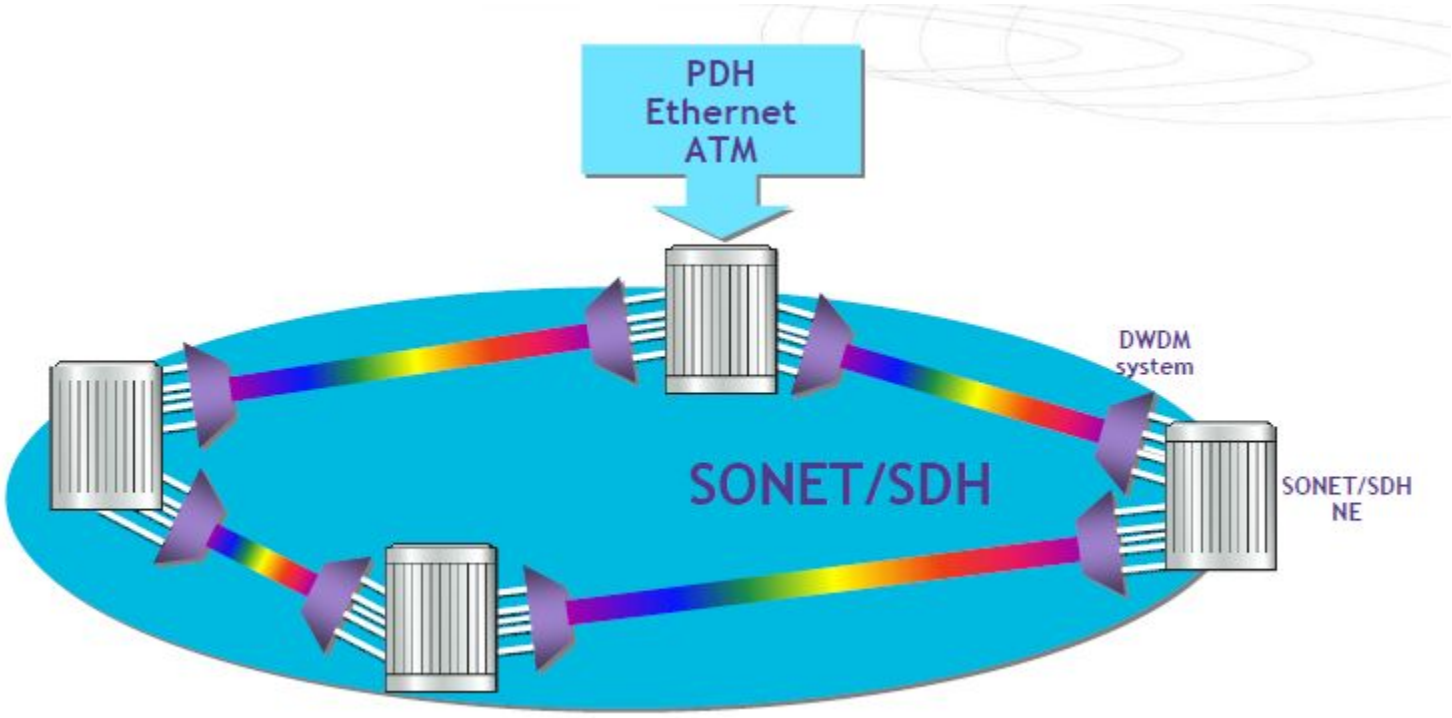
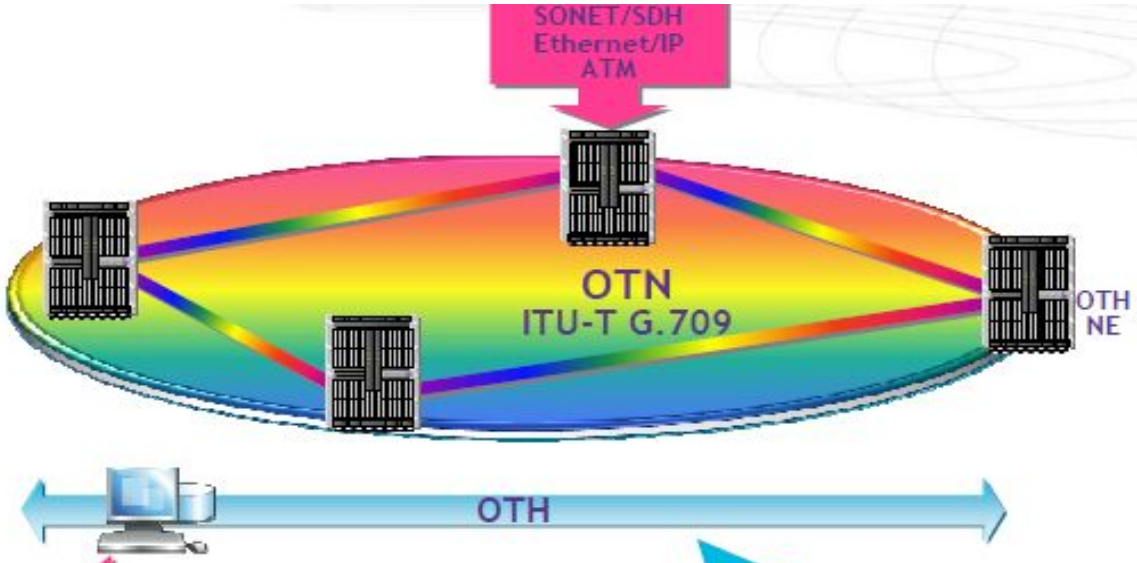
# Введение в оптические транспортные сети OTN

