Fiber Data Communication

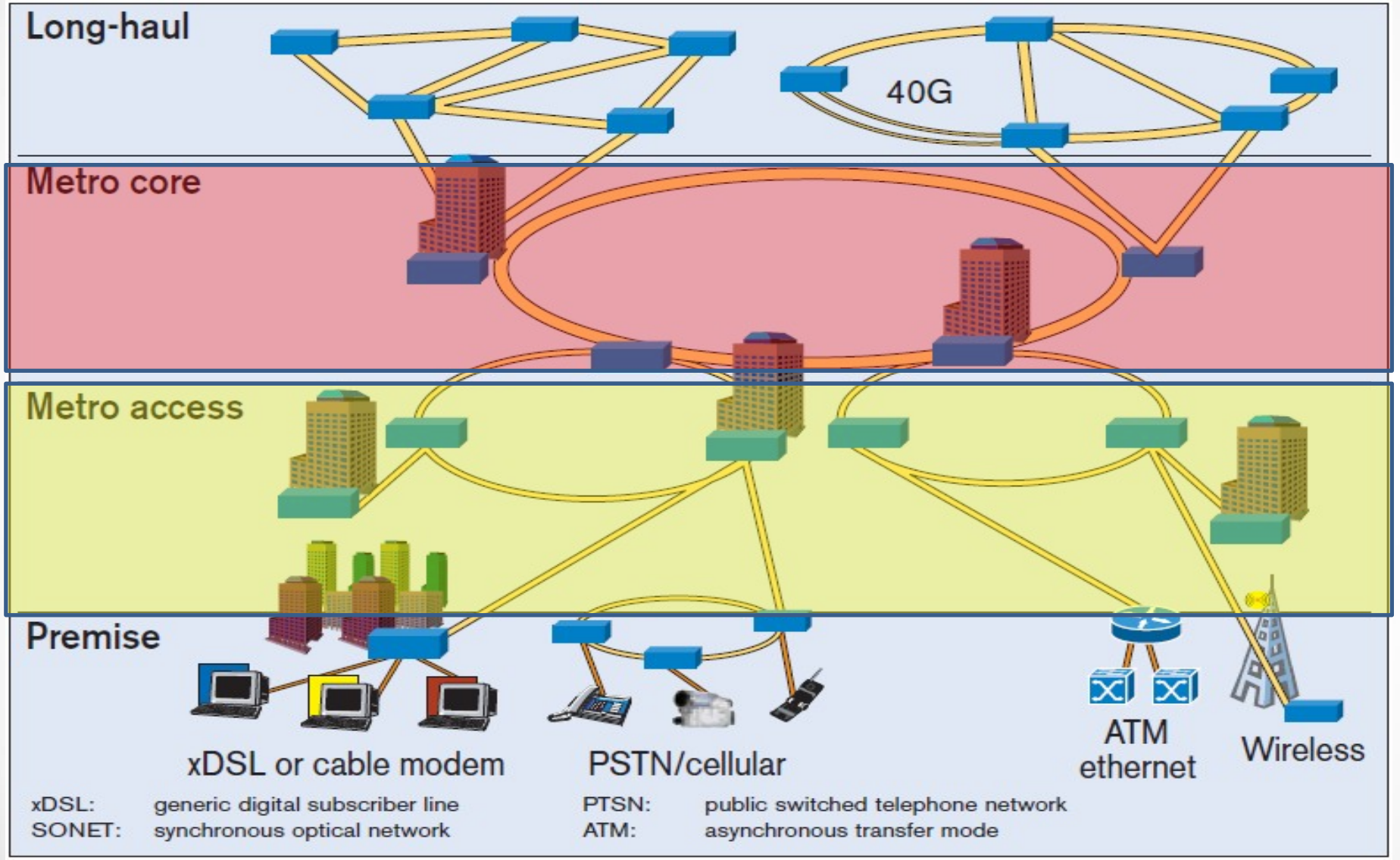
Joint master program Skoltech and CMC MSU

Prof. R. Smelyanskiy

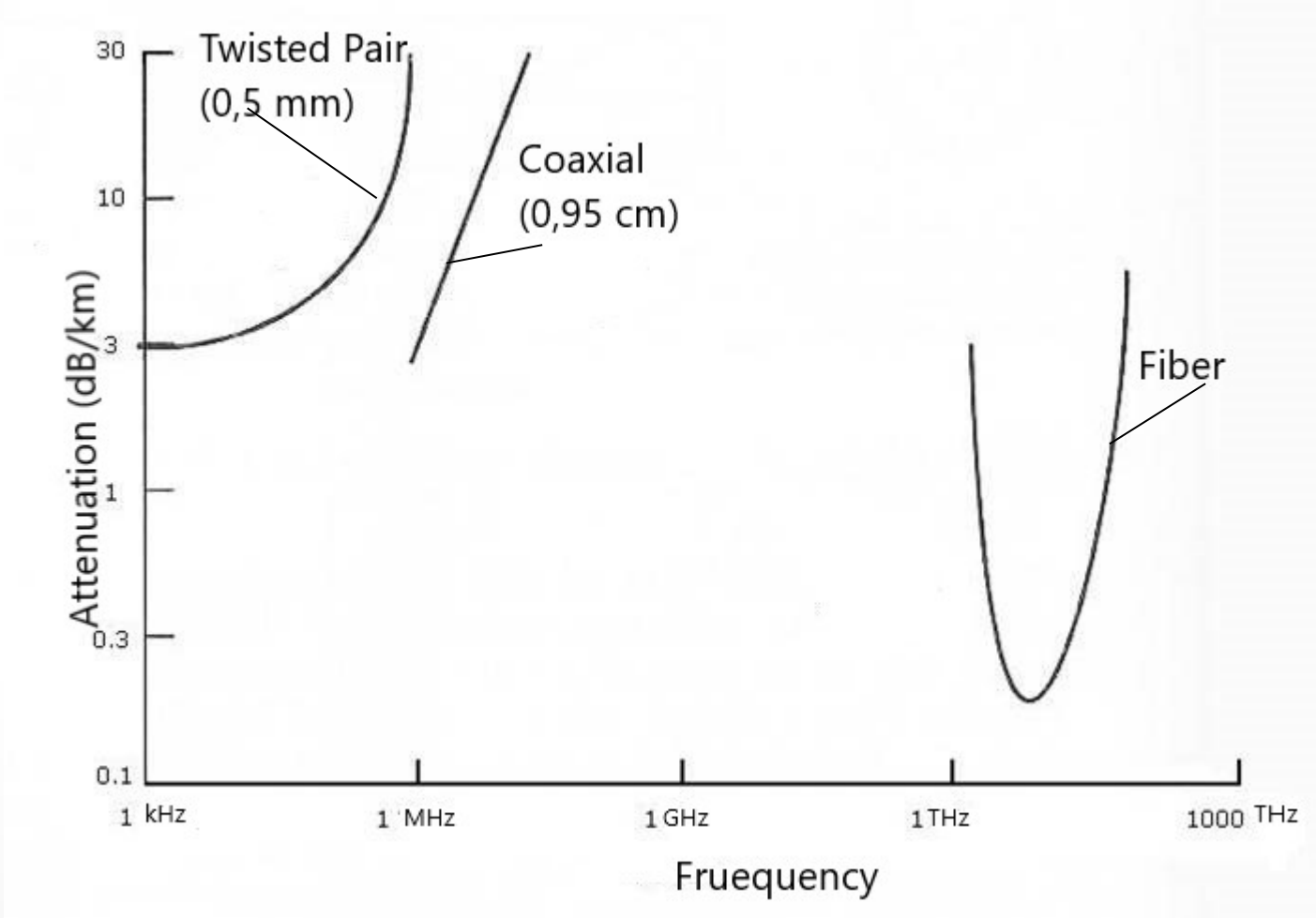
Fiber Network Market

1) In 2012 76% of respondents plan to deploy OTN switching;
2) OTN switching has a key role in 77% of long-distance communication nodes and 46% of metropolitan network nodes;
3) 94% of respondents recognize OTN switching as a key means of increasing 40G and 100G communication utilization;
4) 69% of respondents believe that OTN switching will automate the network configuration to implement new services.

