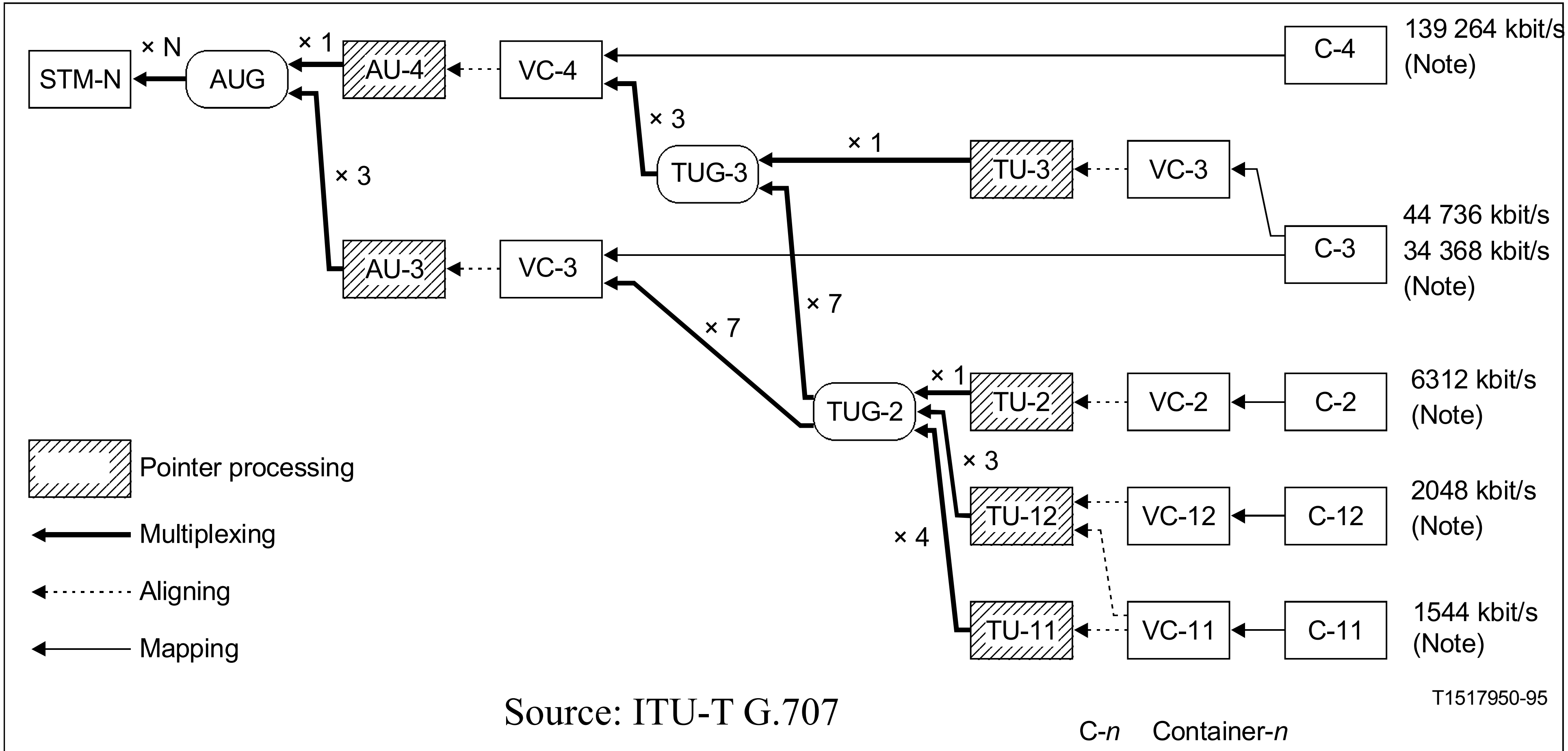
C-4 containers

C-4 + POH = VC-4 virtual containers

AU-4 + SOH -> STM Synchronous Transport Module

AU PTR Administrative Unit Pointer

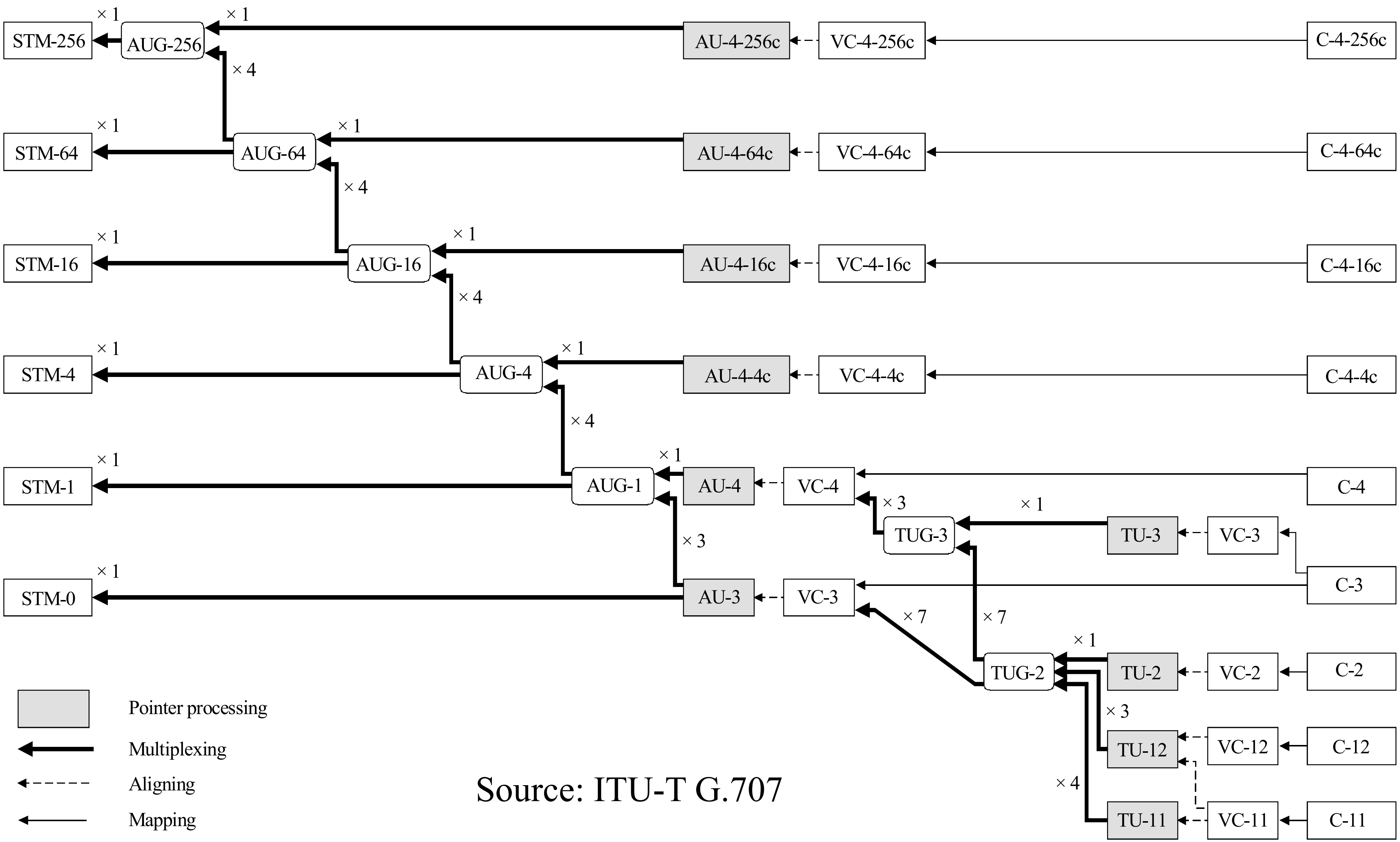
Multiplexing (ITU-T G.707e)



Source: ITU-T G.707

NOTE – G.702 tributaries associated with containers C-*x* are shown. Other signals, e.g. ATM, can also be accommodated (see 10.2).