Профессор В.Ю. Деарт

# Передача трафика поверх сети SDH



# Преимущества концепции OTN/OTH



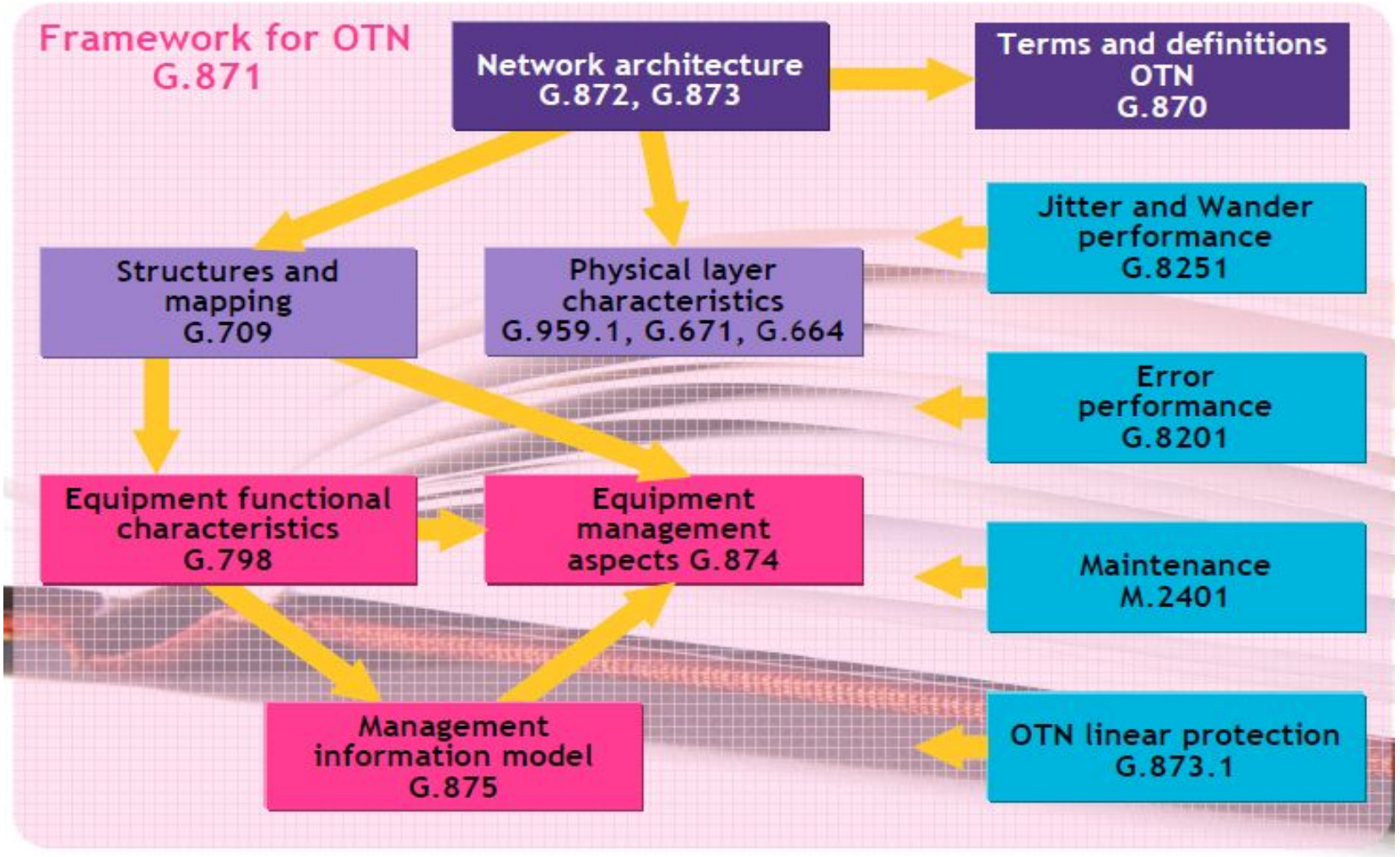

**Functionality**

- Transport / Multiplexing / Routing
- Network and Service Management
- Supervision & Survivability

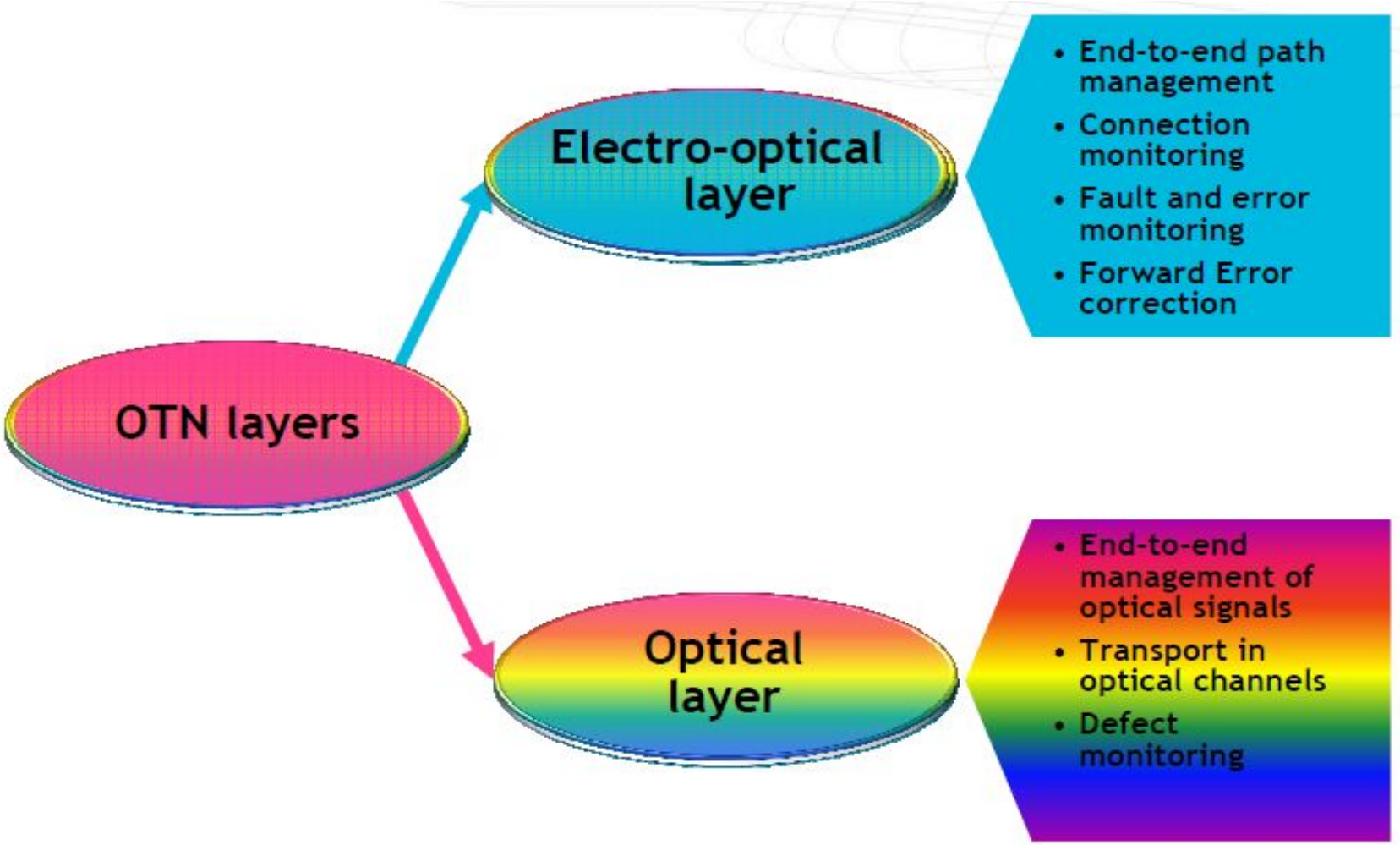
**Advantages**

- Forward Error Correction (FEC)
- More Levels of Tandem Connection Monitoring (TCM)
- Transparent Transport of Client Signals
- Switching Scalability