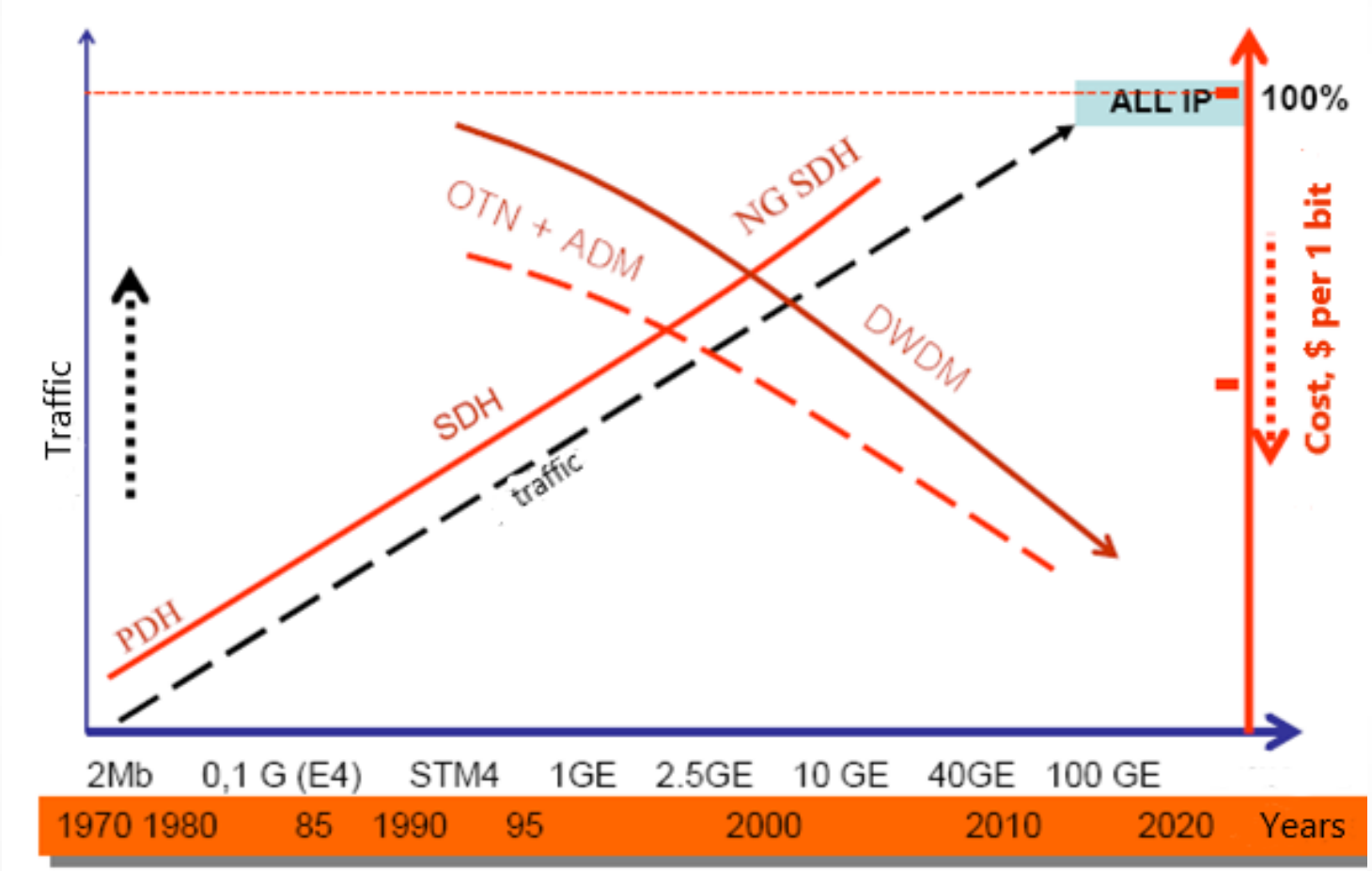
Network structure



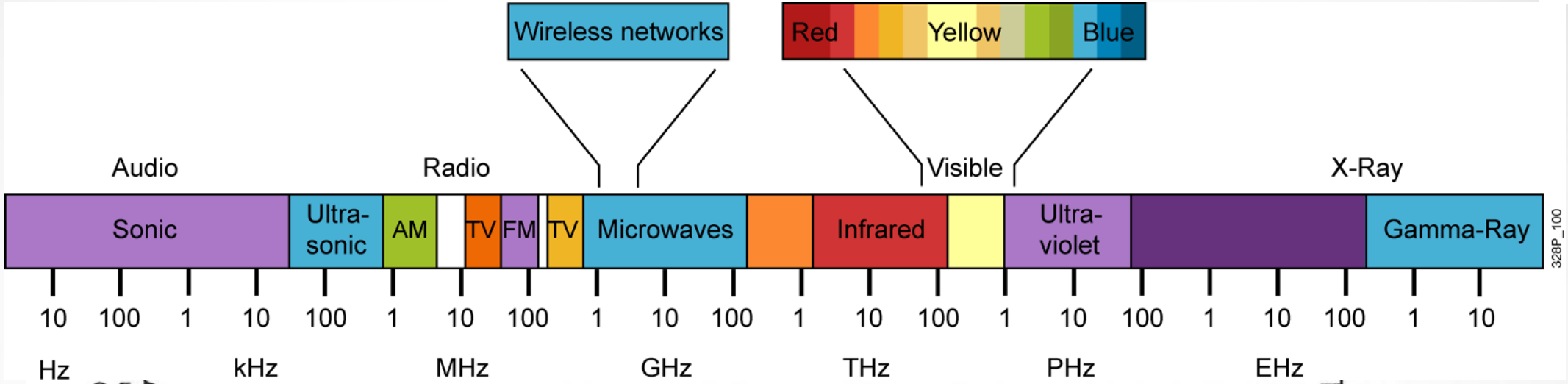
Cable attenuation

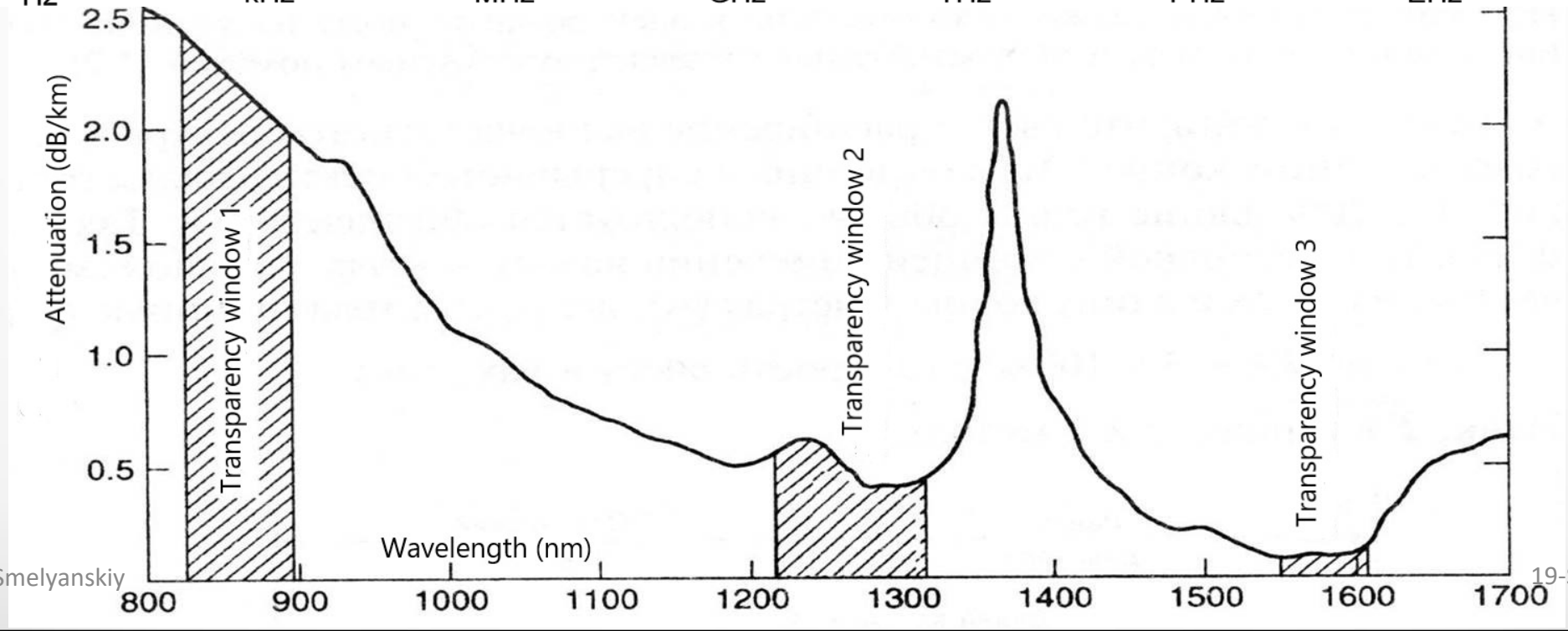


Price vs Velocity

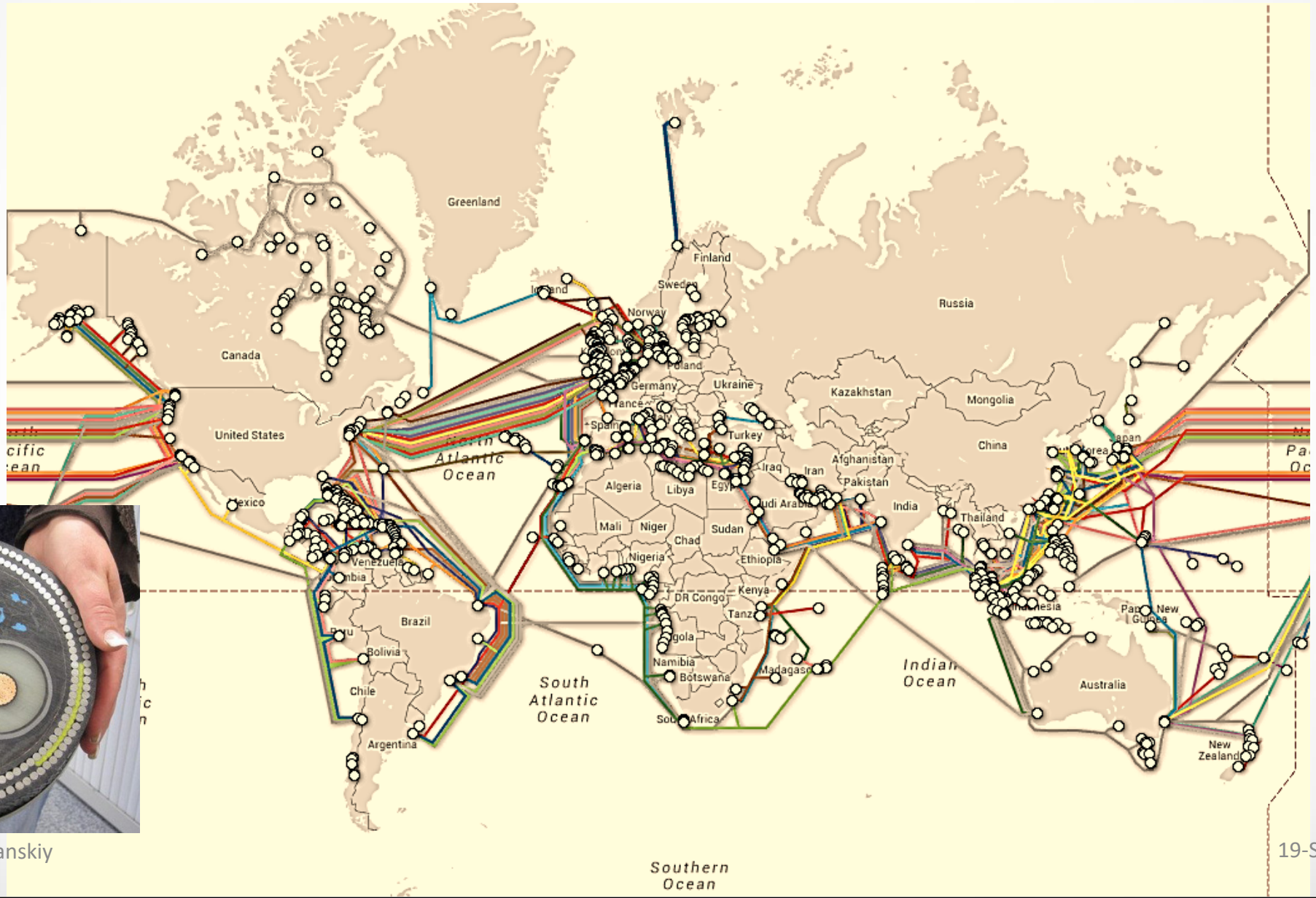


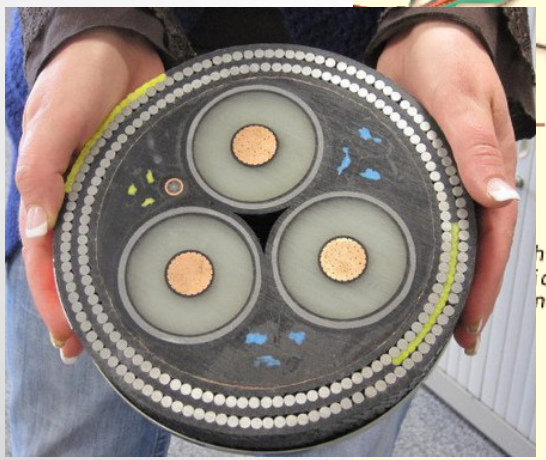
Fiber optic attenuation





Trans Ocean Fiber Lines



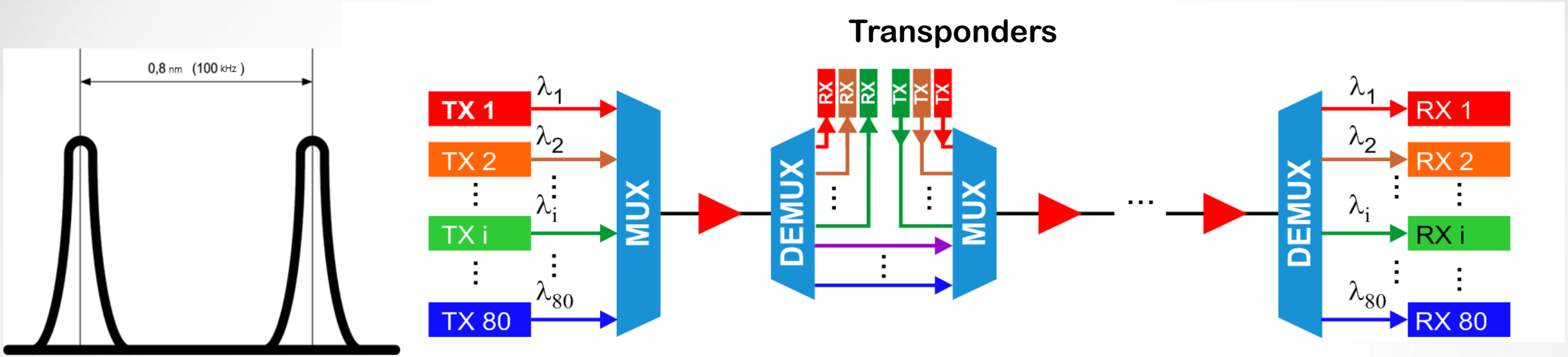


CWDM и DWDM fiber systems

Speed characteristics of multiplexing methods on Fiber

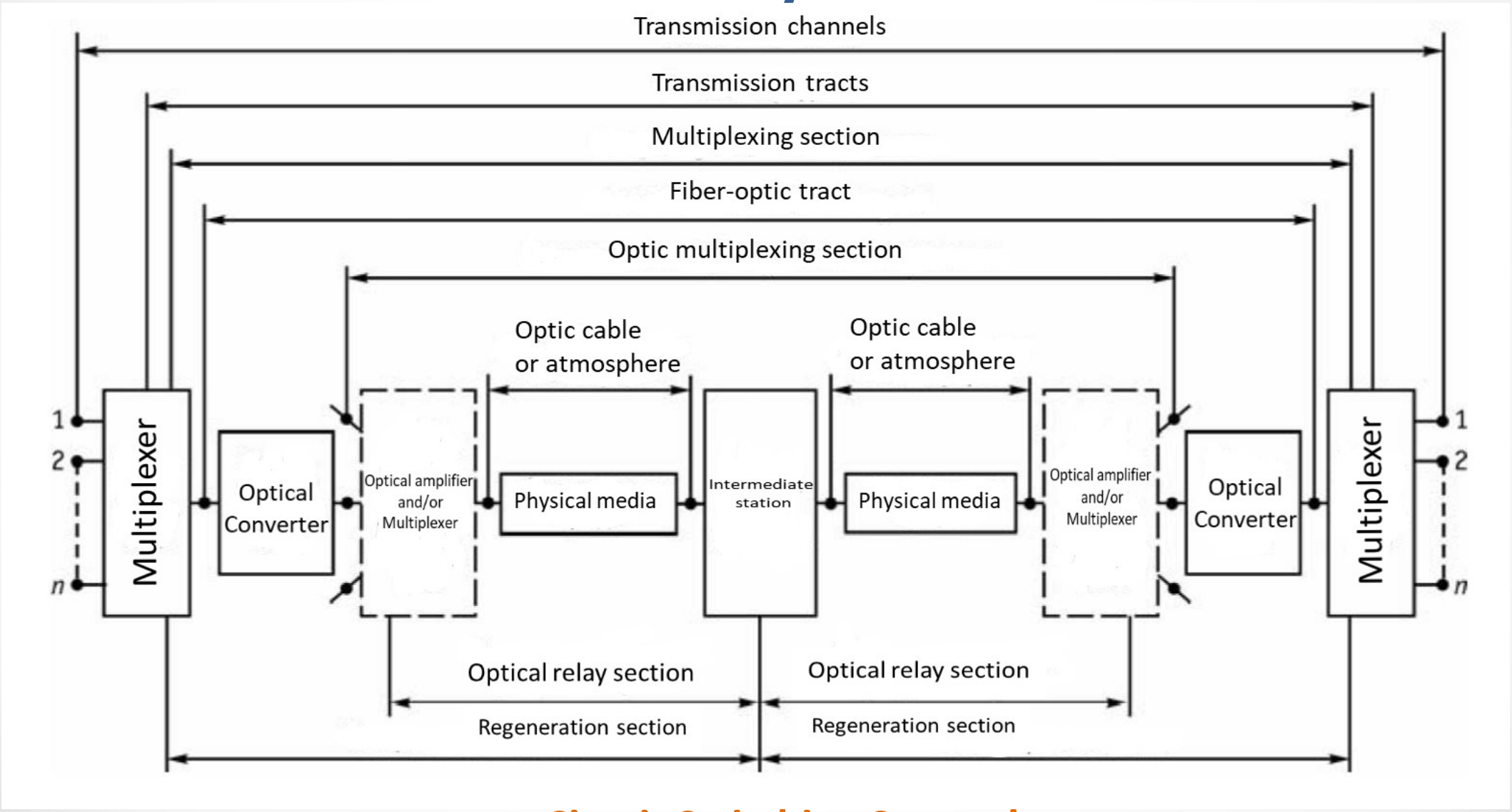
- TDM 1980-2000 – Max. speed of Electronic Component ~ 10 Gbps
- WDM: CWDM (Coarse) and DWDM (Dense)
  - CWDM - an increase of 18 (max) is usually 8 times (channel density: 20 nm)
  - DWDM - increase in speed by 100 times (channel density: 100 GHz or 50 GHz (0.8 or 0.4 nm)
- Coherent communication systems + multi-level formats one character carries 4 or more bits
- Optical signal can be polarized
- QPSK, DP-QPSK

DWDM - Dense Wavelength-Division Multiplexing



- Protocol Transparency: OTN OTU1 / 2/3/4, SDH STM-1/4/16/64/256, Ethernet FE / GE / 10GE / 100GE, etc.
- Simultaneous channels amplification of all spectrum
- High network capacity while transmitting multiple channels
- Quick upgrade by introducing new channels. Multiservice