ITU-T G.707 – Multiplexing structure



Source: ITU-T G.707

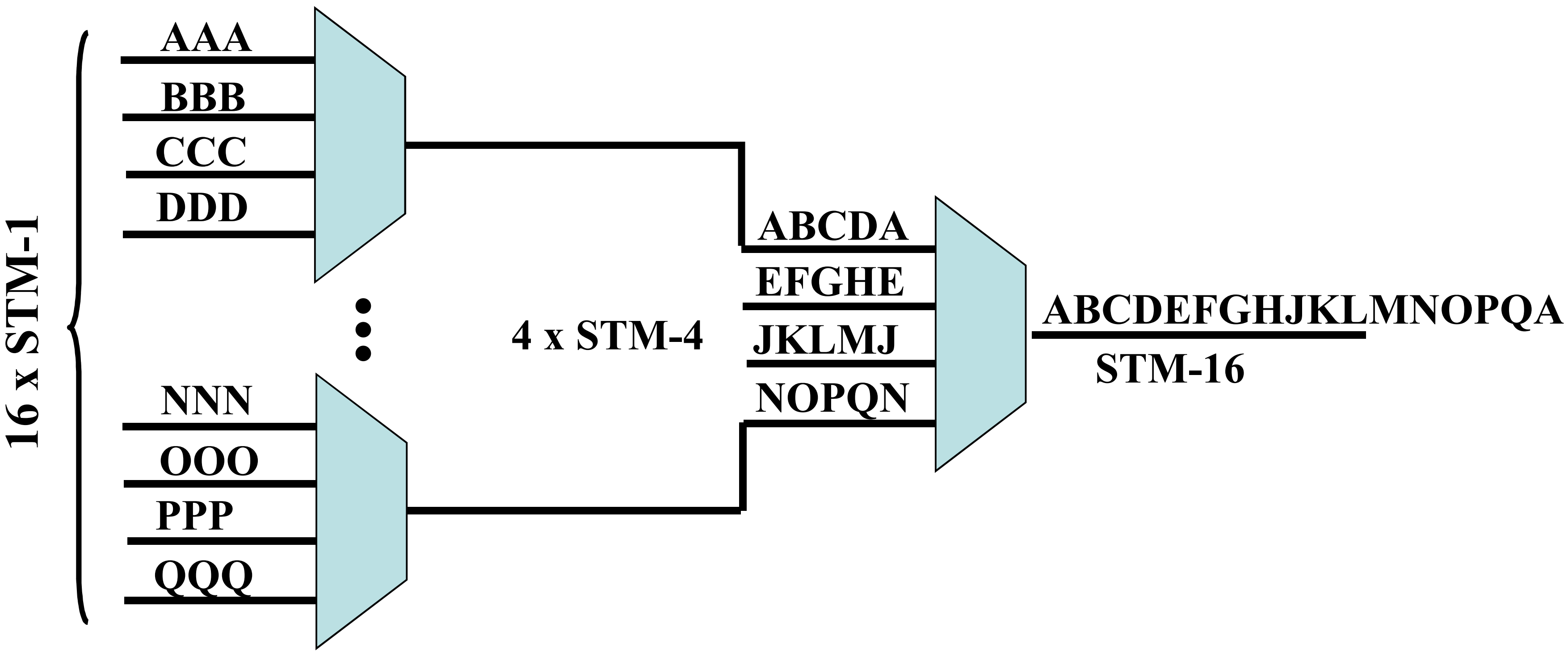
ITU-T SDH Hierarchy

STM-256	39 813,12 Mbps			OC-768	STS-768
STM-64	9 953.28 Mbps			OC-192	STS-192
STM-16	2 488.32 Mbps			OC-48	STS-48
STM-4	622.08 Mbps			OC-12	STS-12
STM[1]-1	155.52 Mbps			OC-3	STS-3
	E4 139.264 Mbps	44.736 Mbps	T3	OC[2]-1	STS[3]-1
	E3 34.368 Mbps	6.312 Mbps	T2		
	E1 2.048 Mbps	1.544 Mbps	T1		
	64 kbps		DS[4]0		

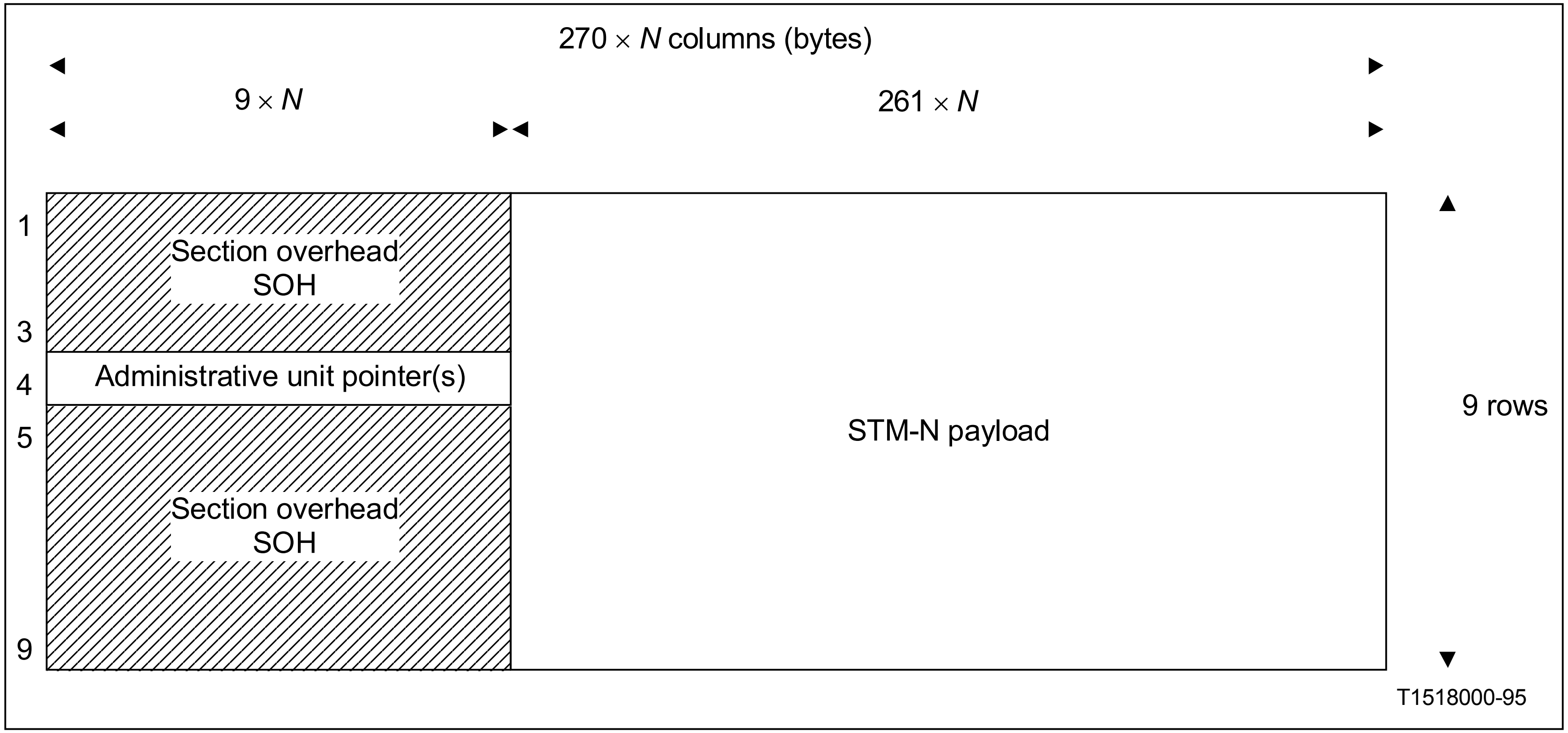
[1] STM: Synchronous Transport Module
[2] OC : Optical Carrier
[3] STS: Synchronous Transport Signal
[4] DS : Digital Signal

STM-N

- **Each Frame lasts for 125 μs**



STM-N



Source: ITU-T G.707

Each Frame 125 μs
N=1, 4, 16, 64

Telecommunication Networks and Services

BMEVITMA310 in English

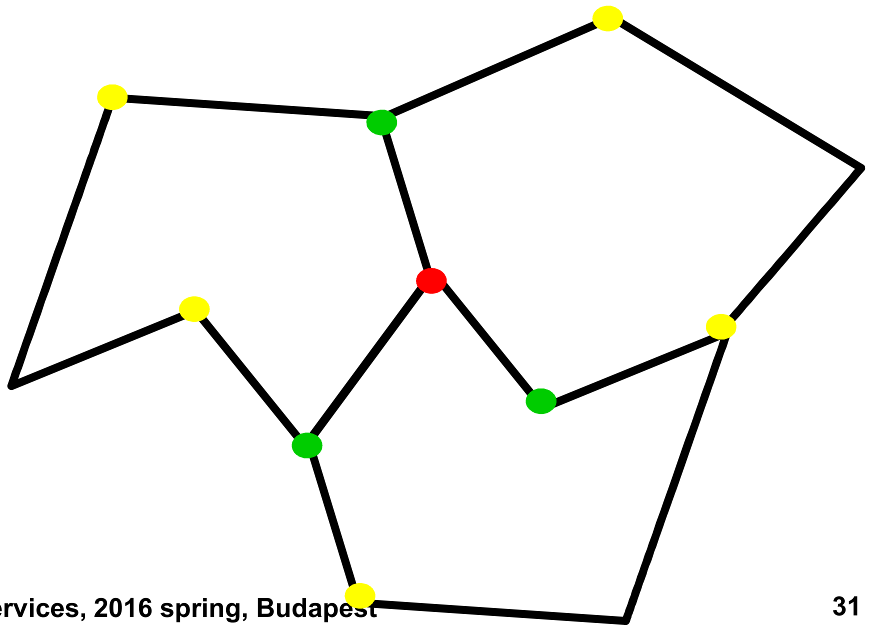
Tibor Cinkler (3.) April 8, 2016

Friday 12:00 – 13:30 (I.B.144)