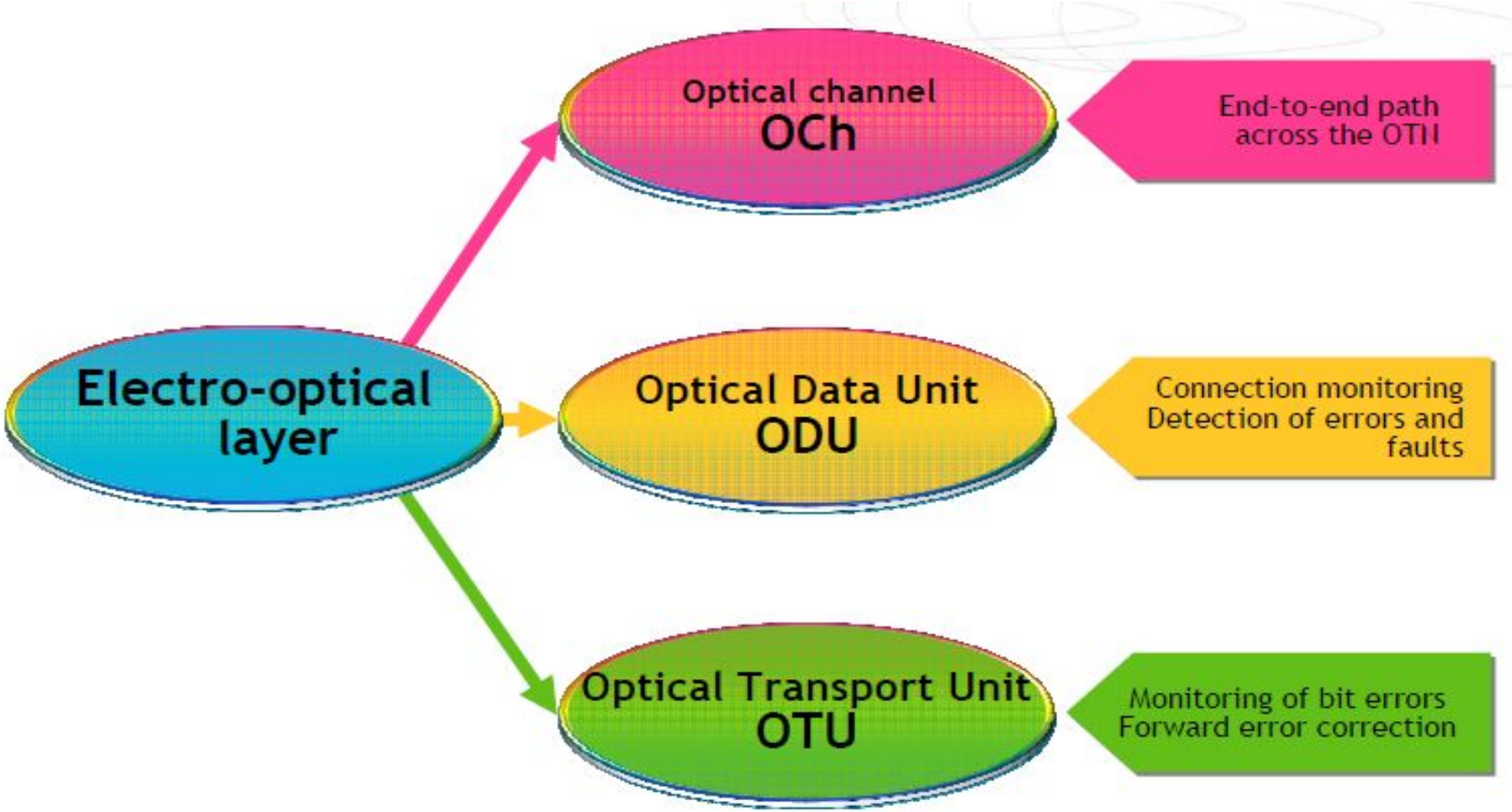
# Сводка Рекомендаций МСЭ-Т по оптическим транспортным сетям OTN