General scheme of Fiber Data Communication System



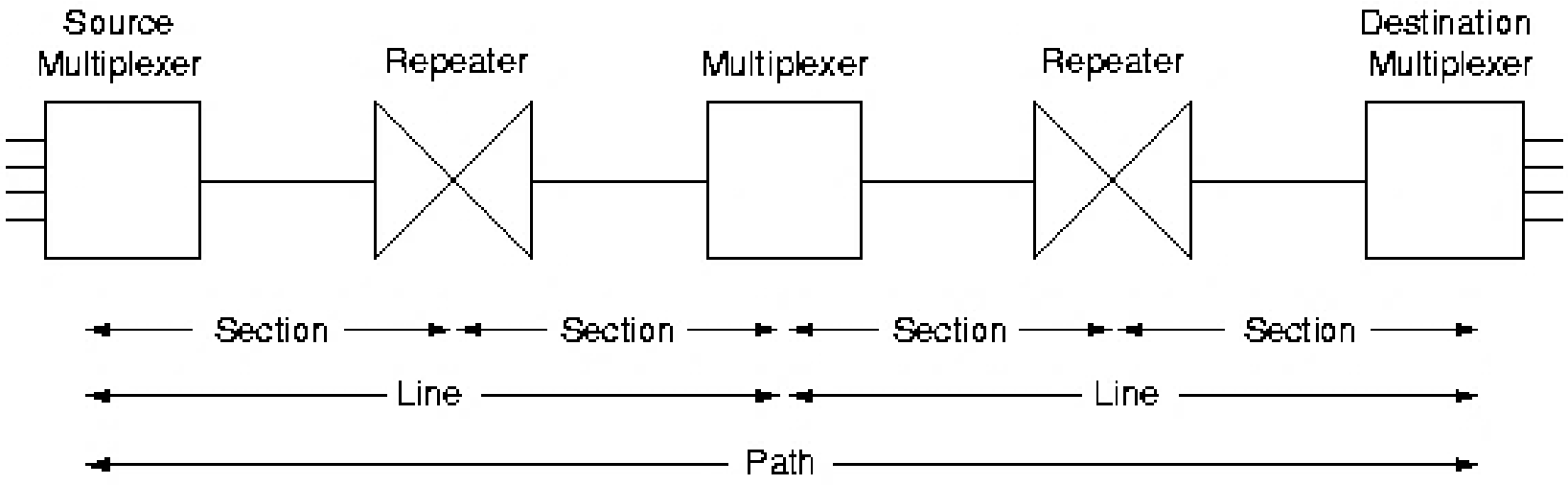
Circuit Switching System!

SONET/SDH
Synchronize Optical NETwork

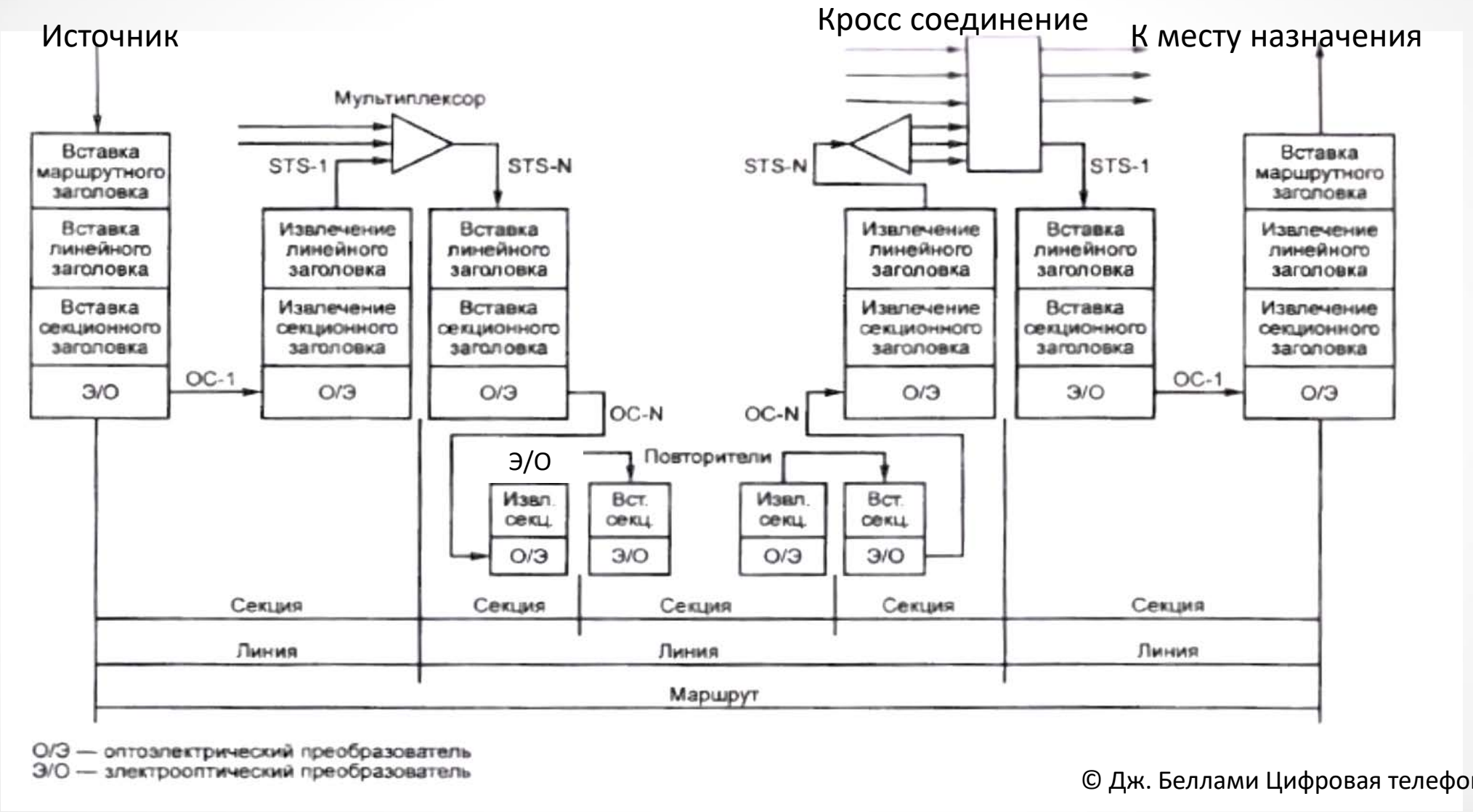
SONET – Synchronous Optical NETwork

- The standard was intended to provide:
  - The ability to use different physical environments on the network. This required the development of a standard for coding at the physical level, the choice of wavelength, frequency, time characteristics, frame structure.
  - The hierarchical multiplexing of several digital channels T1 - T4 (E1 - E4) to unify American, European and Japanese digital systems.
  - The rules of operation, administration and support.

Path structure in SONET



OAM structure in SONET



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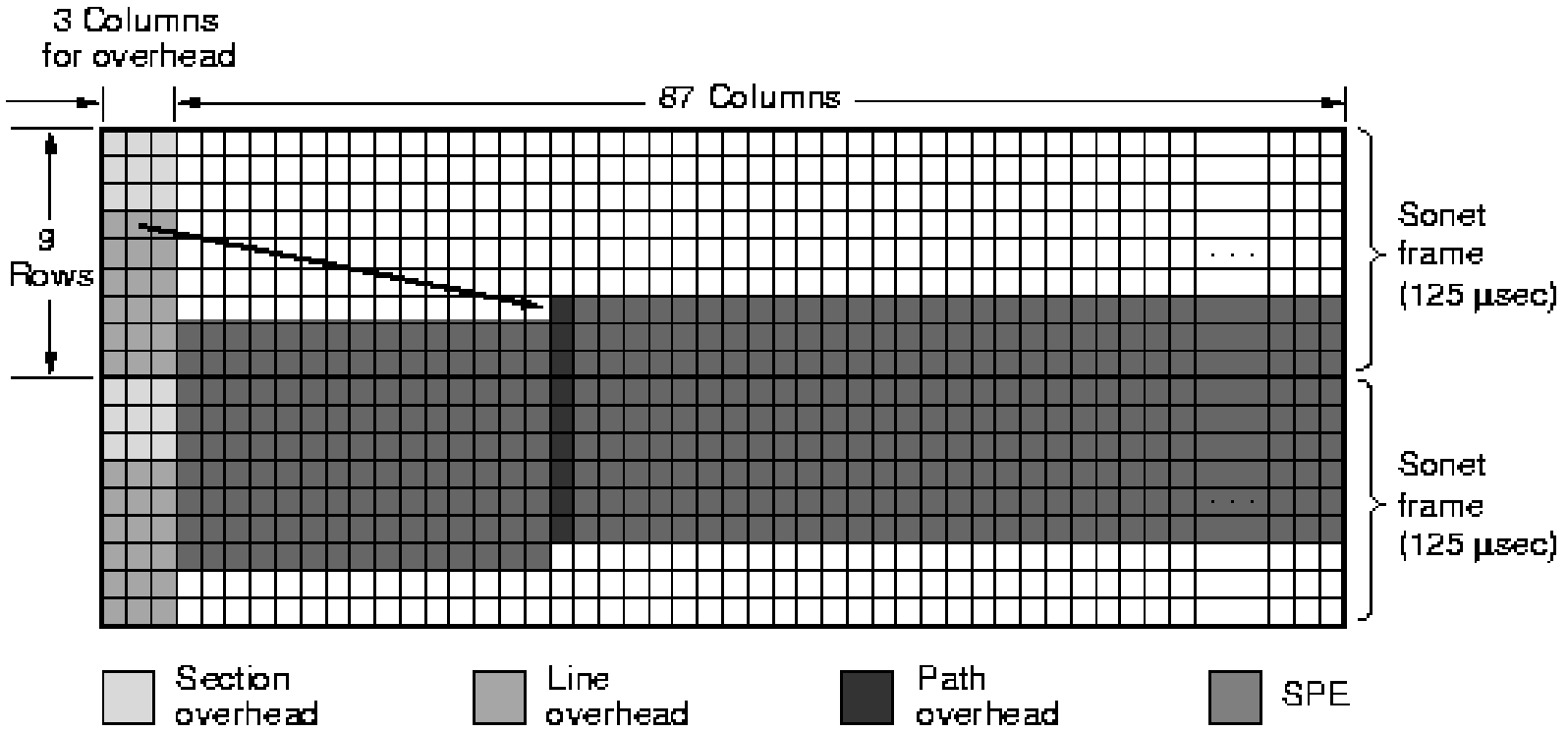
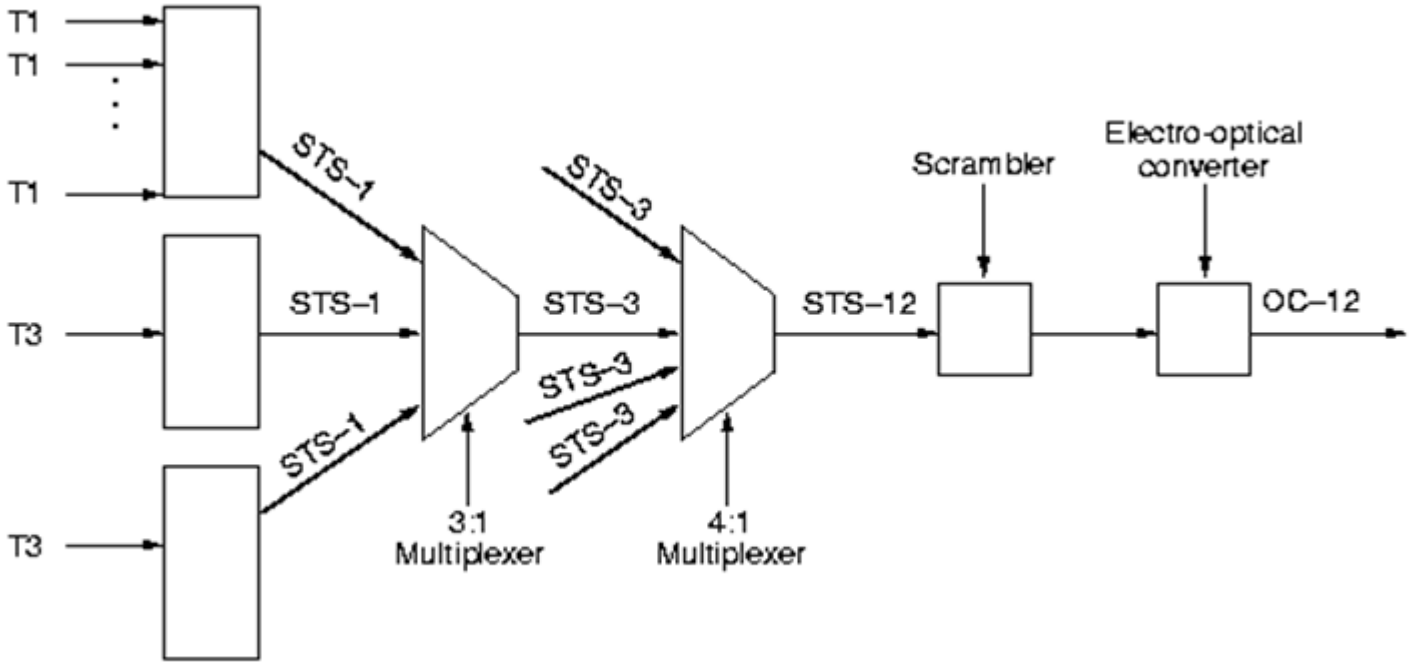
Two adjacent SONET frames



Multiplexing into SONET frame



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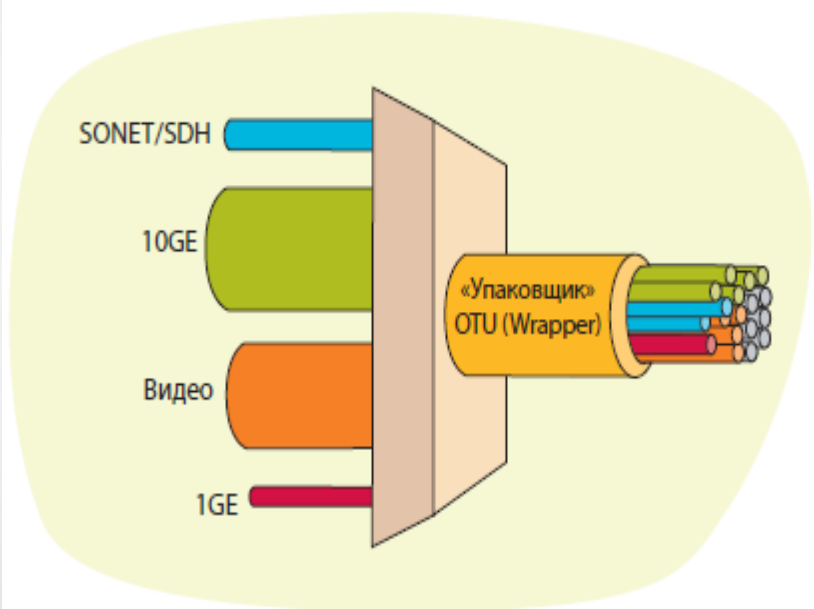
OTN ITU G.709 purpose