http://opti.tmit.bme.hu/~cinkler/TNS

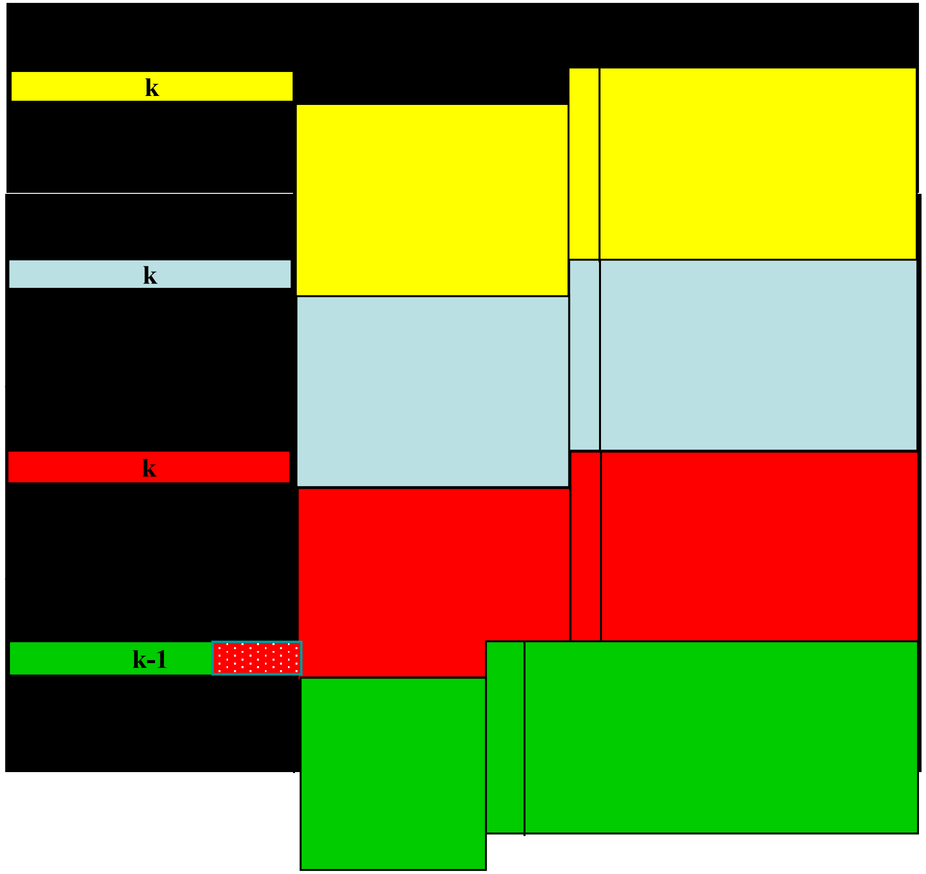
How to synchronise network elements?

- Reference clocks (atomic, e.g., cesium) en.wikipedia.org/wiki/Atomic_clock
- GPS (Global Positioning System)
- Based on bit timing
- BFS: Breadth First Search Graph Algorithm
- PRC: Primary Reference Clock
- PLL: Phase Locked Loop (master - slave)



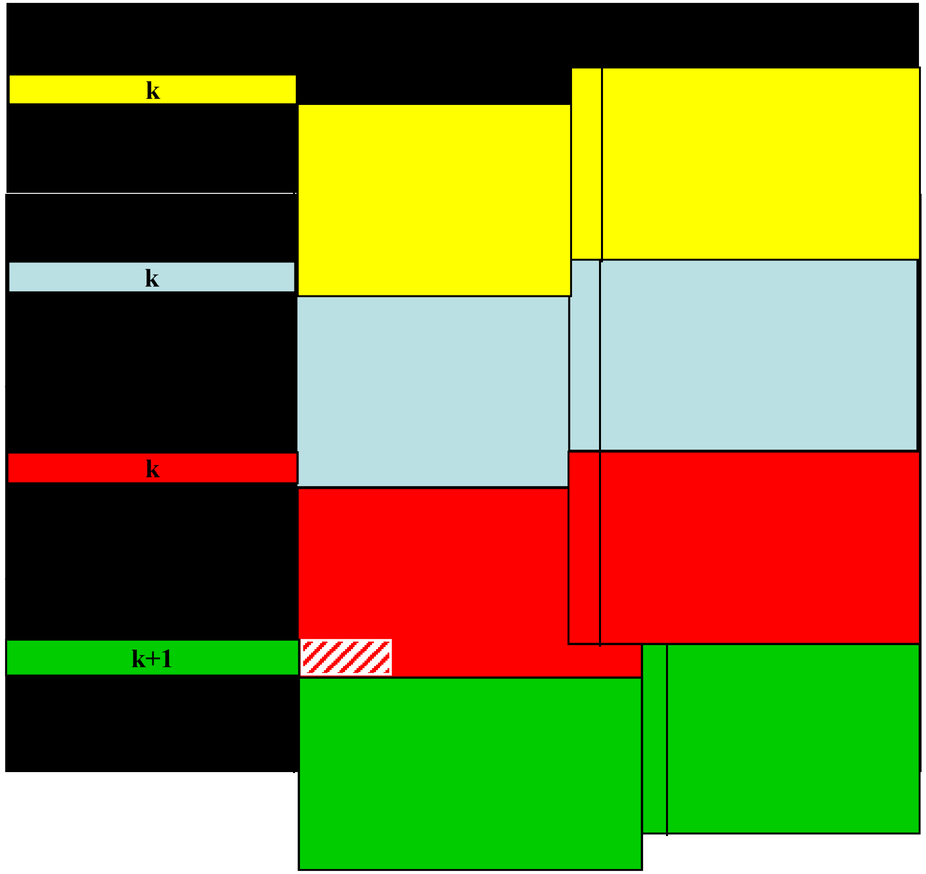
Justifying SDH clock difference when connecting two SDH networks (fast → slow)

- Different networks – Different Reference Clocks
  - Justification (Clock alignment)
  - max every 4th frame
  - exactly 3 octetts
  - 1. Pointer
  - 2. Pointer
  - 3. Inverting bits
  - 4. New pointer value
  - From faster to slower system
    - C-4 becomes shorter in time
    - Uses header bits
    - „D" bits inverted
    - Ptr velue decremented by 1 (k → k-1)



Justifying SDH clock difference when connecting two SDH networks (slow → fast)

- **slow → fast**
- C-4 becomes "longer" in time
  - 3 octetts after H3 unused
  - „I" bits inverted
  - Ptr incremented (k → k+1)
  - Rare Ptr adjustments
    - Because accurate reference clocks
    - Because of redundancy requirement – against bit errors



How to signal justification?

- 4th row of header (9 bytes): H1 □ □ H2 □ □ H3 H3 H3
- H1+H2 bits: NDF NDF NDF NDF S S I D I D I D I D I D
  - NDF: (New Data Flag)
    - 1001 active pointer justification
    - 0110 inactive – ptr action not allowed
  - S – frame content?
  - I – incremment (ptr+1)
  - D – decrement (ptr-1)

These 10 bits are the ptr value!