# Электрический и оптический уровни OTN



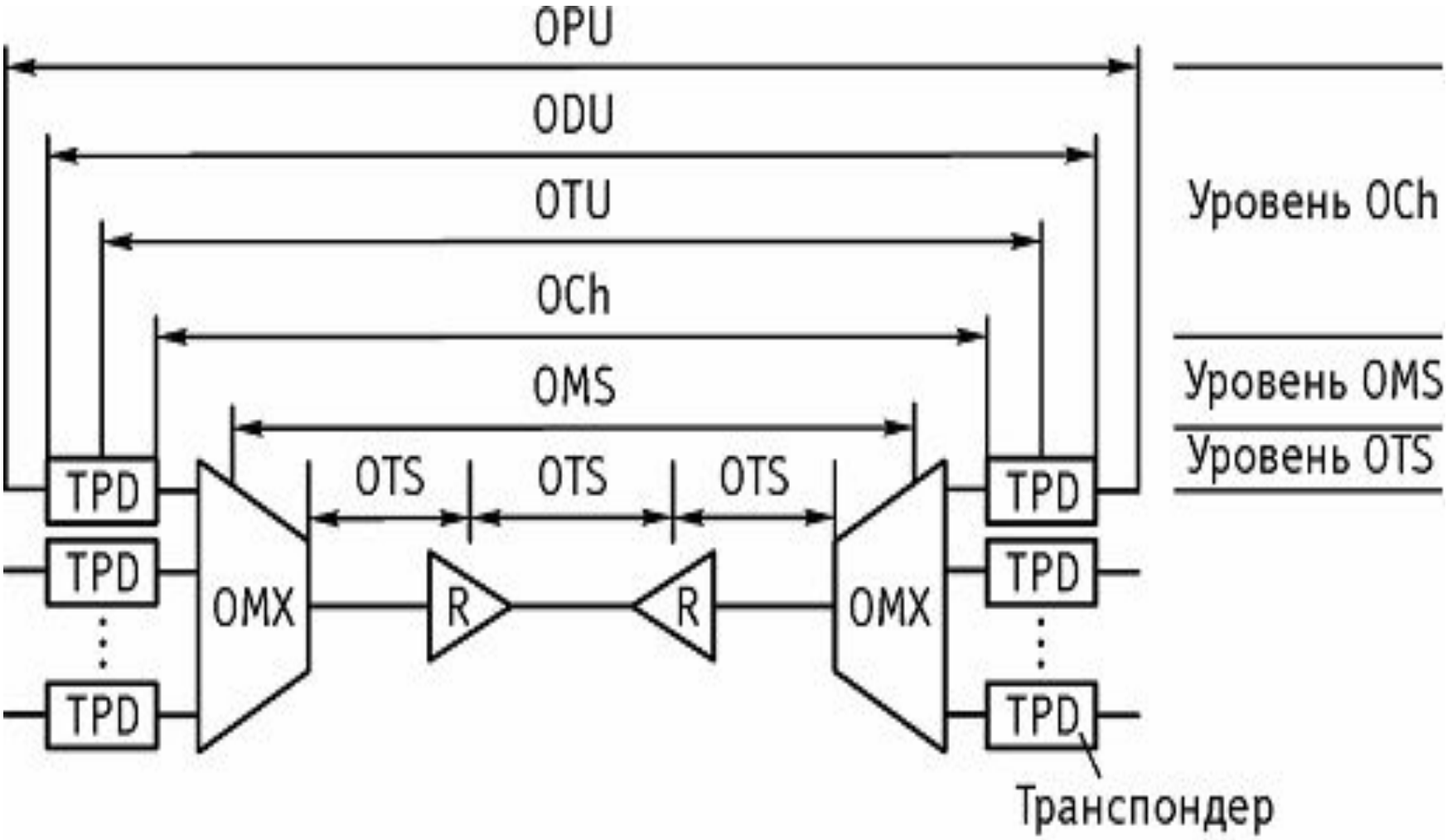
# Электро-оптический уровень OTN



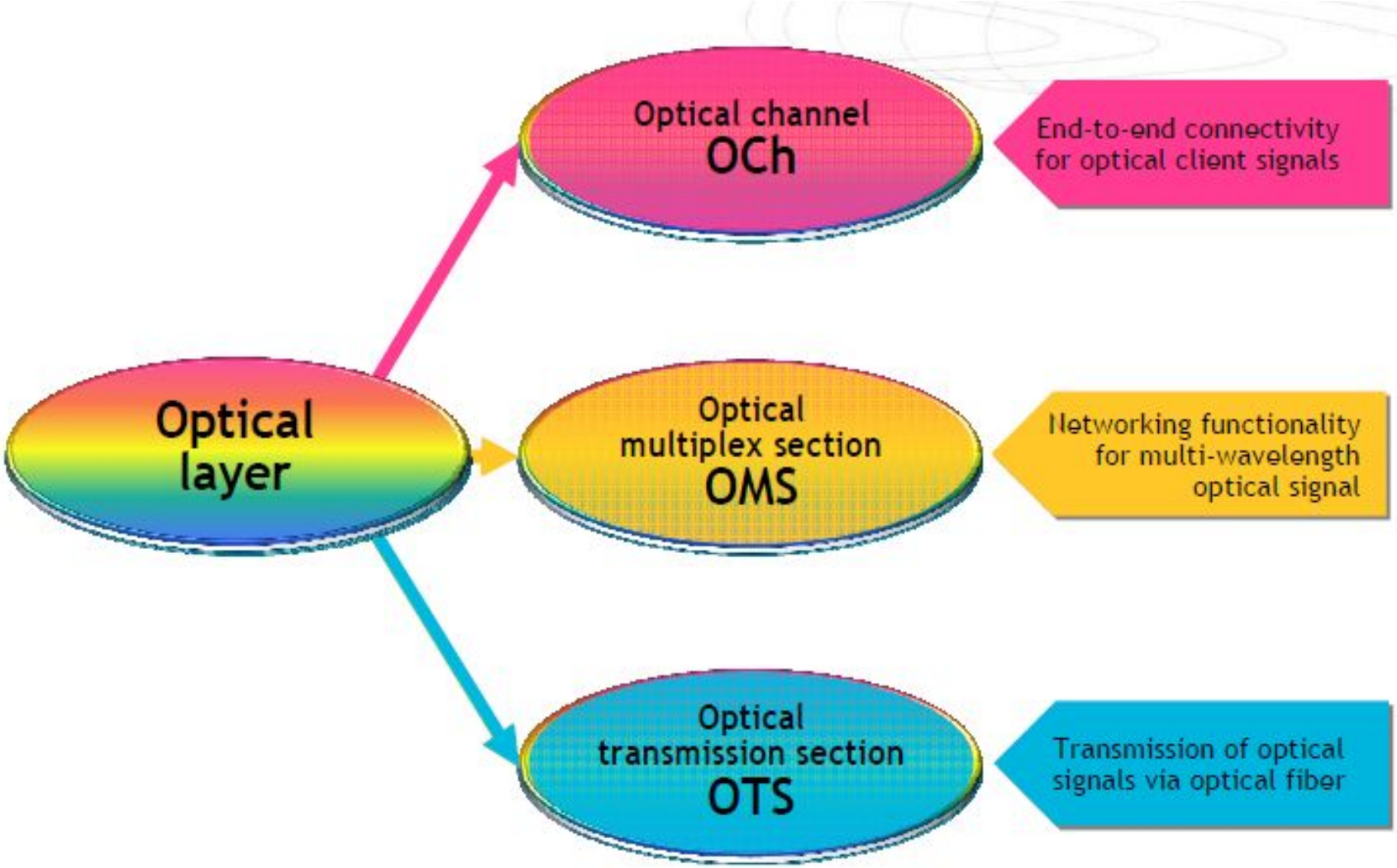
# Подуровни электро-оптического уровня OTN

- The electro-optical layer is composed of three functional sublayers:
- The client signal is mapped into the **Optical Payload Unit (OPU)** layer. The OPU path connects the client equipment in an end-to-end manner and is not changed inside the OTN. The OPU overhead specifies the structure of the payload signal.
- The **Optical Data Unit (ODU)** layer enables monitoring of the end-to-end OPU paths. It enables detection of faults and bit errors and tandem connection monitoring. This information can be used for protection switching purposes.
- The **Optical Transport Unit (OTU)** layer monitors bit errors and faults. It adds additional information for Forward Error Correction as well. The OTU is the last electrical layer. It covers the same network parts as the first optical layer described later on.