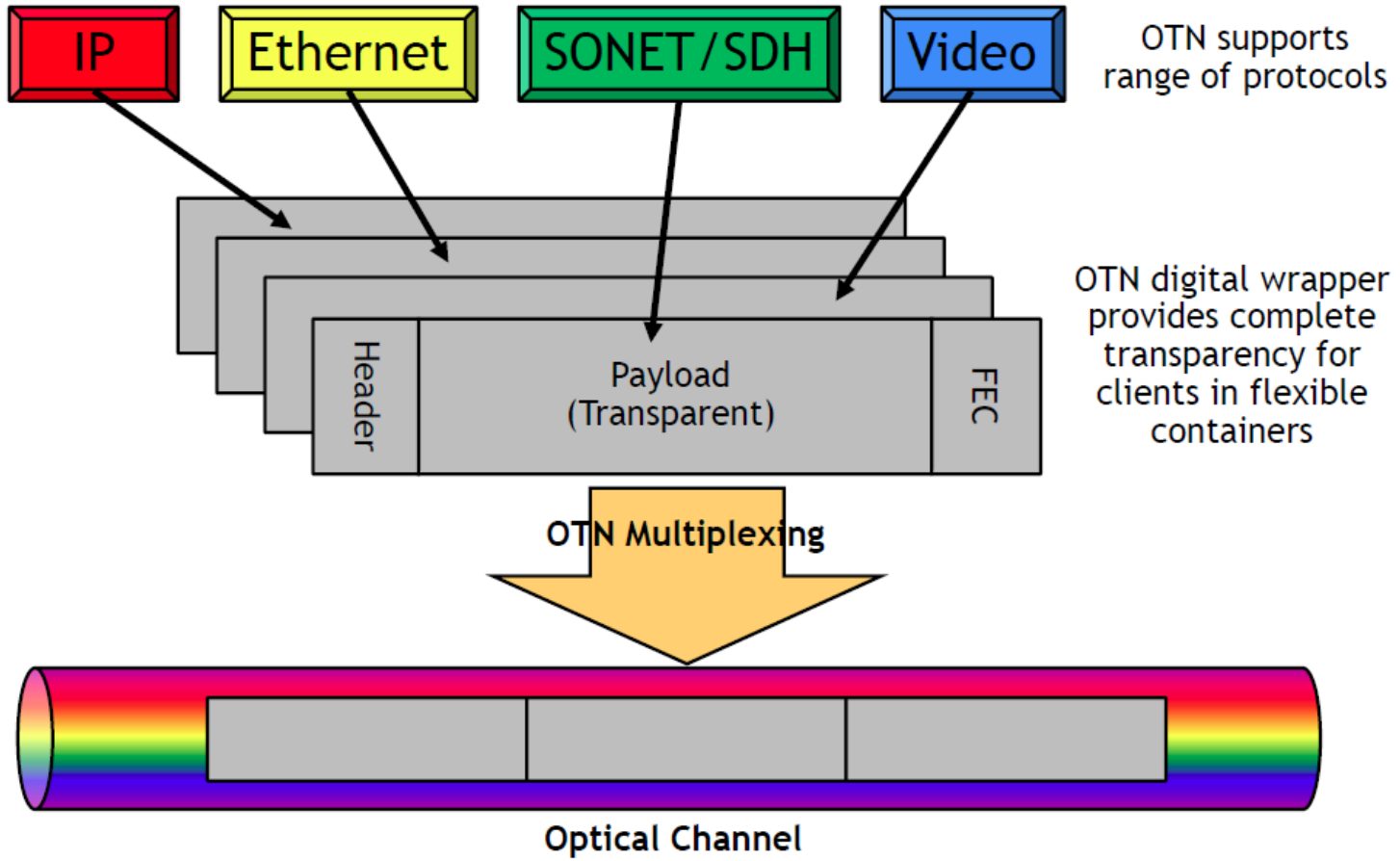
"…to cater for the transmission needs of today's wide range of digital services, and to assist network evolution to higher bandwidths and improved network performance."

ITU-T G.709 Application Note: 1379

OTN is transparent to many protocols



OTN Supports Variety of Protocols



14 | Understanding OTN | December 10, 2009

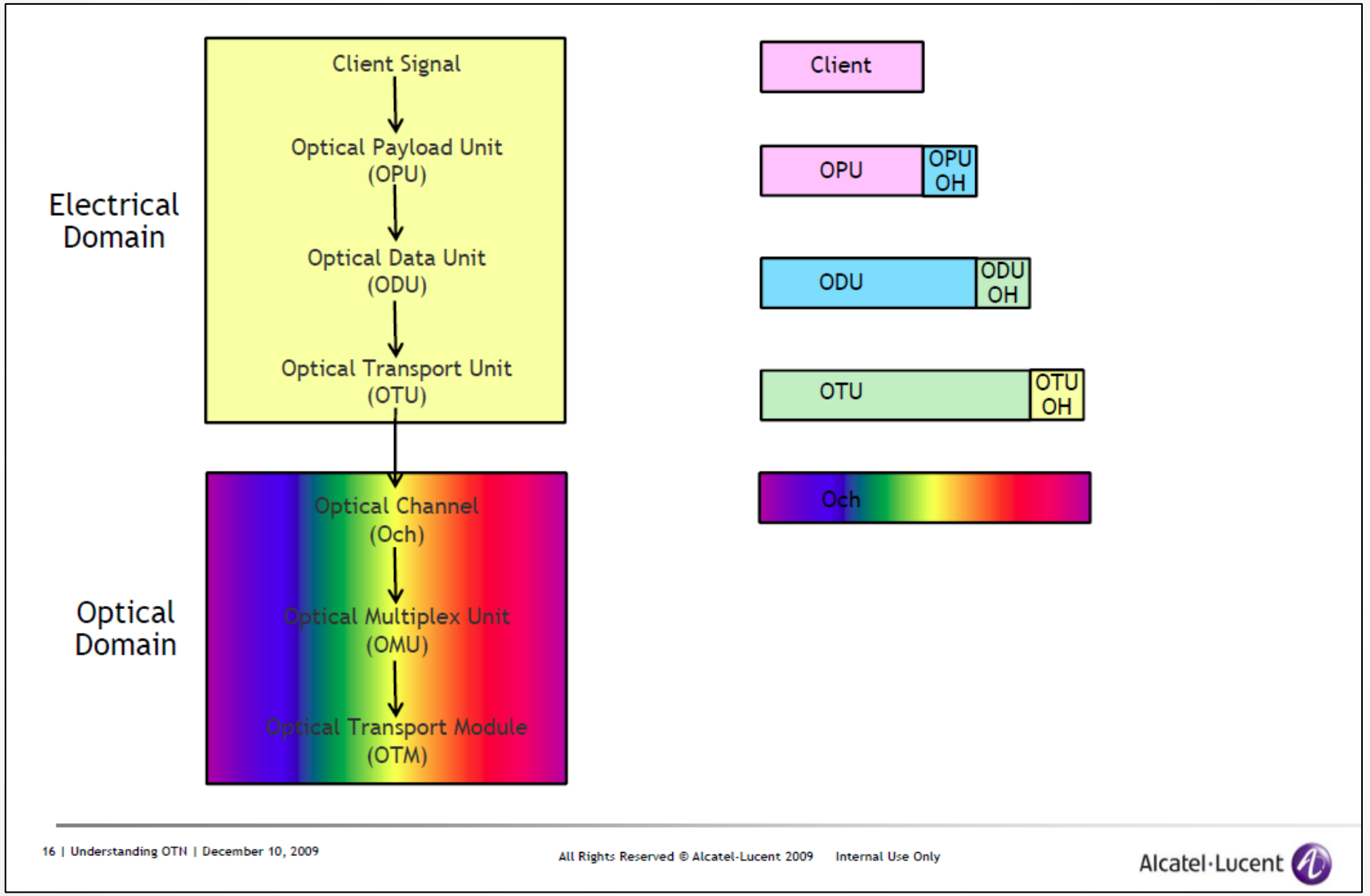
Alcatel·Lucent

OTN - advantages

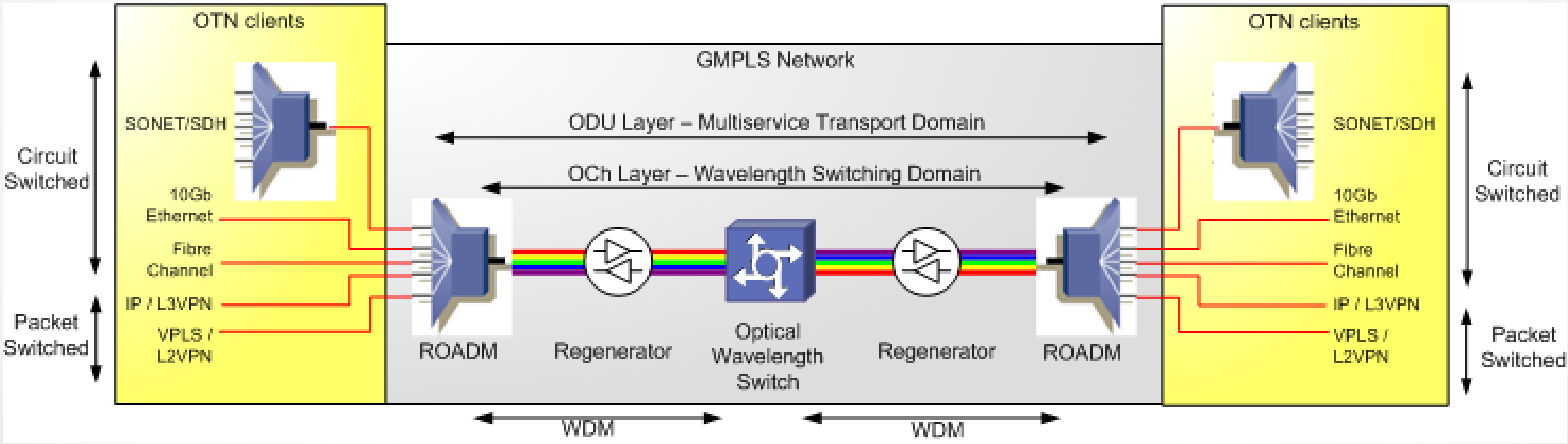
Specification G.709 (2003).

- OTN defines the OTU (Optical Transport Unit) frame (packaging, wrapper) for encapsulating application data frames, regardless of the particular protocol that generated the frame.
- The G.709 specification includes digital container agreements (ODUs), performance monitoring, error correction, multiplexing, and network recovery mechanisms.
- ODU allows you to place several frames from different protocols in it and is designed for 2.5, 10, 40 and 100Gbps Ethernet, SDH / SONET frames.
- The error correction mechanism (FEC - Forward Error Correction) is based on the Reed-Solomon code.
- To transmit an ODU of a frame, the specification defines an optical OTU container - an optical transport unit.
- Defines a mechanism for end-to-end monitoring of network services.