SDH/SONET Conclusion: Pro

- **SDH/SONET Pro:**
  - Small delay
  - Significant bandwidth (with WDM even more)
  - Simple
  - Synchronous
  - Simple access of VCs
  - Fixed frame size
  - Worldwide standard
  - Low BER due to optical transmission
  - Enough space in headers for OAM&P
  - High-availability point-point bps “pipes”
    - 50 ms protection switching time
  - The majority of backbones used SDH/SONET
  - Suitable for voice and data

SDH/SONET Conclusion: Contra

- SDH/SONET Contra:
  - No dynamicity – no routing
  - No switching (only cross-connecting)
  - Rigid bandwidth granularity
  - Limited to up-to 10 Gbps (3R)

Acronyms

- PCM: Pulse Coded Modulation
- PDH: Plesyochronous Digital Hierarchy
- ISDN: Integrated Services Digital Network
- SDH: Synchronous Digital Hierarchy
- SONET: Synchronous Optical NETwork (északamerikai terminológia)
- ANSI: American National Standards Institute www.ansi.org
- CCITT: Consultative Committee on International Telegraphy and Telephony (Franciául: Comité Consultatif International Téléphonique et Télégraphique)
- ITU-T (International Telecommunications Union - Telecommunication Standardization Sector www.itu.int
- PSTN: public switched telephone network
- ETSI: European Telecommunications Standards Institute www.etsi.org
- ATM: Asynchronous Transfer Mode
- IP: Internet Protocoll
- DWDM: Dense Wavelength Division Multiplexing
- FR: Frame Relay
- O&M: Operation and Maintenence
- OAM: Operation, Administration and Maintenence
- OAMP: Operation, Administration, Maintenence and Provisioning
- 3R: Regenration: Re-Amplification, Re-Shaping, Re-Timing
- APS: Automatic Protection Switching
- STM: Synchronous Trasport Module
- C, VC: Container, Virtual Container
- RSOH, MSOH, POH: Regenerator Section, Multiplex Section, Path OverHead
- O/E/O: Optical/Electronic/Optical
- ADM: Add and Drop Multiplexer
- DXC, DCC: Digital Cross-Connect
- DS: Digital Signal (északamerikai terminológia)
- OC: Optical Carrier (északamerikai terminológia)
- STS: Synchronous Transport Signal (északamerikai terminológia)
- GPS: Global Positioning System
- NDF: New Data Flag
- I: Increment
- D: Decrement
- PPP: Point-to-Point Protocol, RFC
- PoS, MAPOS: Packet over SDH/SONET , Multiple Access Protocol over SDH/SONET, www.mapos.org
- HDLC: High-level data link control, ISO 3309
- RFC: Request for Comments, www.ietf.org
- QoS: Quality of Service
- kbps, Mbps, Gbps, Tbps: kilo, Mega, Giga, Tera bit per secundum (10^3, 10^6, 10^9, 10^{12})
- ppm: parts per million, (parts per billion (ppb), and parts per trillion (ppt))
- PRC: Primary Reference Clock
- PLL: Phase Locked Loop

Backbone / Transport Networks

Outline:

1.: PCM/PDH (http://www.hte.hu/ob/2.pdf: 2.1.1.1, 2.1.1.2)

2.: SDH/SONET (http://www.hte.hu/ob/2.pdf: 2.1.1.3)

3.: ATM

4.: MPLS

Discussed later

5.: ngSDH/SONET (GFP, VCat, LCAS)

6.: OTN

7.: Optical Networks

5. ngSDH/SONET

- next generation SDH/SONET
- SDH/SONET

  + GFP

  + VCat

  + LCAS

ng SDH/SONET: GFP, VCat, LCAS

- "next generation SDH/SONET"
  - Uniform frameing for diverse higher layers
  - Uniform circuit switched layer
  - Statistical Multiplexing via GFP
  - Improved granularity via VCat
- SDH/SONET compatibility
  - Not all nodes have to be "ng"
  - Smooth transition better than total technology replacement

GFP, Vcat, LCAS G.7041

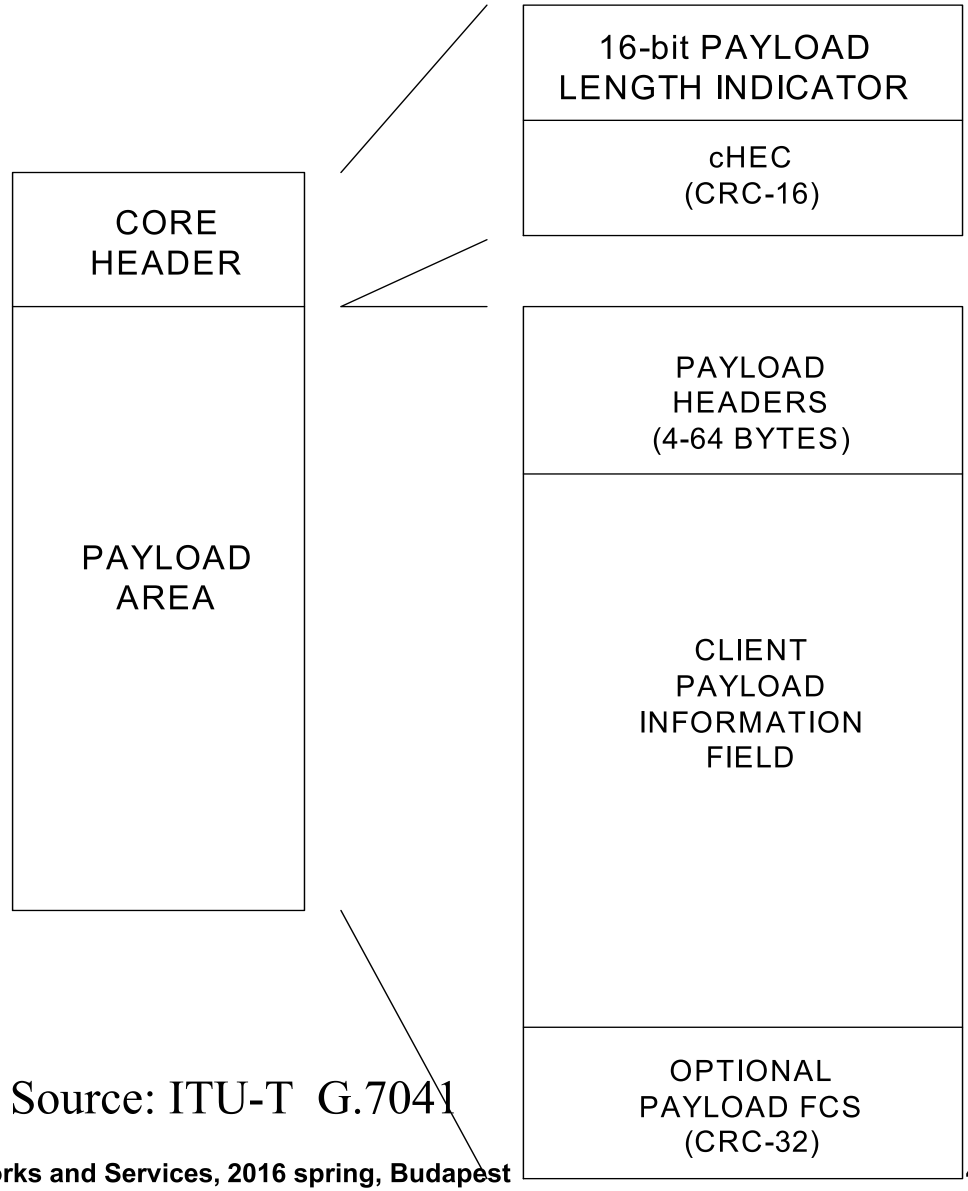
Generic Framing Procedure

- Core Header (scrambled)
- Payload
- CRC
- Octet synchron

Two modes:

- GFP-T: Transparent
- GFP-F: Frame mapped

Ctrl & User (Data) frames



<table>
<tr><td>Ethernet</td><td>IP/PPP</td><td>8B/10B</td><td>MAPOS</td></tr>
<tr><td colspan="4">GFP</td></tr>
<tr><td colspan="2">VC-n</td><td colspan="2">ODU-k</td></tr>
</table>