# Структура соединения в сети OTN-OTH



# Оптический уровень OTN



# Подуровни оптического уровня OTN(1)

The optical layer is composed of three functional sublayers**: OCh, OMS, OTS.**
The **Optical Channel (OCh)** layer provides end-to-end connectivity for the transparent transmission of the different optical client signals. Therefore it enables optical channel connection rearrangement for flexible network routing. The optical channel corresponds with the OTU of the electro-optical layer. It uses a single wavelength also referred to as “λ” to transport the OTU. The optical channel layer includes overhead information which is transmitted in a separated optical channel, the so called Optical Supervisory Channel (OSC).
This overhead provides supervisory functions for enabling network level operations and management functions, such as connection provisioning, quality of service parameter exchange and network survivability. This includes the assessment of transmission quality and the transmission of defect detection and indication

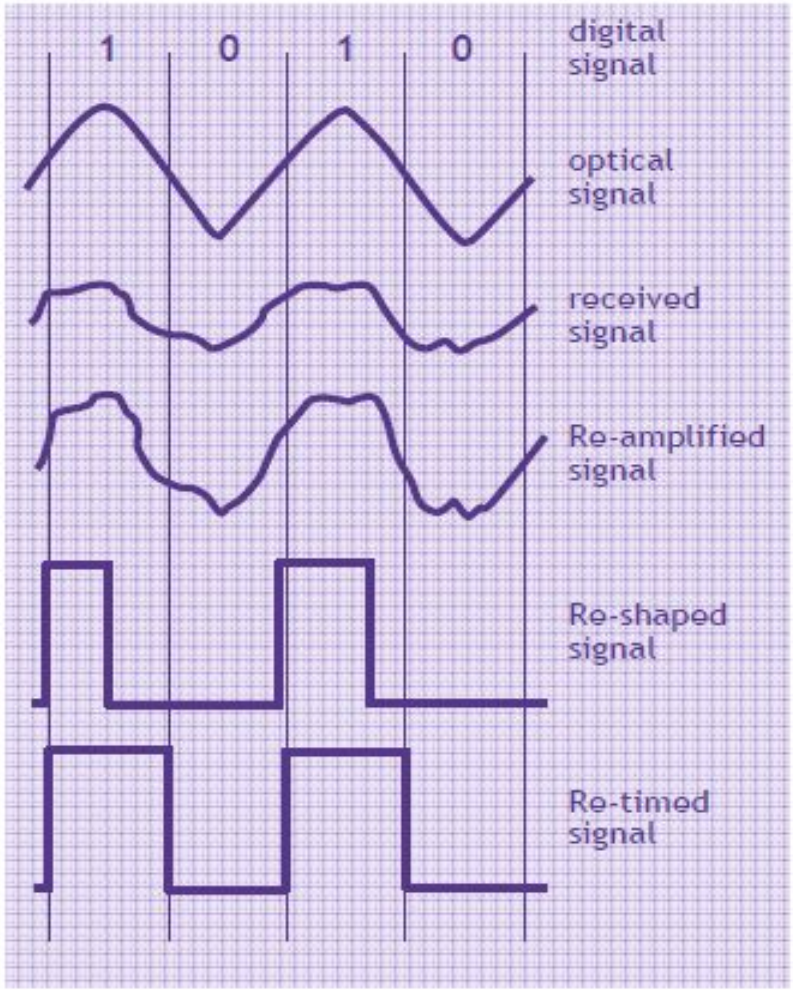
# Подуровни оптического уровня OTN(2)

- Multiplexing several optical channels creates the **Optical Multiplex Section (OMS)** layer. It provides networking functionality for the transmission of a multi-wavelength optical signal. The OMS layer includes overhead information to monitor signal integrity and provide functions for operations and management, such as defect indications. This overhead is transmitted in the Optical Supervisory Channel (OSC) as well.

# Подуровни оптического уровня OTN(3)

- **The Optical Transmission Section (OTS**) layer provides transport function for the OMS layer signal. There is a one-to-one mapping between both layers. The OTS defines the optical parameter of the physical interface such as: Frequency and power level. The optical transmission section layer includes overhead bytes for maintenance and management purposes, which are transmitted in the optical supervisory channel together with the overhead of the optical channel layer and optical multiplex layer.