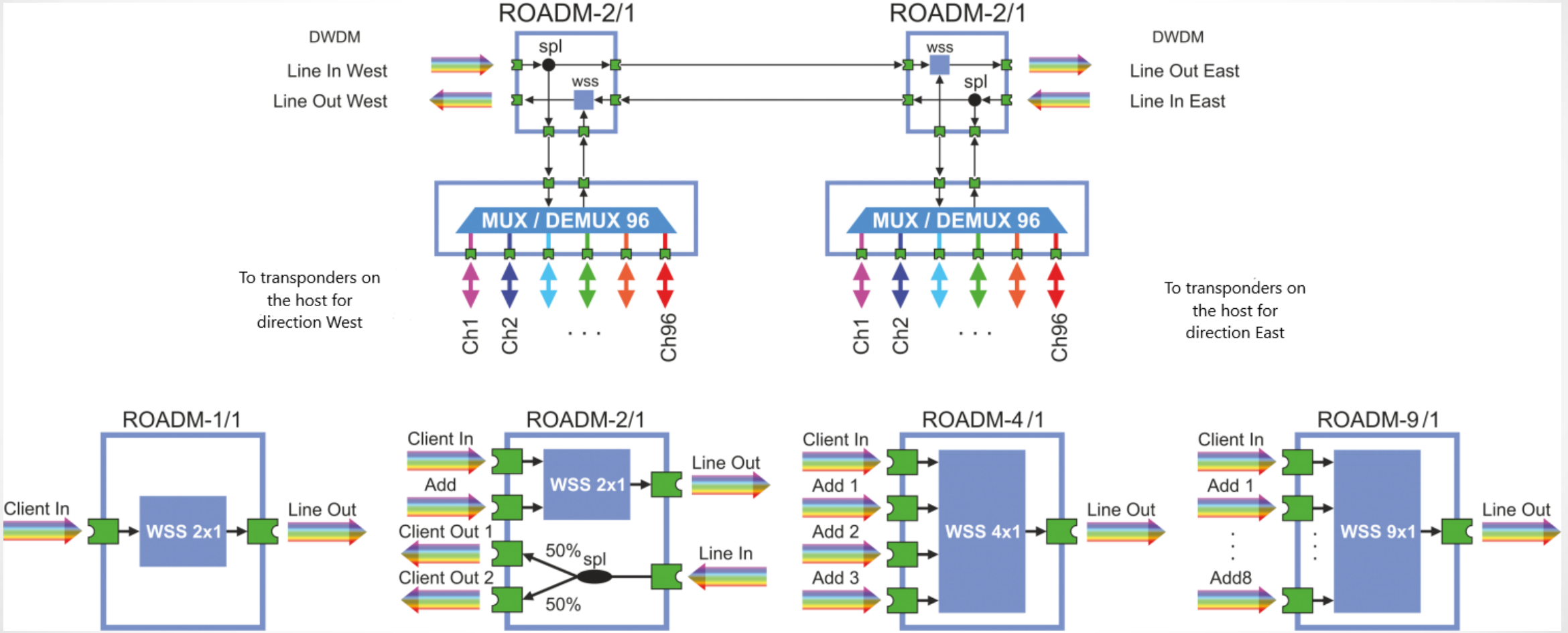
Building an OTN Container



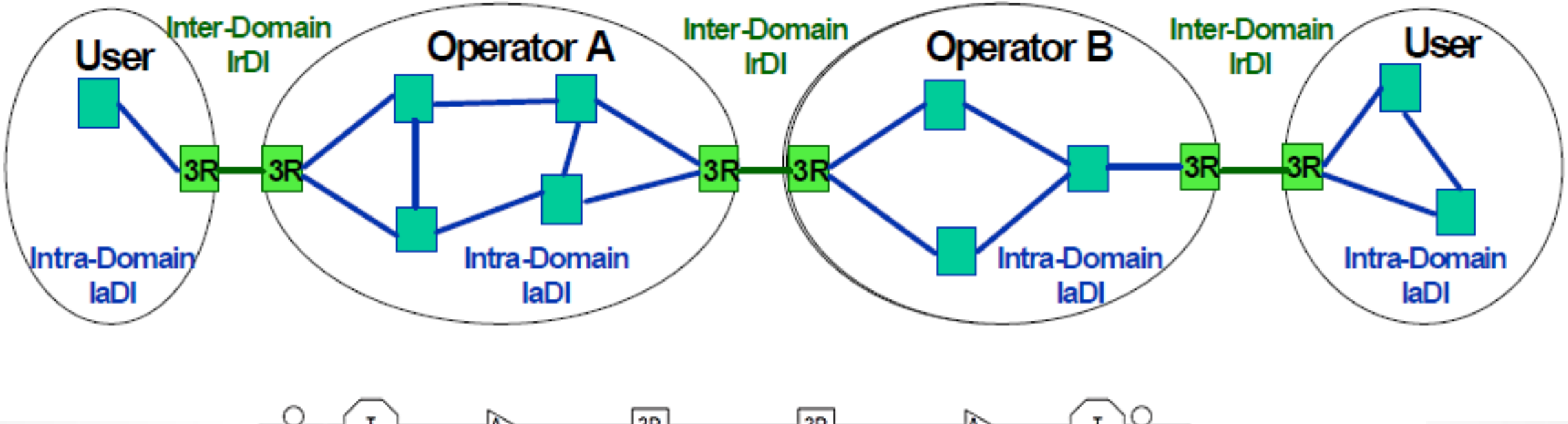
OTN line equipment

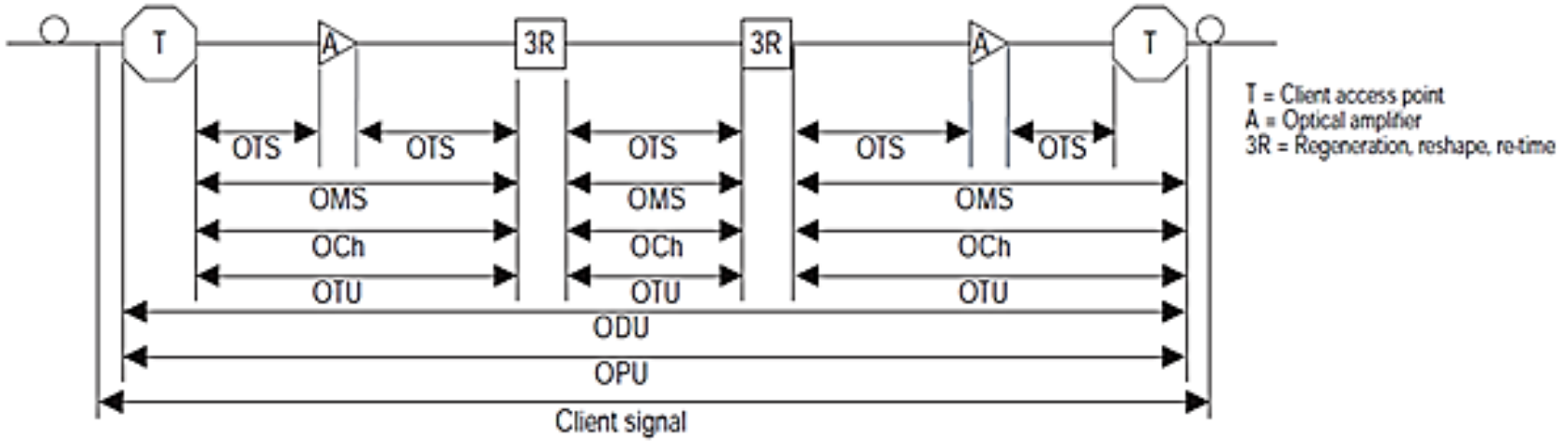


ROADM configuration



Hierarchy of OTN Network Interfaces





Forward Error Correction (FEC)

- Allows to increase the line length or the number of lines for transmission without amplification
- Reduces the threshold value for the S / N ratio, which increases the number of channels in the DWDM system

Forward Error Correction (FEC)

ITU G.709 recommendation - Reed-Solomon Code RS (255,239)

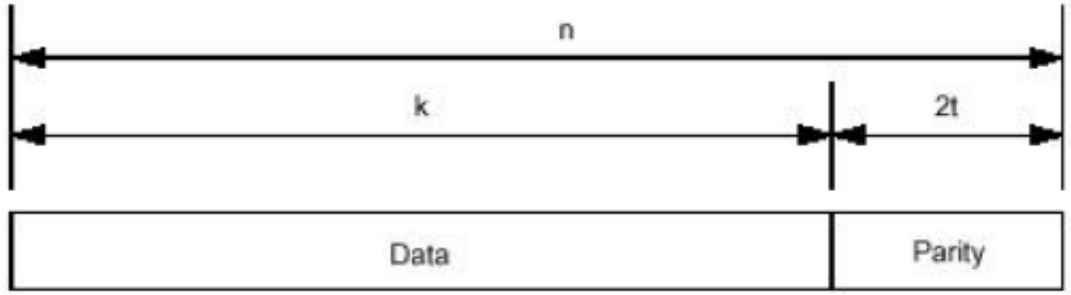
s = Size of the symbol = 8 bits

n = Symbols per codeword = 255 bytes

k = Information symbols per codeword = 239 bytes

2t = n - k = 255 - 239 = 16

t = 8



+ = XOR

$g(x) = \prod_{(i = 1..D-1)}(x+a^{i}) = (x+a_1)(x+a_2)....(x+a_{D-1})$ generating polynomial

the message is "shifted" by N-K characters

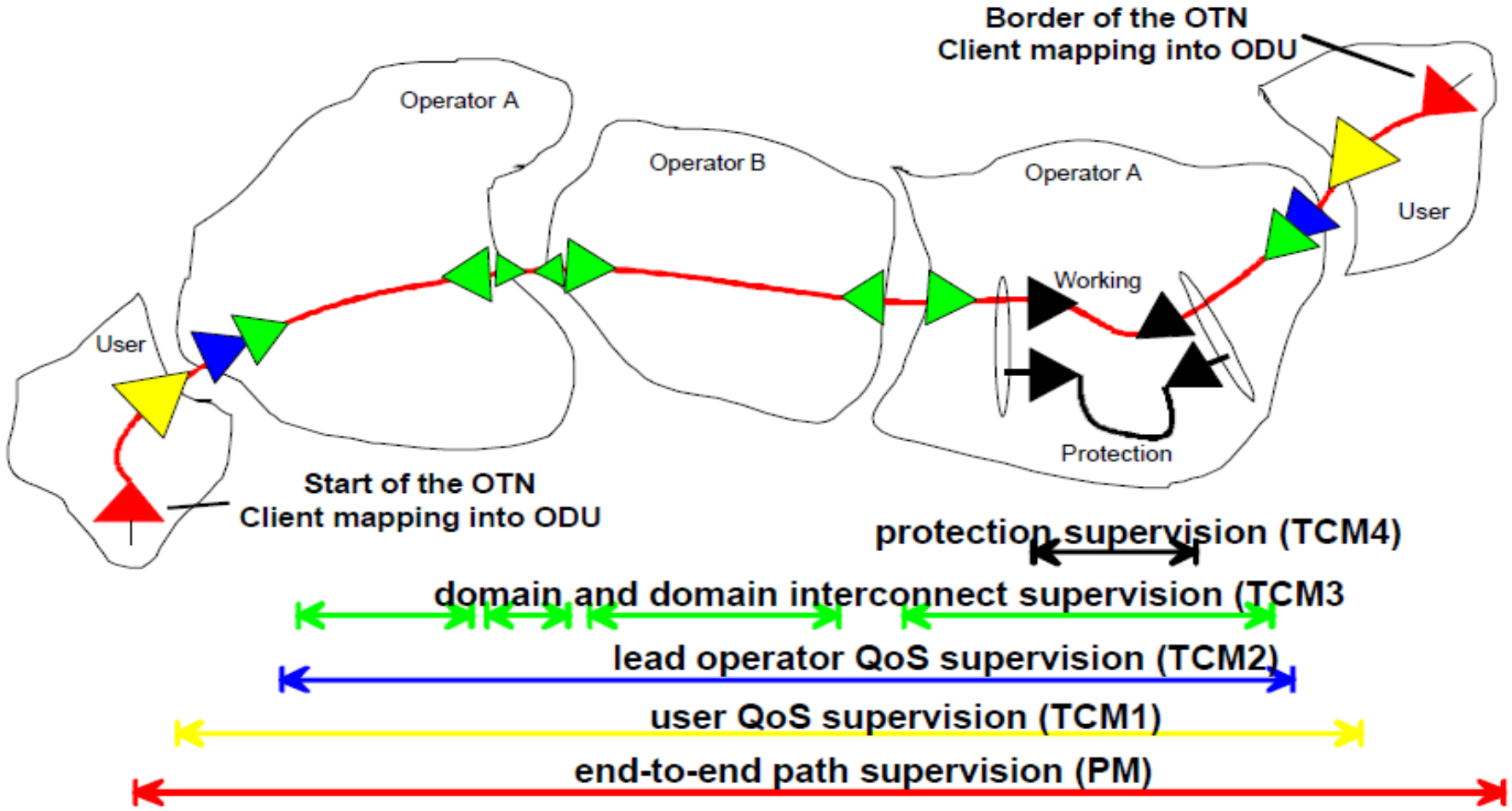
C(x) = p'(x) + p'(x) mod g(x)

C'(x) = C(x) + E(x), тогда
C'(x) mod g(x) = E(x) mod g(x) = e(x) <> 0.