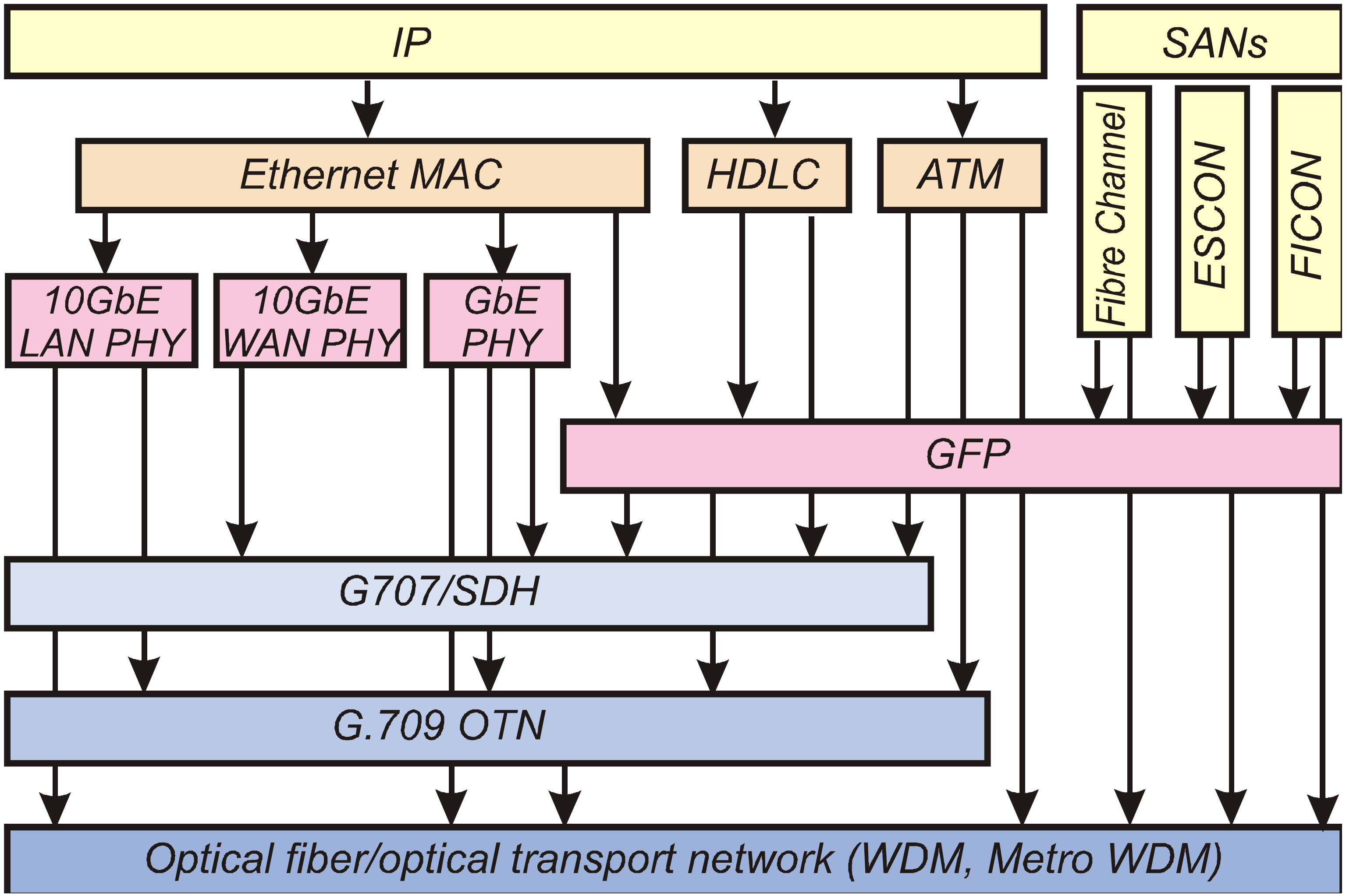
Source: ITU-T G.7041

GFP: Generic?

Generic?

- **Frame-Mapped Ethernet**
- **Frame-Mapped PPP**
- **Transparent Fiber Channel**
- **Transparent FICON**
- **Transparent ESCON**
- **Transparent Gb Ethernet**
- **Frame-Mapped Multiple Access Protocol over SDH (MAPOS)**

GFP: Generic


IP
SANs
Ethernet MAC
HDLC
ATM
Fibre Channel
ESCON
FICON
10GbE LAN PHY
10GbE WAN PHY
GbE PHY
GFP
G707/SDH
G.709 OTN
Optical fiber/optical transport network (WDM, Metro WDM)

GFP, Vcat, LCAS

- Virtual instead of Contiguous
- Virtual (**K4:b2**)
  - Better granularity
  - Better resource utilisation
  - Larger point-to-point bandwidth
    - **Inverse MUX!**
    - Better stat. mux.
  - Multi-Path Protection
  - Concatenation conversion a new option for SONET/SDH ...

Contiguous	**Virtual**
VC-4-4c: 599.04 Mbps	VC-12-nv (n=1-64), 2.2 Mbps-139 Mbps
VC-4-16c: 2396.16 Mbps	VC-3-nv (n=1-64), 49 Mbps- 3.1 Gbps
VC-4-64c: 9584.64 Mbps	VC-4-nv (n=1-64), 149 Mbps -9.6 Gbps

E.g.: Gbit Ethernet VC-4-7v

GFP, VCat, LCAS

Link capacity adjustment scheme (LCAS) G.7042

- Tunes capacity with no interruption
- Of SDH and OTN systems that use VCat
- According to the requirements of applications
- Resilience via removing failed virtually concatenated VC-s and adding new ones

- “…**a control mechanism to hitless increase or decrease the capacity of a VCG link to meet the bandwidth needs of the application.**”

Backbone / Transport Networks

Outline:

1.: PCM/PDH

2.: SDH/SONET

3.: ATM

4.: MPLS

5.: ngSDH/SONET (GFP, VCat, LCAS)

6.: OTN

7.: Optical Networks

3. ATM

- Asynchronous Transfer Mode
- 90'-es
  - ITU-T
  - ATM Forum
  - IETF
- Where is it still beeing used?
  - IP backbone (less and less)
  - ADSL (ATM → Ethernet)
  - 3G (ATM still dominates!)

Networks

Telecom (telephone)

- wireline
  - Circuit switched
    - analog
    - PDH
    - ISDN
    - SDH
  - Multicast
    - cabel TV
- wireless
    - broadcast
    - Point-to-point links
    - mobil

Data (computer)

- PAN, LAN, MAN, WAN, GAN - SAN

(Token Ring, Ethernet, FDDI, DQDB)

  - Shared medium
  - Switched
- Data communications
  - Interconnecting LANs
  - (virtual) Private networks (VPN/VON)
  - Leased lines
  - X.25
  - Frame Relay
  - SMDS
  - N-ISDN

ATM

Transmission modes (1)

1. Circuit Switching
   - E.g., Telephony
   - Communication over pre-allocated channels
     - Connection setup and tear-down
   - Fixed bit-rate
   - Good QoS — bad resource utilisation

Transmission modes (2)

2. Packet Switching

- Data in Packets
- Control based on Packet Headers

Two types:

1. Datagram
   - “Traditional” packets
2. Virtual circuits
   - Pre-established virtual circuits

- Traffic Control and Error Correction in switches or end-points
- Good Resource Utilisation — bad QoS
- **Buffer!!!**

ATM features

- Recommended transfer mode for B-ISDN
- Packet (cell) switching
  - Cells are packets of fixed length
- Fast switching with no error correction
- Minimal functions and size of cell headers
- Virtual Circuits (VP/VC concept)
- Flexible Bandwidth on Demand – granularity, in time, …
  - Statistical multiplexing
- Arbitrary QoS

Why is ATM Asynchronous?

- Physical and networking aspects? Bits or framing (mode)?
- isochronous, pleziochronous, sincronous, asynchronous
- PDH
  – Only pre-assigned bit-slots used by each input in the output frame (TDM)
- SDH/SONET
  – Only pre-assigned parts (of arbitrary size) of the outgoing frame used by each input
- Pre-assigned slots are in synchronization with the frame
- These slots can be allocated but unused
- ATM cells use any free timeslot!!! — Statistical Multiplexing

Telecommunication Networks and Services

BMEVITMA310 in English

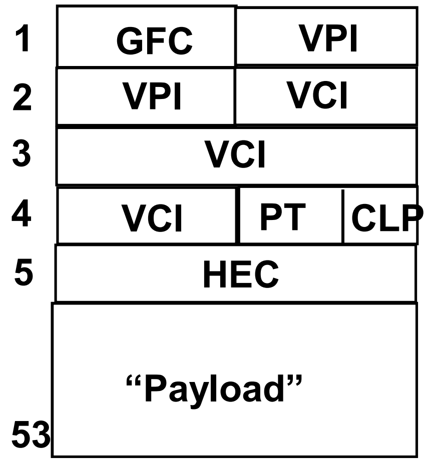
Tibor Cinkler (4.) April 14, 2016

Thursday 12:30 – 14:00 (I.B.144)