# Способы восстановления оптического сигнала




**1R**
**Re-Amplification**

- Analogical process
- Applied to optical signal
- Signal amplitude changes

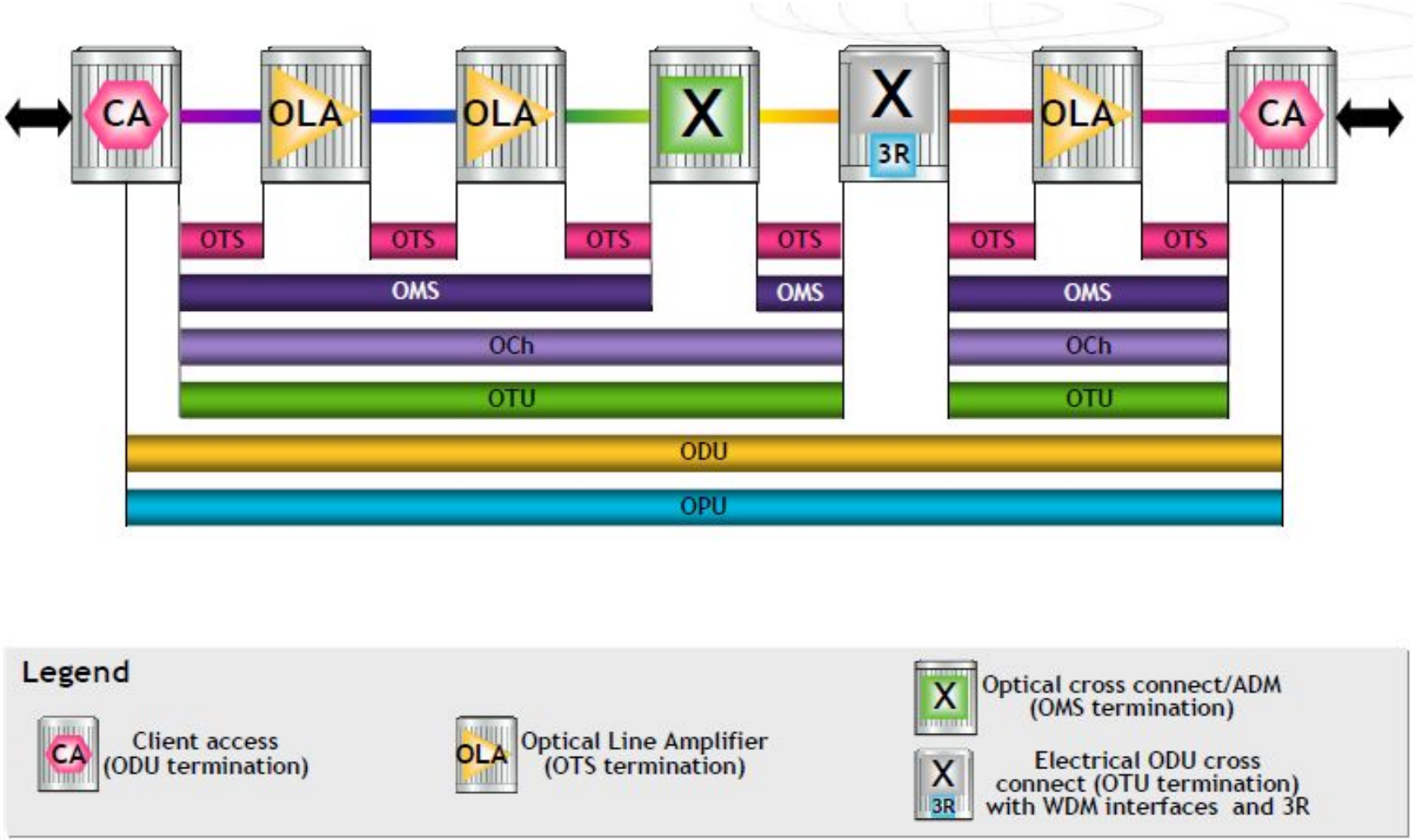
**2R**
**Re-shaping**

- 1R regeneration
- Applied to optical signal
- Digital processing without clock recovery
- Noise suppression
- Not transparent to line code

**3R**
**Re-timing**

- 1R regeneration
- 2R regeneration
- Complete digital pulse regeneration
- Optical-to-electrical conversion

# Пример оптической транспортной сети OTN



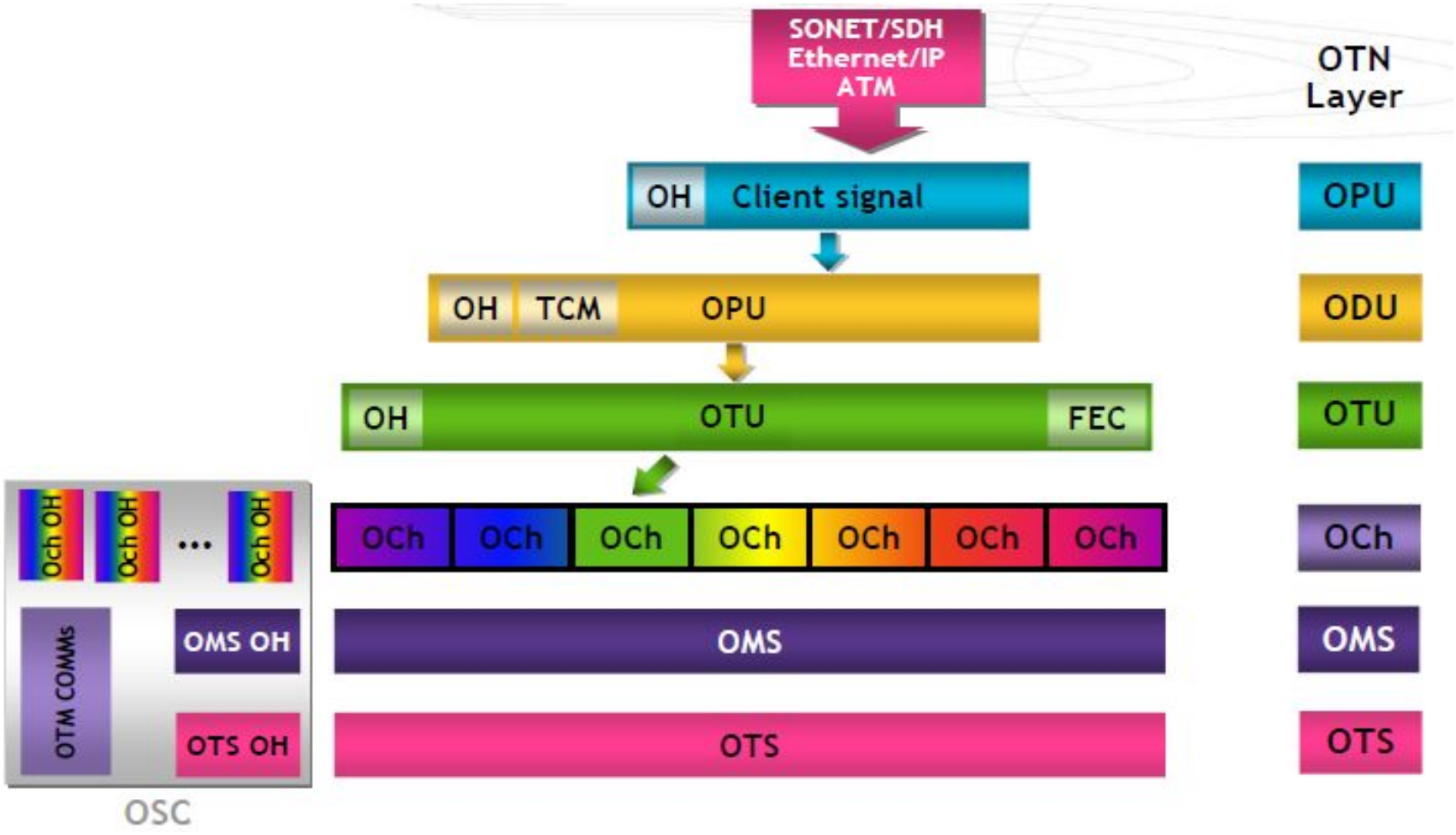
# Организация участков оптической транспортной сети (1)

- The client access **(CA)** equipment mappes the client signal, e.g. an STM-N signal or Ethernet, into the **OPU** and creates the OTH signal. This signal is transmitted through the OTN and terminated at client access equipment.
- To cover long distances optical line amplifiers (**OLA**) are used to amplify the optical signal.
- Optical cross connects or optical add/drop multiplexers are used to switch the optical channels between different ports.
- To switch a single **ODU** signal, which is an electrical layer, it's necessary to terminate higher levels of the signal. This requires optical-electrical conversion, including 3R regeneration. For this operation an electrical ODU cross connect can be used. After switching the ODU, an electrical-to-optical conversion is performed to build the optical **OTS** signal.
- The optical transmission section **OTS** with its associated overhead is terminated at each network element.