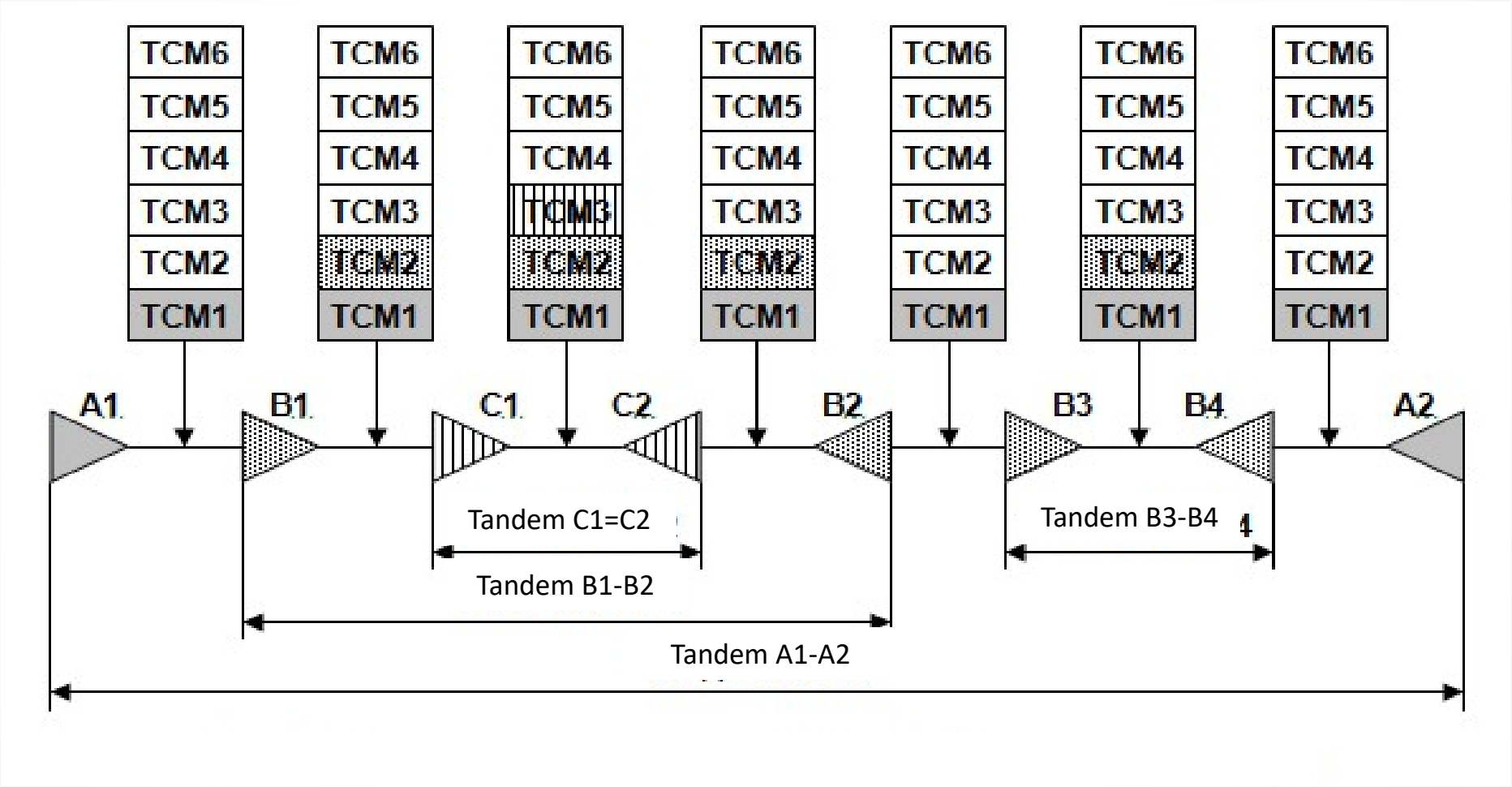
$$n = 2^s - 1 = 255$$

RS(255,239) max length

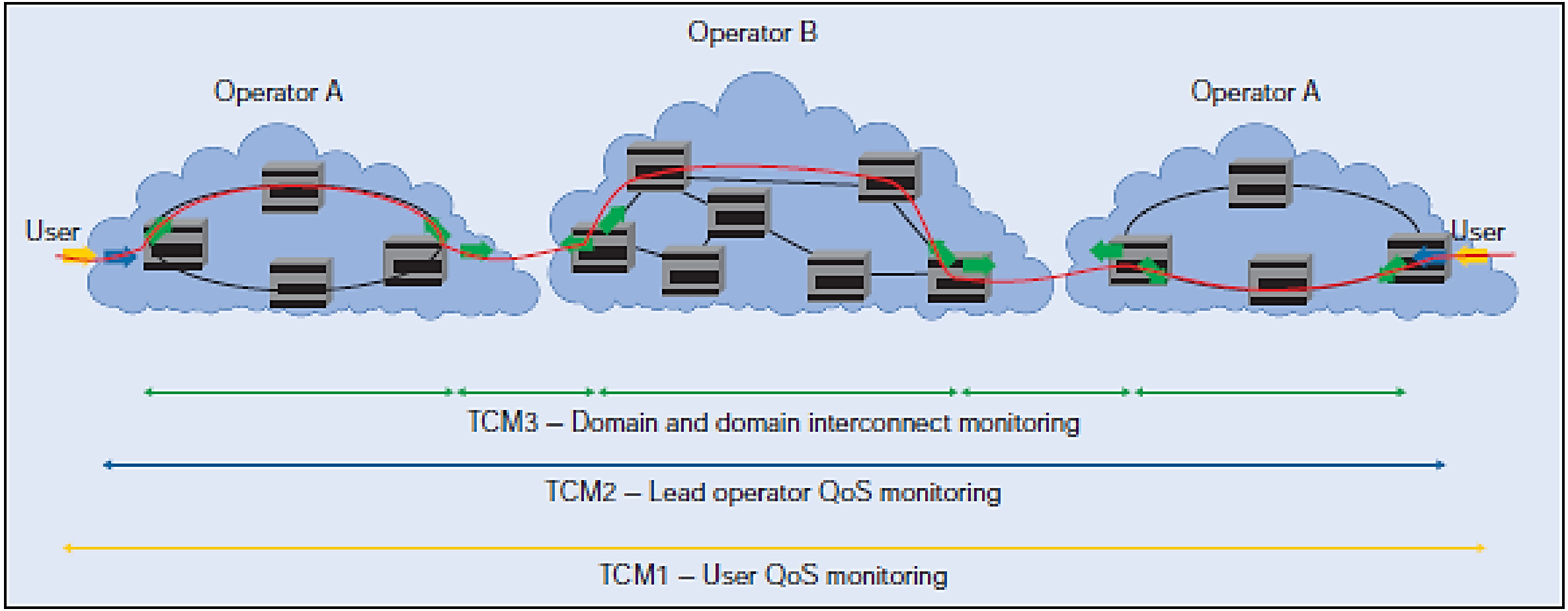
Tandem Connection Monitoring (TCM)



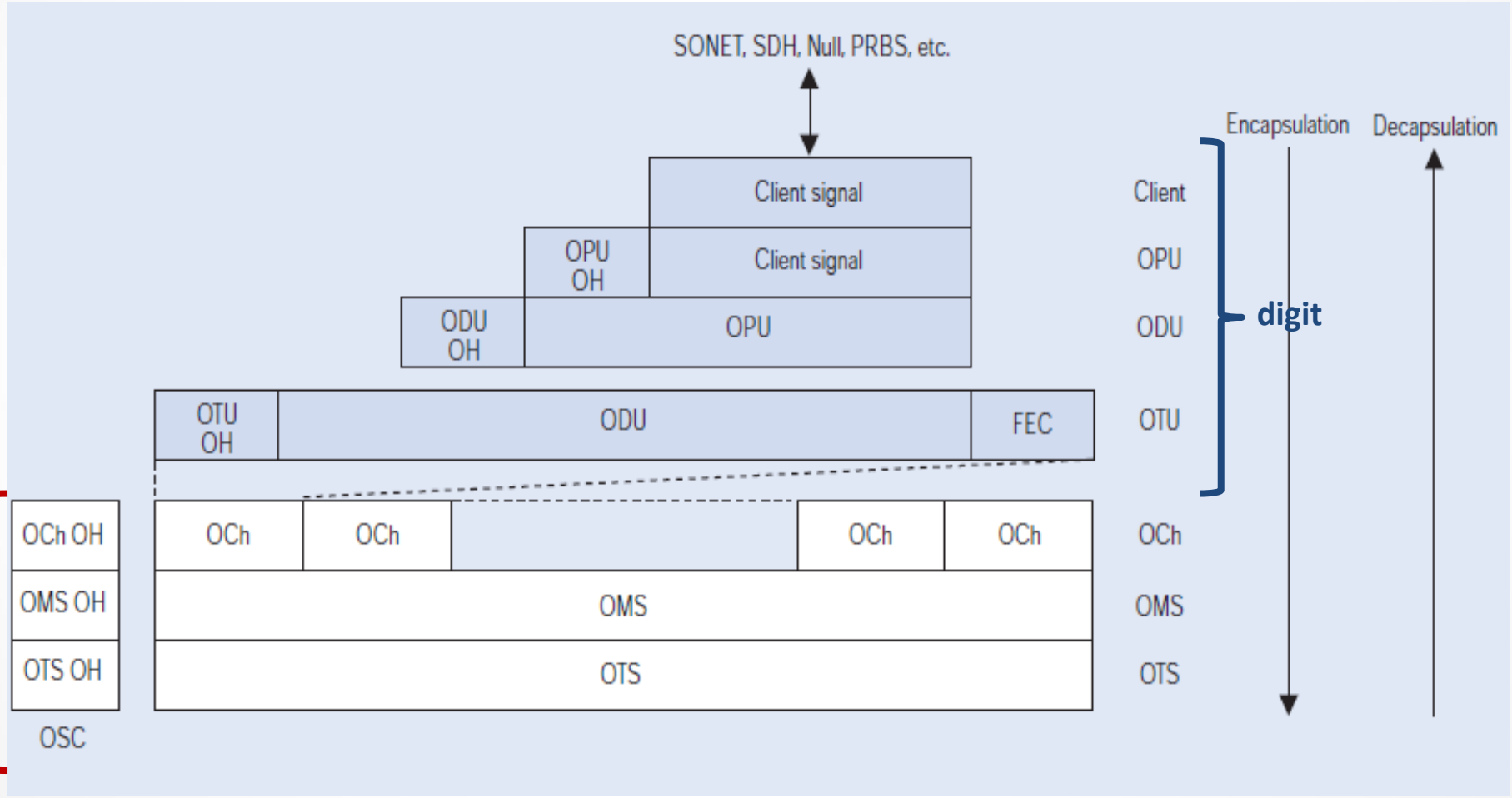
TCM Level Allocation



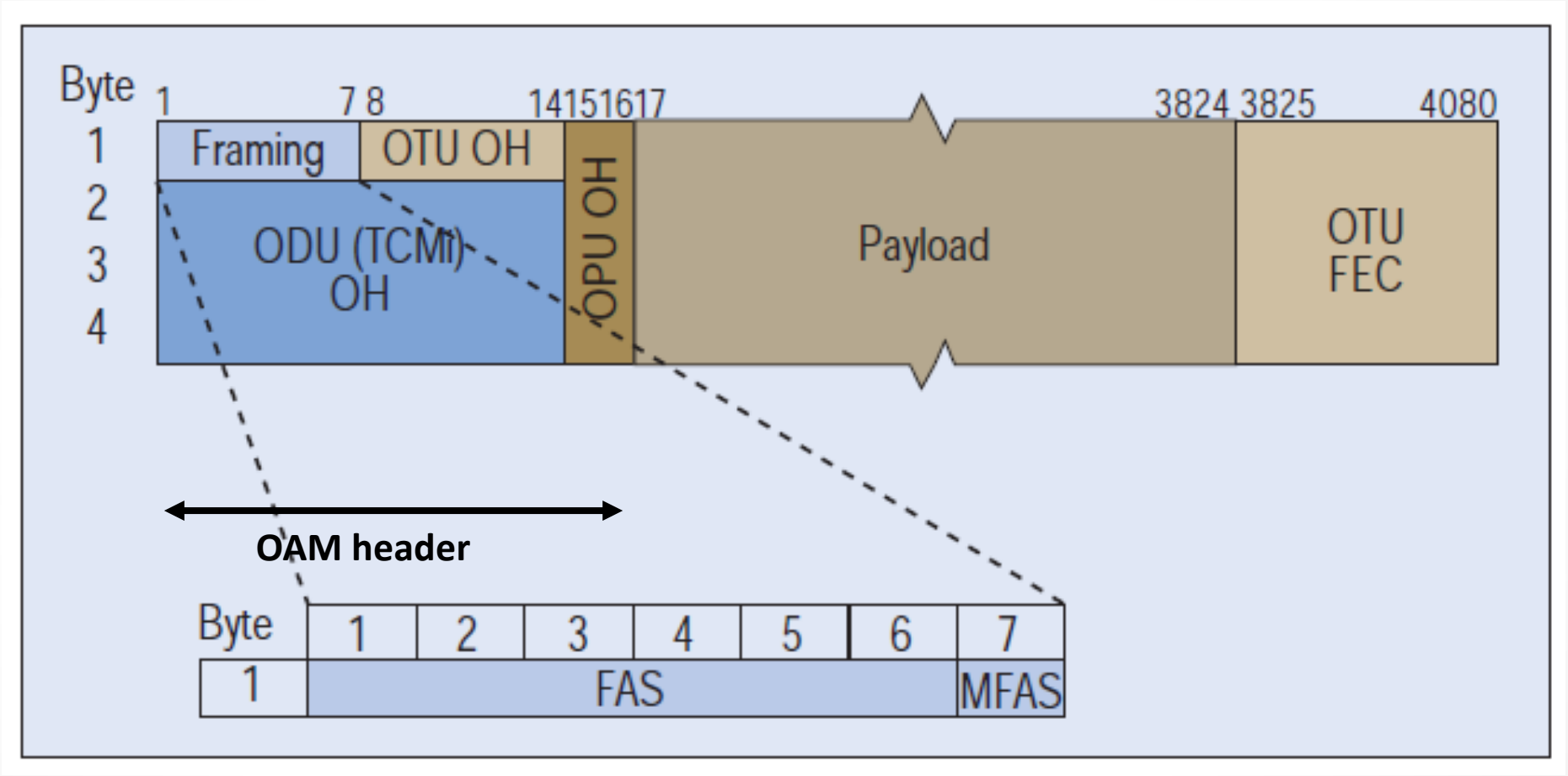
TCM – transit monitoring



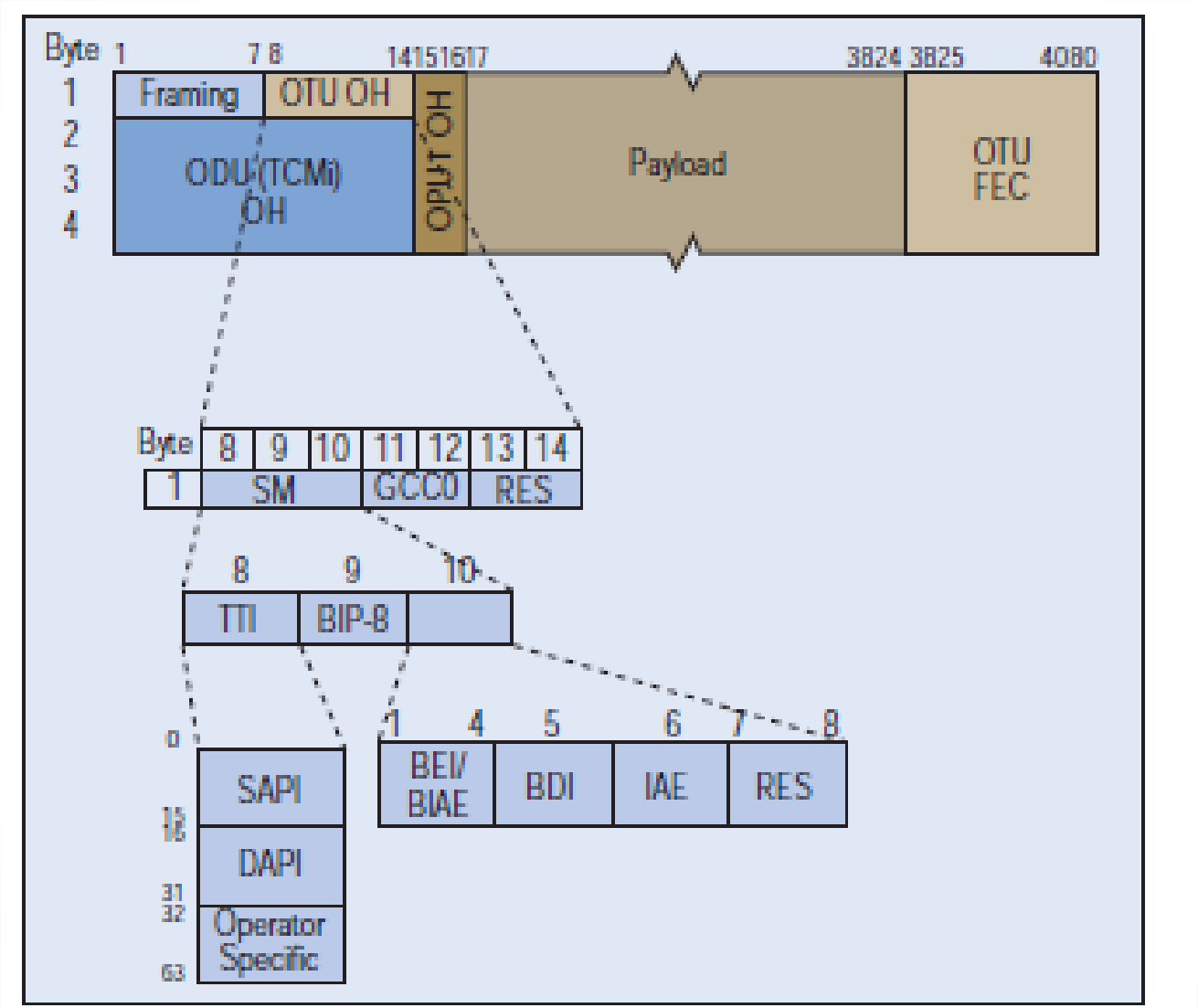
OTN Basic Information Structures



OTU Frame Structure



OTU Header


Byte
1
2
3
4
1
7 8
14151617
3824 3825
4080
Framing
OTU OH
ODU (TCMi) OH
OPU LTJO
Payload
OTU FEC
Byte
8
9
10
11
12
13
14
1
SM
GCC0
RES
8
9
10
TTI
BIP-8
0
1
4
5
6
7
8
SAPI
DAPI
Operator Specific
BEI/ BIAE
BDI
IAE
RES