http://opti.tmit.bme.hu/~cinkler/TNS

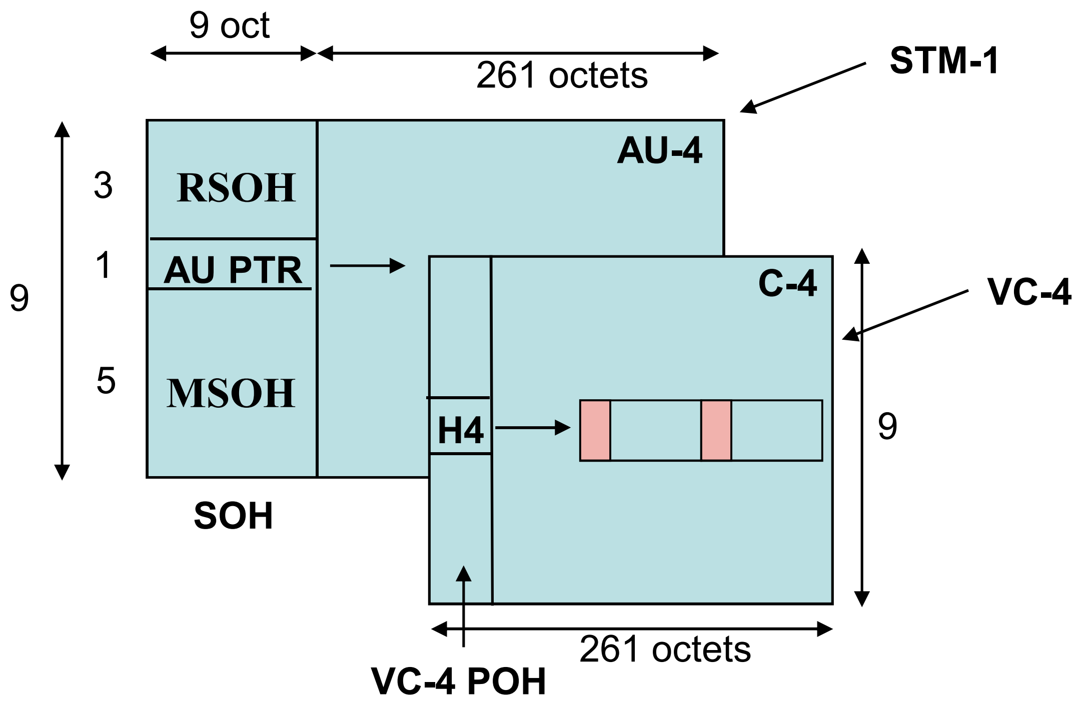
ATM cells

- Cell size: 53 octets (bytes)
- Header size: 5 octets

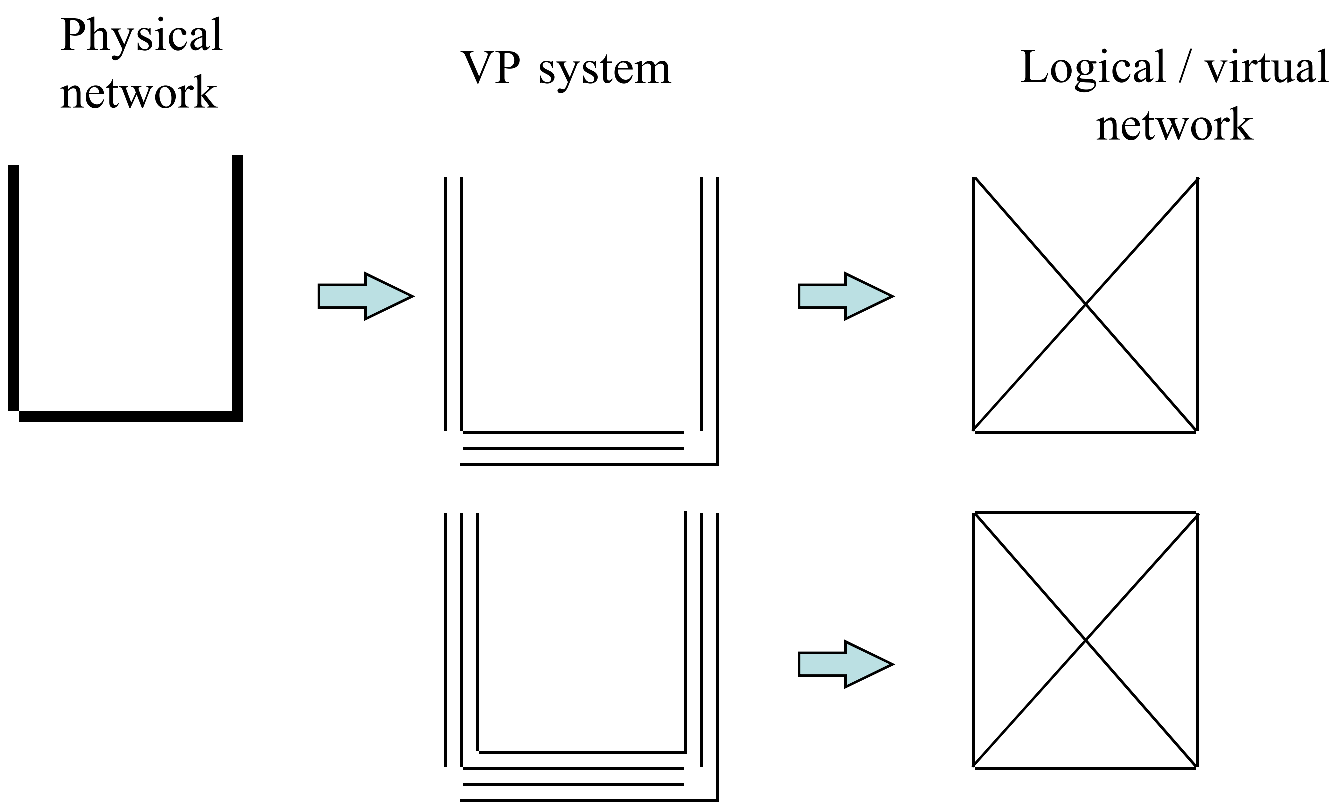


  - **GFC** (Generic Flow Control): at the UNI
  - **VCI/VPI**: connection identification
  - **PT** (Payload Type): what does the cell carry? OAM ...
  - **CLP** (Cell Loss Priority):can a cell be discarded?
  - **HEC** (HE Control) header only!

ATM over SDH Example



Virtual Topology
VPC configuration



What are VPCs good for?

Advantages

- Fast connection provisioning (less hops)
- Less signalling (smaller forwarding tables)
- Fast protection switching
- Excellent VPN/VON capability
- Separating QoS groups

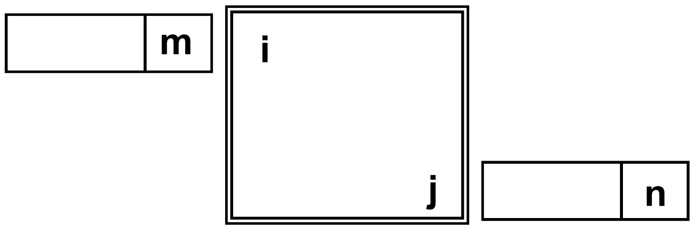
Drawbacks

- Worse Statistical Multiplexing
- Does not adapt to traffic changes

- PVC, SVC

ATM cell forwarding

- Forwarding based on labels
  - Not the whole destination address
  - Since a cell is much shorter!



Lookup Table

VCI & VPI in	m
Port in	i
VCI & VPI out	n
Port out	j

  - Forwarding tables set at connection setup time
  - Port/VPI/VCI tripplet defines the forwarding
  - VPI/VCI local meaning only

IP and Ethernet over ATM

Various Solutions:

- Multi-protocol encapsulation (RFC 1483)
- Classical IP over ATM (RFC 1577)
- Classical IP and ARP over ATM (RFC 2225)
- LAN Emulation over ATM Version 1.0 (ATM Forum)
- LANE v2.0 (ATM Forum)
- MPOA (Multi-Protocoll over ATM)
- ATM API
- MPLS (IETF)

- PBB-TE, T-MPLS, MPLS-TP, ...
- CGE/CCE (PTT)

Backbone / Transport Networks

Outline:

1.: PCM/PDH (http://www.hte.hu/ob/2.pdf: 2.1.1.1, 2.1.1.2)

2.: SDH/SONET (http://www.hte.hu/ob/2.pdf: 2.1.1.3)

3.: ATM

4.: MPLS

5.: ngSDH/SONET (GFP, VCat, LCAS)