# Организация участков оптической транспортной сети (2)

- The optical transmission section **OTS** with its associated overhead is terminated at each network element.
- **Optical cross connects** or optical add-drop multiplexers switch on optical level only. They do not perform optical-electrical-optical conversion. Therefore only the **OMS** needs to be terminated.
- If an optical-electrical conversion has to be performed, the complete optical section has to be terminated, including the optical channel and OTU path using **Electrical ODU cross connect**

# Размещение клиентского сигнала и мультиплексирование оптических каналов



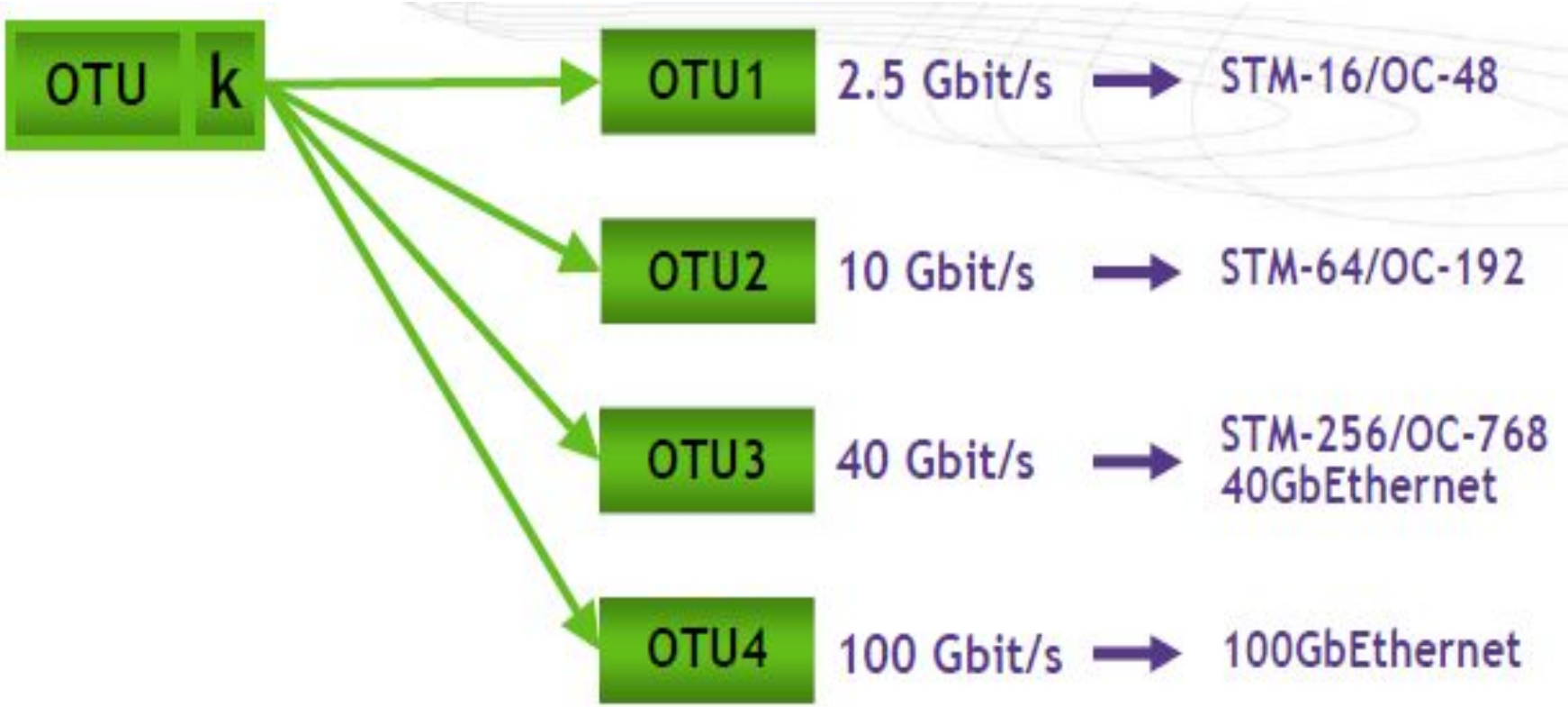
# Электро-оптические уровни OTN

- The client traffic is mapped into the payload area and the overhead bytes are added. This results in the **Optical Payload Unit (OPU).**
- The next layer is based on the OPU: To the OPU, overhead bytes and bytes for Tandem Connection Monitoring (TCM) are added to built **the Optical Data Unit (ODU).**
- The ODU together with overhead bytes and bytes for Forward Error Correction (FEC**) represent the Optical Transmission Unit (OTU)**, the last electrical layer.
- The **OTU** is then converted into an optical channel of a specific wavelength. Several wavelengths are multiplexed.