Optical Transport Unit

- OTU level is transmitted only within the multiplexing section.
- The OTU level performs the following functions:
  - framing, i.e. breakdown of the signal into frames and multi-frames (FAS / MFAS fields)
  - transmission of the feedback signal on errors detected within the multiplexing section (SM)
  - transmission of service information within the multiplexing section (field GCC0)
  - transmission of information necessary for error correction (FEC)

Optical Payload Unit (OPU) functions

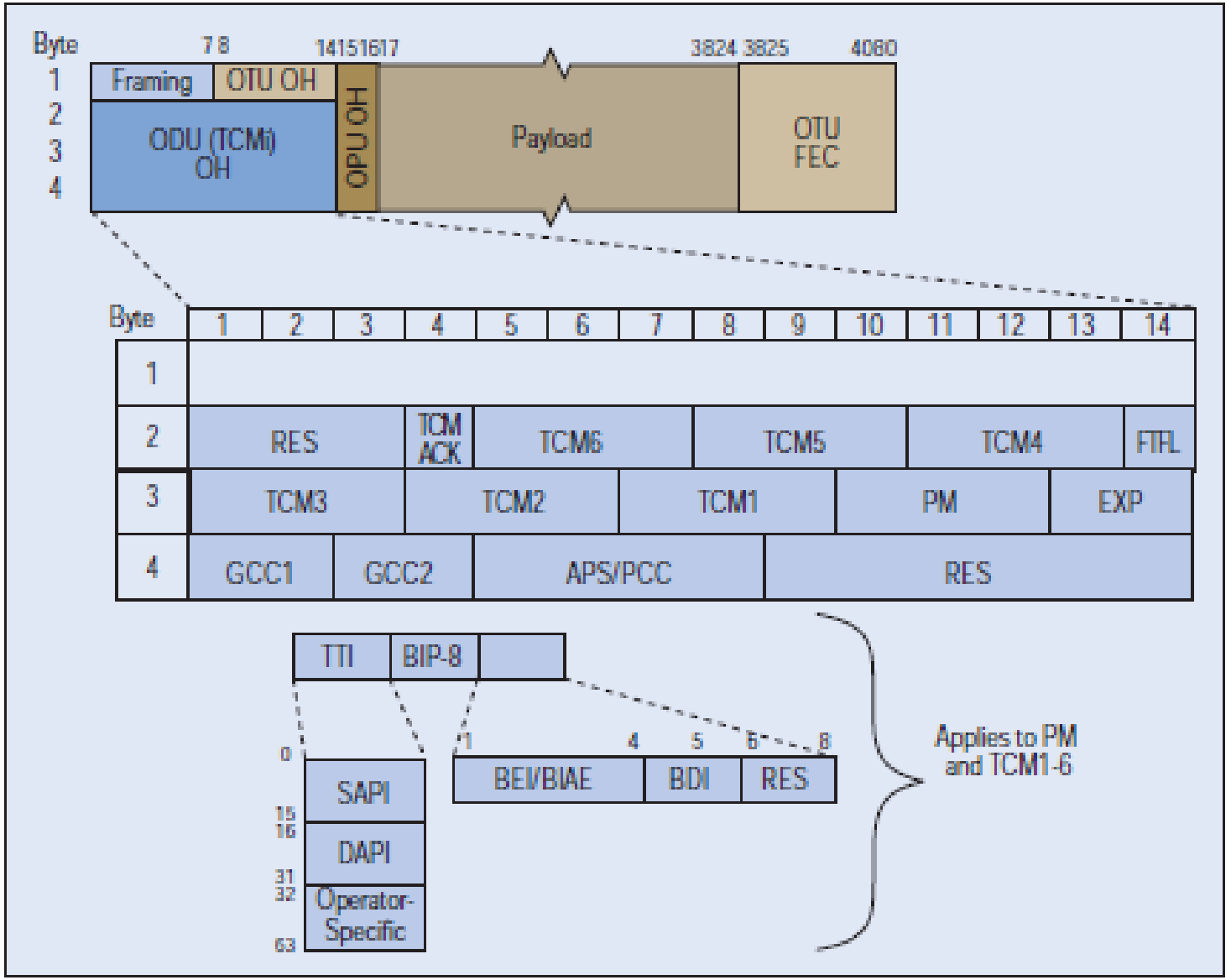
- The OPU is transmitted from end to end of the entire signal path, i.e. between terminal multiplexers.
- OPU service information performs two functions:
  - **determination of the type of transmitted signal (PSI field).** The special value of byte 0 of PSI 20h indicates that the OPU contains a multiplexed signal (several lower level ODUs), and bytes 2-17 in this case determine the type and number of each stream in the multiplex.
  - **transmission of the synchronization signal if the transmitted signal is asynchronous (JC field).** Thus, the OPU level solves the problem of encapsulating the useful signal in the OTN signal and the problem of signal multiplexing.

Optical Data Unit (ODU)

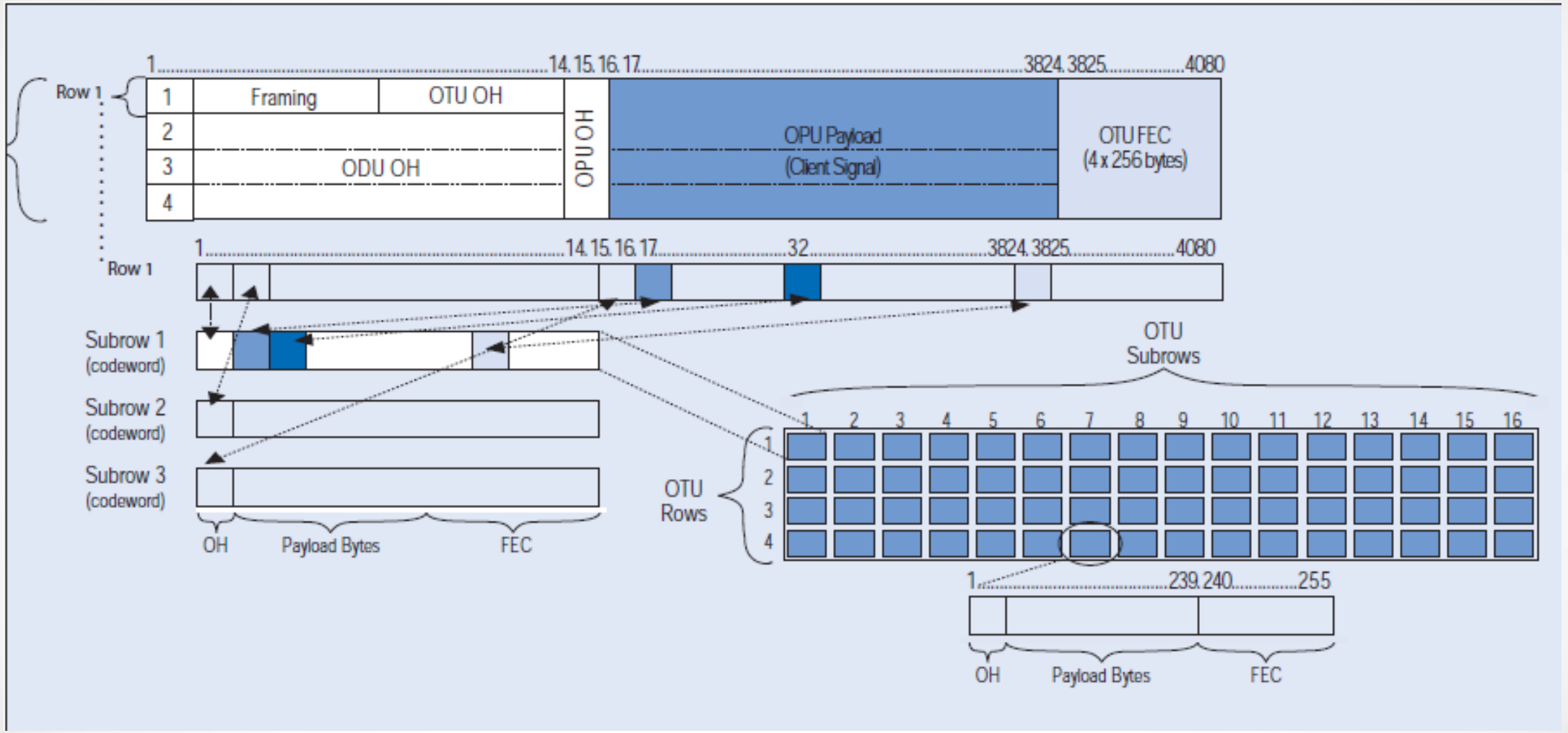
- The ODU is also transmitted from end to end of the path, it is targeted to the implementation of the tasks of controlling and monitoring the entire signal transmission path between the end nodes.
- The ODU performs the following functions:
  - transmission of emergency messages (PM) in the opposite direction
  - transmission of service information during the passage of the path through the networks of various operators (TCMi, TCMACT fields)
  - transmission of information about detected errors and their intended location (FTFL field)
  - transmission of service information from end to end of the path (fields GCC1 / GCC2)
  - transfer of information about switching the main and service channels to the backup path (nested fields APS / PCC)

ODU level solves the problems of monitoring and controlling the transmission path to the whole m, from end to end.

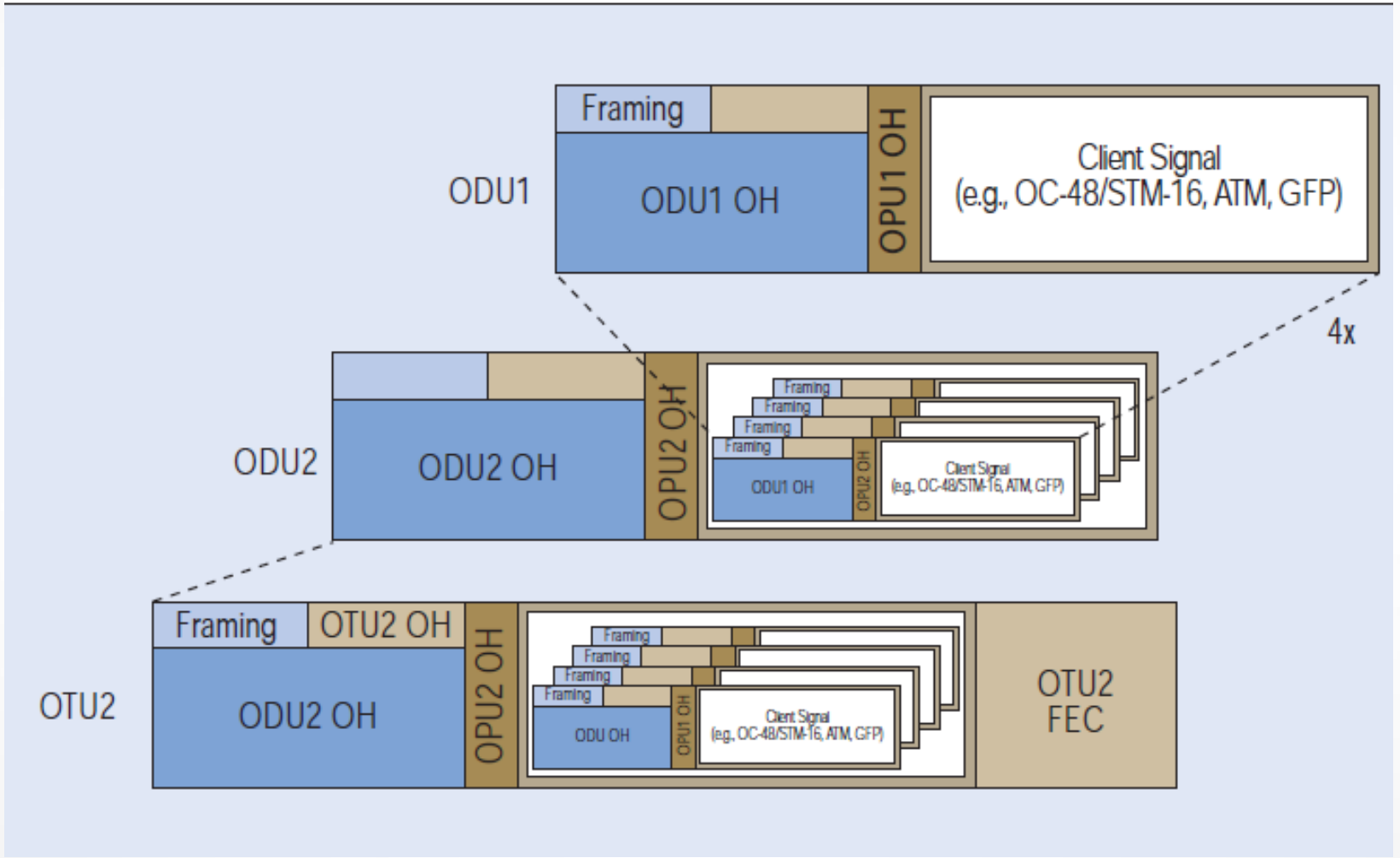
ODU Header


Byte
1
2
3
4
7 8
14 15 16 17
3824 3825
4080
Framing
OTU OH
ODU (TCMi) OH
OPU OH
Payload
OTU FEC
Byte
1 2 3 4 5 6 7 8 9 10 11 12 13 14
1
2
RES
TCM ACK
TCM6
TCM5
TCM4
FTFL
3
TCM3
TCM2
TCM1
PM
EXP
4
GCC1
GCC2
APS/PCC
RES
TTI
BIP-8
0
15
16
31
32
63
SAPI
DAPI
Operator-Specific
1
4
5
6
8
BEI/BIAE
BDI
RES
Applies to PM and TCM1-6