6.: OTN

7.: Optical Networks

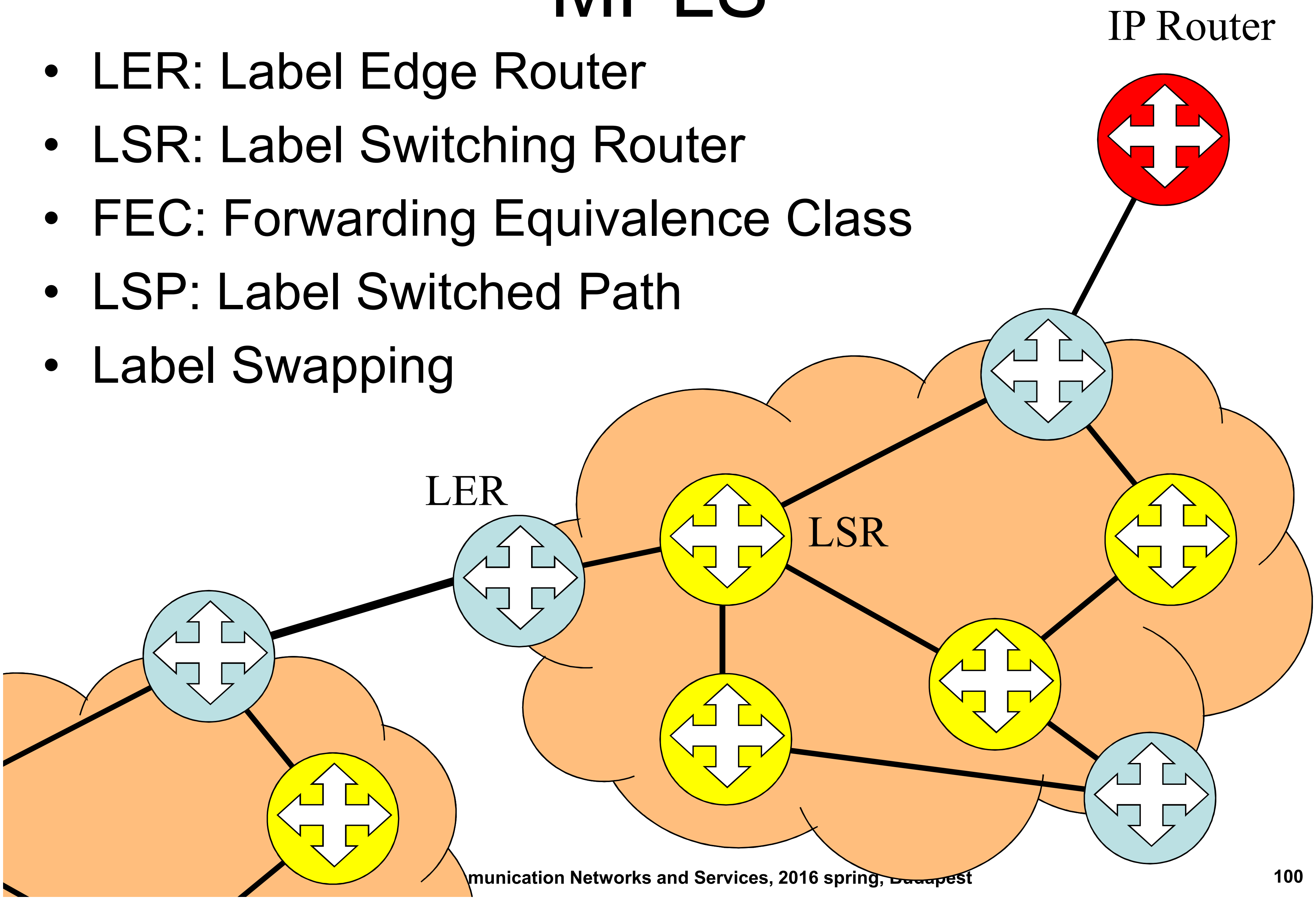
4. MPLS (http://opalsoft.net/qos/MPLS.htm)

MultiProtocol Label Switching:

- Unified IP/MPLS control
- Simpler than ATM
- Reduced label space rquirement via FEC (Forwarding Equivalence Class)
- Label Swapping and Stacking
- Not much new compared to ATM ☺
- Topology or Traffic driven
- Some QoS issues still open
- TE and VPN support (Traffic Engineering and Virtual Private Networks)
- IPoMPLS: Peer Model !
  - RSVP-TE
  - CR-LDP

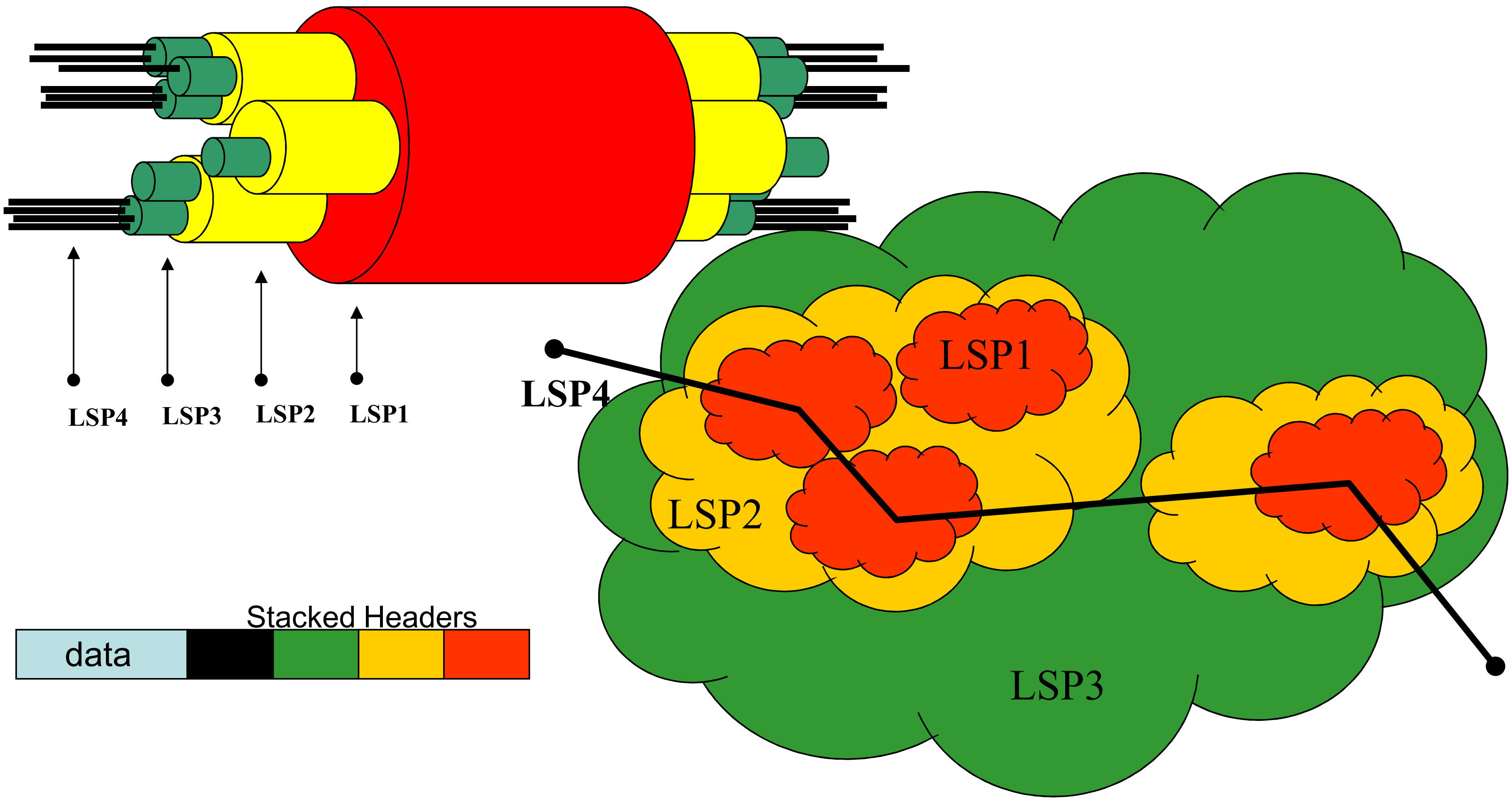
MPLS

- LER: Label Edge Router
- LSR: Label Switching Router
- FEC: Forwarding Equivalence Class
- LSP: Label Switched Path
- Label Swapping



Label "Stacking" or "Swapping"?