FEC organizing



ODU multiplexing

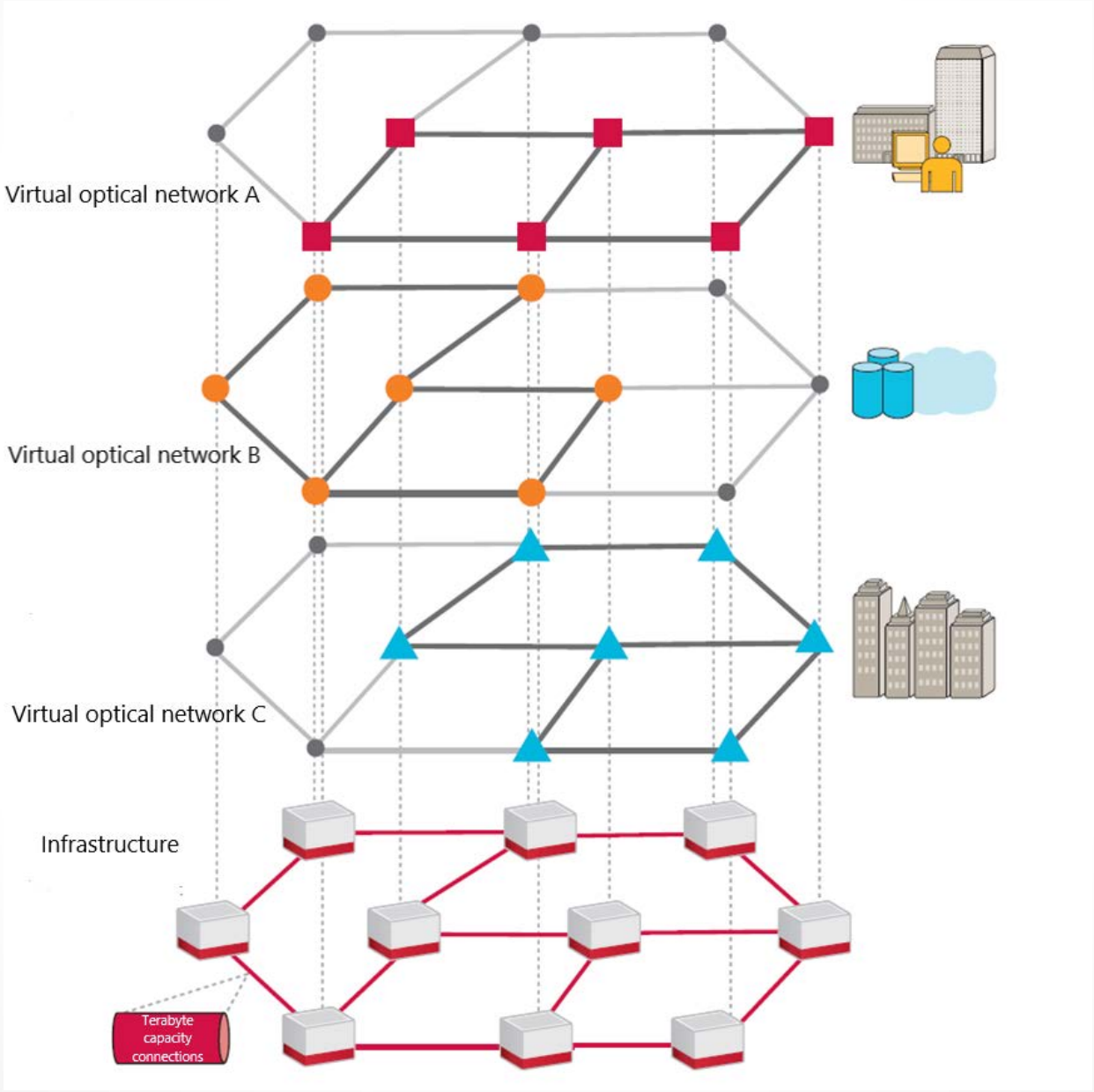


ODU Types
and their speed characteristics

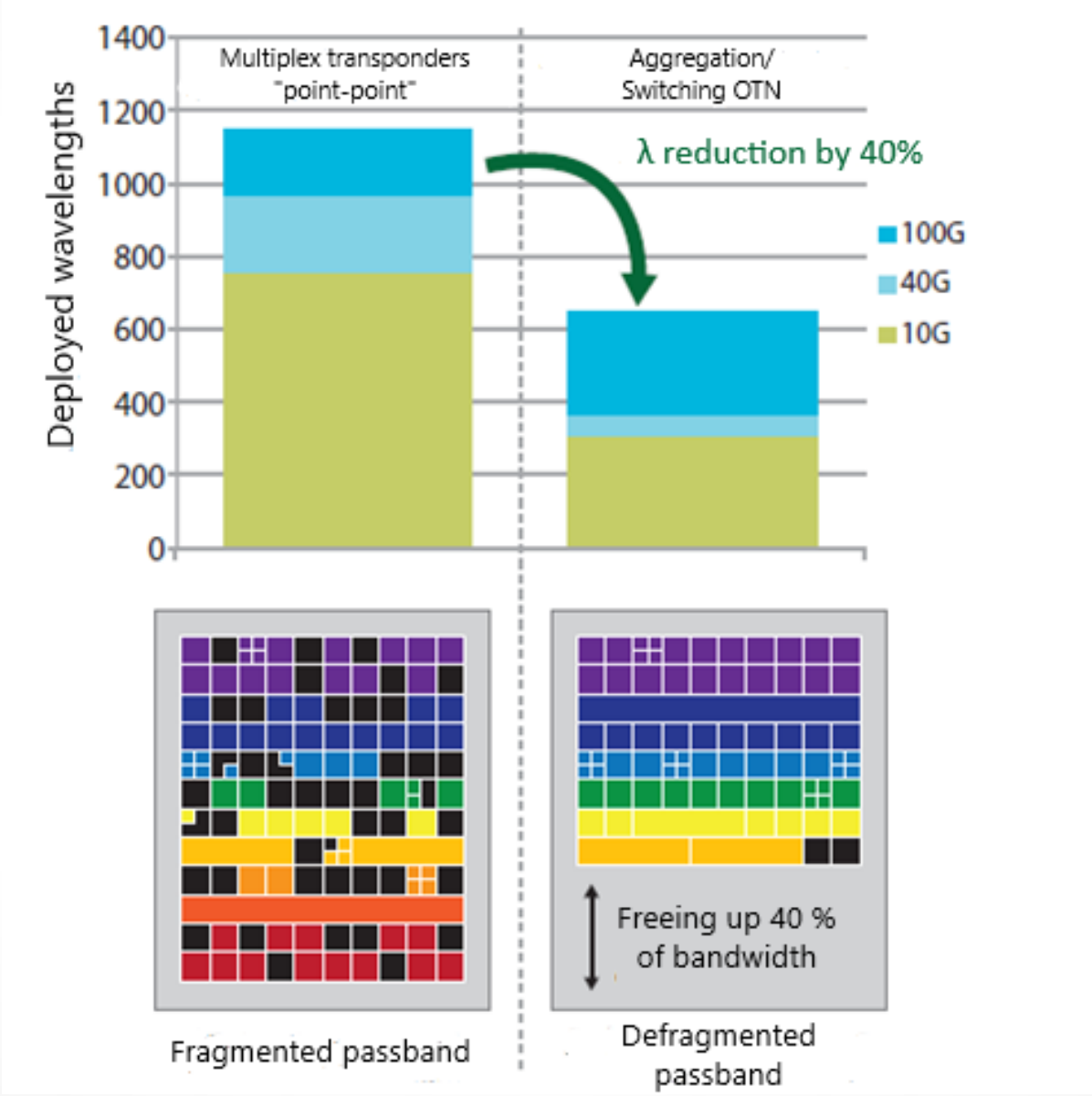
ODU Clients	ODU Server
1.25 Gbit/s bit rate area	ODU0
–	
2.5 Gbit/s bit rate area	ODU1
ODU0	
10 Gbit/s bit rate area	ODU2
ODU0, ODU1, ODUflex	
10.3125 Gbit/s bit rate area	ODU2e
–	
40 Gbit/s bit rate area	ODU3
ODU0, ODU1, ODU2, ODU2e, ODUflex	
100 Gbit/s bit rate area	ODU4
ODU0, ODU1, ODU2, ODU2e, ODU3, ODUflex,	
CBR clients from greater than 2.5 Gbit/s to 100 Gbit/s, or GFP-F mapped packet clients from 1.25 Gbit/s to 100 Gbit/s.	ODUflex
–	

Use cases

OTN based virtual networks



Defragmentation of the line workload



Conclusion

- Services for customers have many differences: from data transfer rates to quality and reliability requirements.
- Packet-switched networks are not always able to meet the stringent requirements of high-performance services, such as minimum latency, no loss, high data transfer rate and predictable recovery time (no more than 50 ms).
- OTN provides a predictable and simple service delivery model that complements packet-switched networks with unique capabilities and features such as service transparency, end-to-end monitoring, enhanced error correction, and built-in delay measurement tools that are required to meet the stringent requirements of high-quality channel services and special services.
- Pairing with MPLS-TE

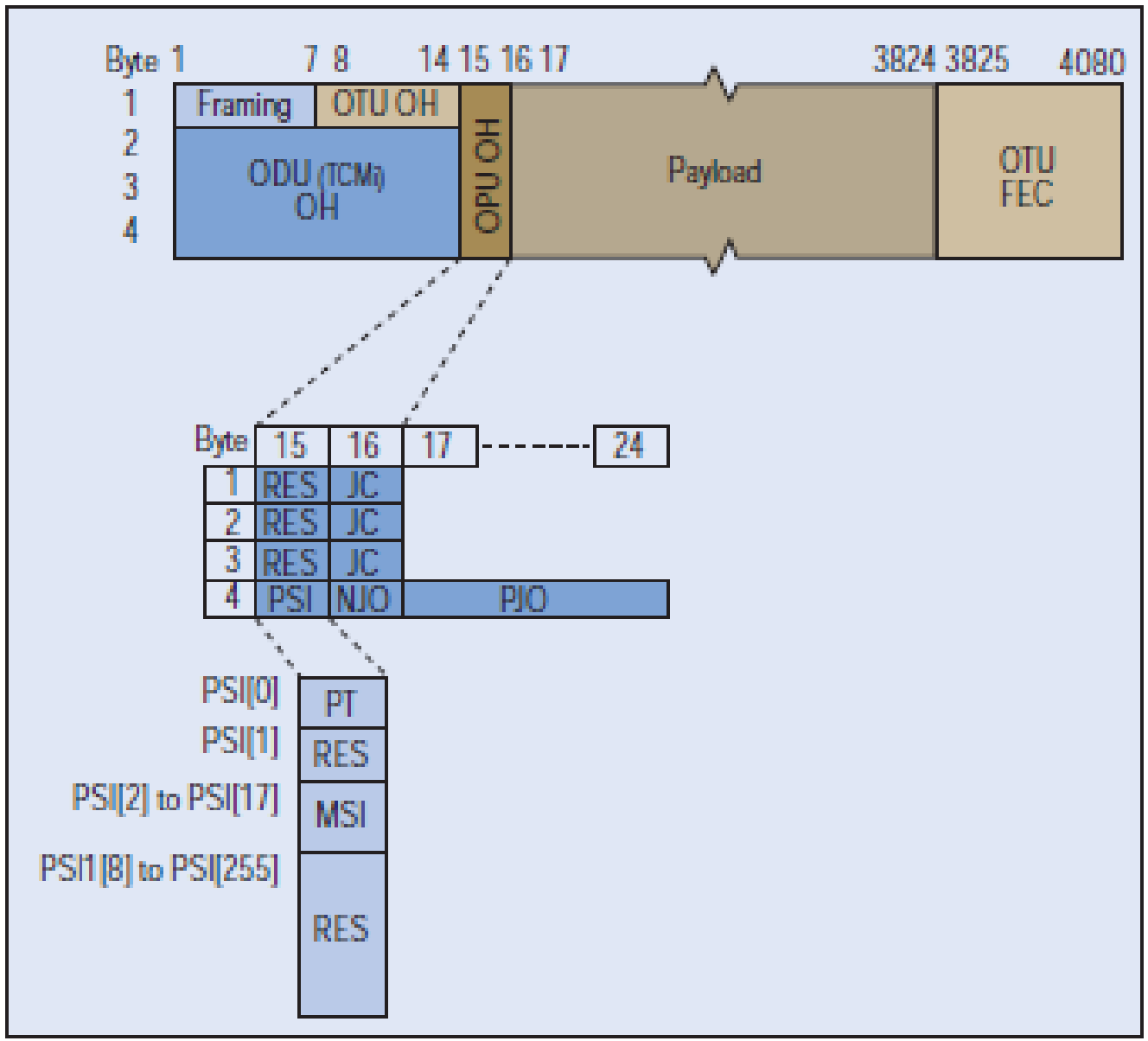
Plesiochronous multiplexing

USA				ITU-T (Europe)		
Speed Designation	Number Of Voice Channels	Number Of Channels of last level	Speed Mbit/s	Number Of Voice Channels	Number Of Channels of last level	Speed Mbit/s
DS-0	1	1	64 Кбит/с	1	1	64 Кбит/с
DS-1	24	24	1,544	30	30	2,048
DS-2	96	4	1,544	120	4	2,048
DS-3	672	7	1,544	480	4	2,048
DS-4	4032	6	1,544	1920	4	2,048

Disadvantages PDH:

- difficult input / output of digital streams of intermediate functions,
- lack of automatic network monitoring and management tools,
- there are three different hierarchies for Europe (E), USA (T), and Japan (DS).

OPU Frame Structure



Thank You

Questions?