- Many layers via stacking!
- Hierarchical LSP encapsulation (embedding, nesting)



MPLS header

- Header: 32 bit = 4 byte
- Label: 20 bits

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|    Label      | Entry Label:
+-+-+-+-+-+-+-+-+ Label Value, 20 bits
|    Label      | Exp: Experimental Use
+-+-+-+-+-+-+-+-+ 3 bits (CoS)
| Label | Exp |S| S: Bottom of Stack
+-+-+-+-+-+-+-+-+ 1 bit
|      TTL      | TTL: Time to Live
+-+-+-+-+-+-+-+-+ 8 bits
```

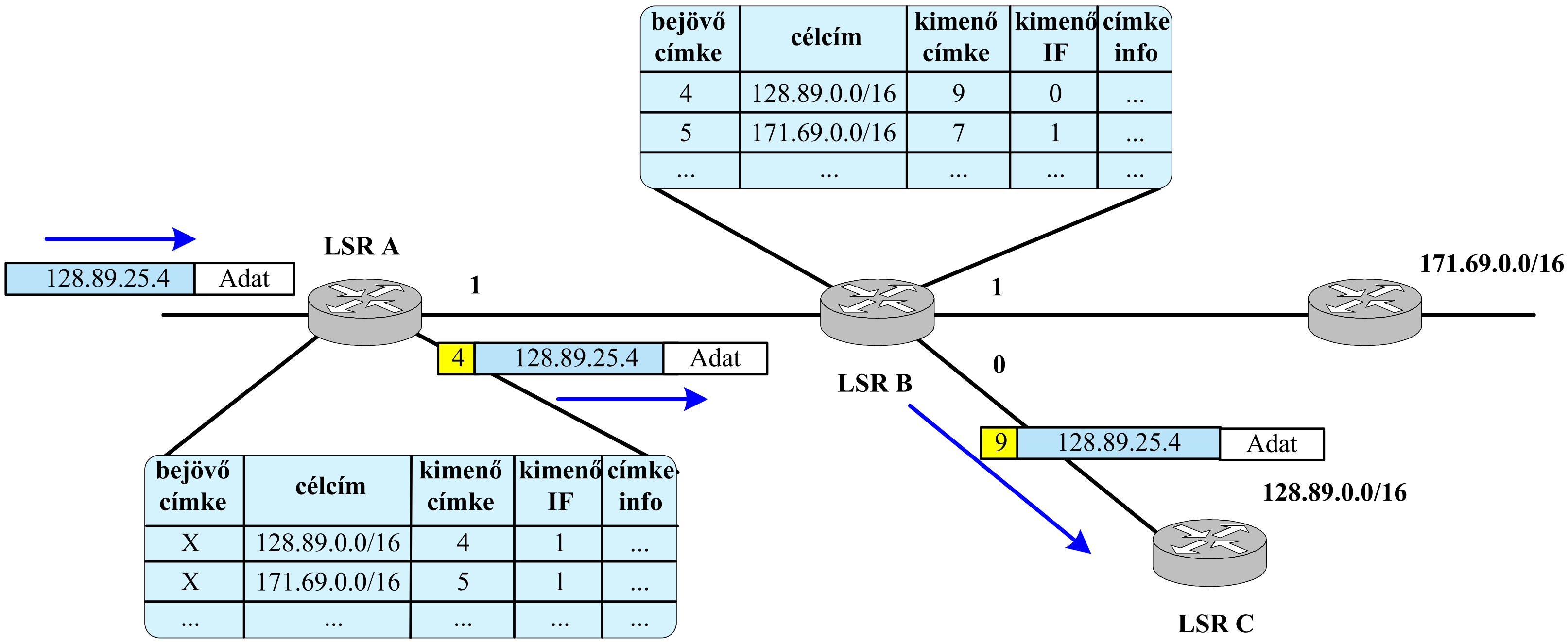
IP and MPLS Headers

- Routing and Forwarding

0	8	16	31
VERS	HLEN	Service Type	Total Length
Identification		Flags	Fragment Offset
TTL	Protocol	Header Checksum	
Source IP Address			
Destination IP Address			
Options			Padding
D a t a			
D a t a			
…			
D a t a			

0		7
Label		
Label		
Label	CoS	S
TTL		

MPLS forwarding



bejövő címke	célcím	kimenő címke	kimenő IF	címke info
4	128.89.0.0/16	9	0	...
5	171.69.0.0/16	7	1	...
...	...	...	...	...

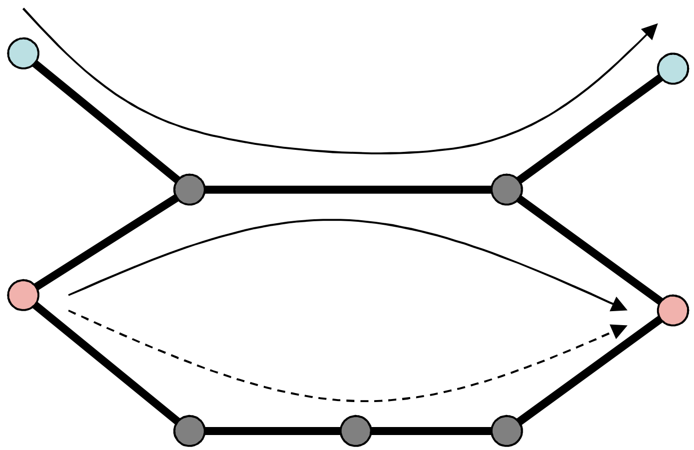
bejövő címke	célcím	kimenő címke	kimenő IF	címke info
X	128.89.0.0/16	4	1	...
X	171.69.0.0/16	5	1	...
...	...	...	...	...

Label distribution mechanisms

- LSP setup
- LSR forwarding tables
- Different Label Distribution protocols:
  - **a Border Gateway Protocol (BGP)**
    - between different Internet AS-es
    - **MPLS extension**
  - **Resource reSerVation Protocol (RSVP)**
    - signalling where label distribution is assigned to RSVP flows
    - **RSVP-TE extension**
  - **Label Distribution Protocol (LDP),** defined by IETF for this purpose only
    - **CR-LDP**

MPLS TE

- IP: shortest path = least-hop path
- MPLS: Arbitrary path can be chosen
  - Alternative paths – load sharing
  - Explicit Route or Hop-by-Hop Routing
    - Loose
    - Strict



MPLS FRR
(Fast Re-Route)
Protection

MPLS QoS: CR-LDP Traffic Parameters

U	F	Traf. Param. TLV		Length	
Flags			Frequency	Reserved	Weight
Peak Data Rate (PDR)					
Peak Burst Size (PBS)					
Committed Data Rate (CDR)					
Committed Burst Size (CBS)					
Excess Burst Size (EBS)					

32 bit fields are short IEEE floating point numbers

Any parameter may be used or not used by selecting appropriate values

Flags control "negotiability" of parameters

Frequency constrains the variable delay that may be introduced

Weight of the CRLSP in the "relative share"

Peak rate (PDR+PBS) maximum rate at which traffic should be sent to the CRLSP

Committed rate (CDR+CBS) the rate that the MPLS domain commits to be available to the CRLSP

Excess Burst Size (EBS) to measure the extent by which the traffic sent on a CRLSP exceeds the committed rate

Forrás: Loa Andersson, Nortel: MPLS Tutorial, Infocom 2000

MPLS Conclusion

MultiProtocol Label Switching:

- Unified IP/MPLS control
- Simpler than ATM
- Reduced label space rquirement via FEC (Forwarding Equivalence Class)
- Label Swapping and Stacking
- Not much new compared to ATM ☺
- Topology or Traffic driven
- Some QoS issues still open
- TE and VPN support (Traffic Engineering and Virtual Private Networks)
- IPoMPLS: Peer Model !
  - RSVP-TE
  - CR-LDP

http://www.mplsrc.com/mplsfaq.shtml

Glossary

MPLS	Multi-Protocol Label Switching	Többprotokollos címkekapcsolás
VPN	Virtual Private Network	Virtuális magán hálózat
IP	Internet Protocol	Internet protokoll
ATM	Asynchronous Transfer Mode	Aszinkron átviteli mód
QoS	Quality of Service	Szolgáltatásminőség
LER	Label Edge Router	Címke behelyező (perem) útválasztó
LSR	Label Switching Router	Címke kapcsoló útválasztó
LSP	Label Switched Path	Címke kapcsolt útvonal
FEC	Forwarding Equivalence Class	Továbbítási ekvivalencia osztály
VPI/VCI	Virtual Path Identifier/Virtual Channel Identifier	Virtuális útvonal azonosító/virtuális csatorna azonosító
DLCI	Data Link Connection Identifier	Adat kapcsolat azonosító
CoS	Class of Service	Szolgáltatásosztály
TTL	Time to Live	Élettartam
LFIB	Label Forwarding Information Base	Címketovábbítási információs bázis
NHLFE	Next Hop Label Forwarding Entry	Következő ugrást leíró címketovábbítási elem
ILM	Incoming Label Map	Beérkező címkék térképe
FTN	FEC-to-NHLFE Map	FEC és NHLFE összerendelő táblázat
BGP	Border Gateway Protocol	Határkapu protokoll
RSVP	Resource reSerVation Protocol	Erőforrásfoglalási protokoll
LDP	Label Distribution Protocol	Címketerjesztő protokoll
OXC	Optical Cross Connect	Optikai rendező
GMPLS	Generalised Multi-Protocol Label Switching	Általánosított többprotokollos címkekapcsolás
MPλ S	Multi-Protocol Lambda Switching	Többprotokollos hullámhosszkapcsolás
STM	Synchronous Transport Module	Szinkron átviteli modul