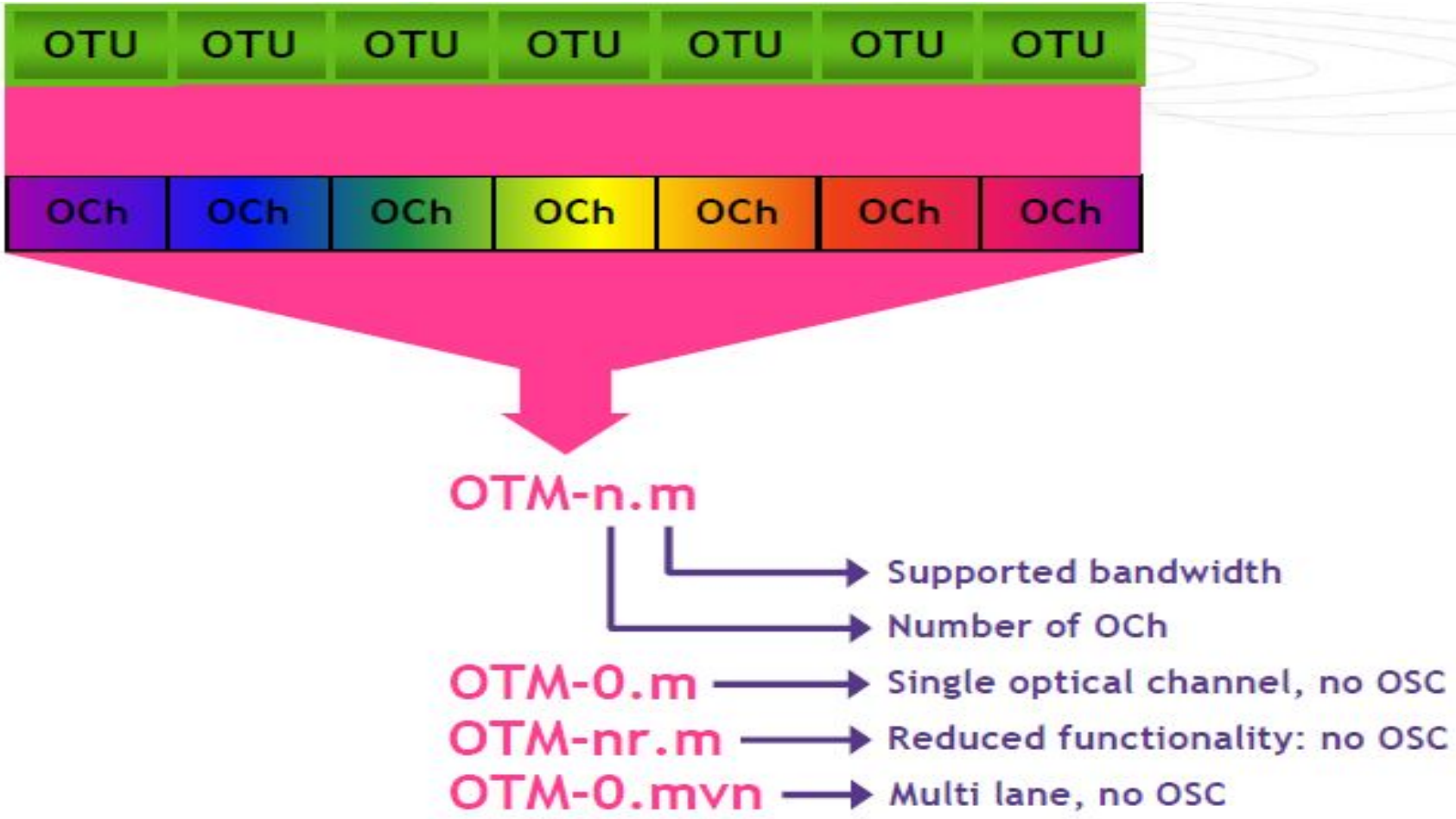
# Секция мультиплексирования OMS и секция передачи OTS

- Additional overhead bytes for each optical channel are added. They are not transmitted on the same wavelength as the optical channel. This additional channel is called the **Optical Supervisory Channel (OSC).**
- The optical channels together with additional overhead bytes built the **Optical Multiplex Section (OMS).** The overhead bytes are transmitted in the OSC as well.
- For the **Optical Transmission Section (OTS)** overhead bytes are added again. They are transmitted in the OSC also.
- In the OSC additional **OTM** communication channels are transmitted for management purposes.

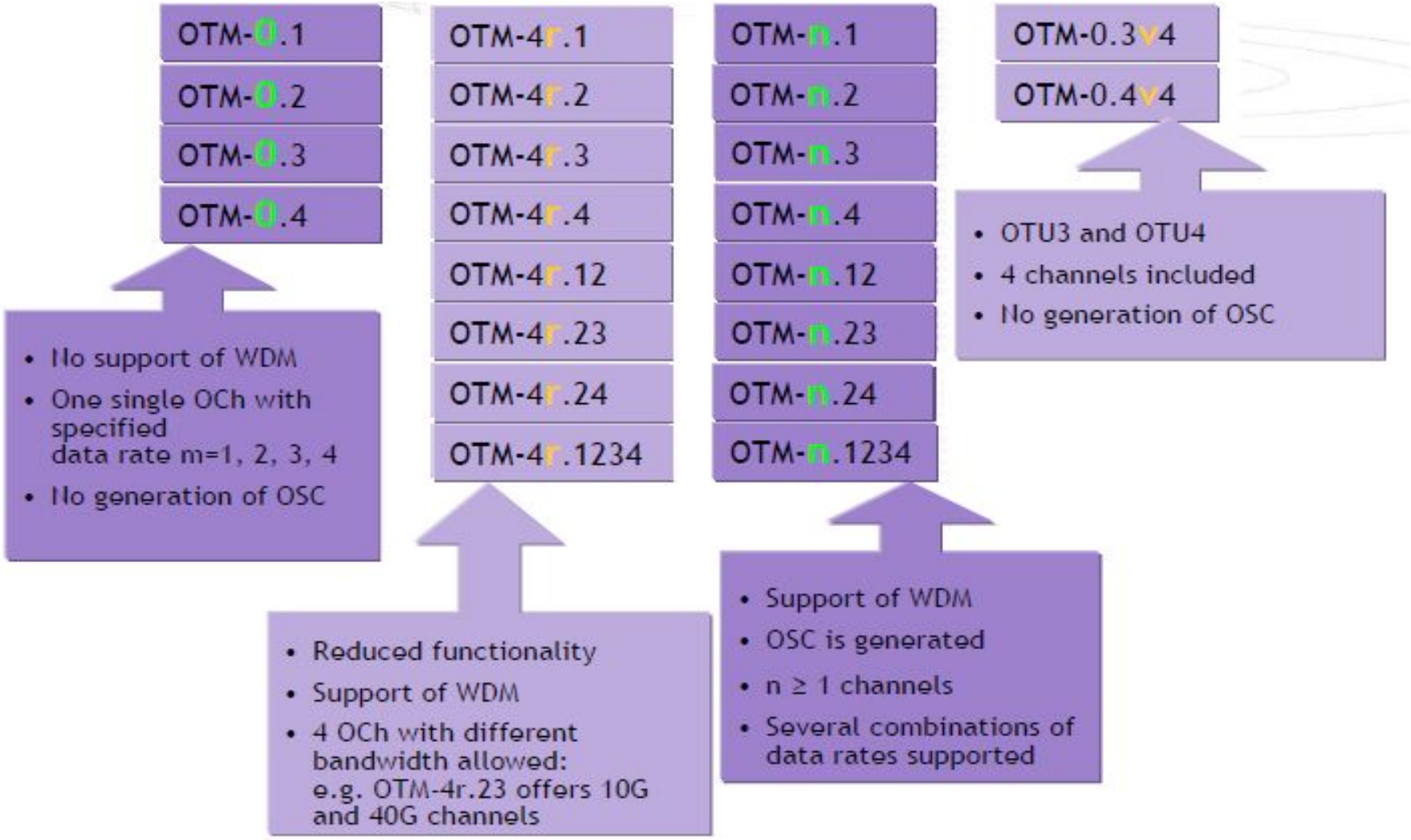
# Оптические транспортные модули (1)



# Оптические транспортные модули(1)



# Структуры транспортных модулей (1)



# Структуры транспортных модулей (2)

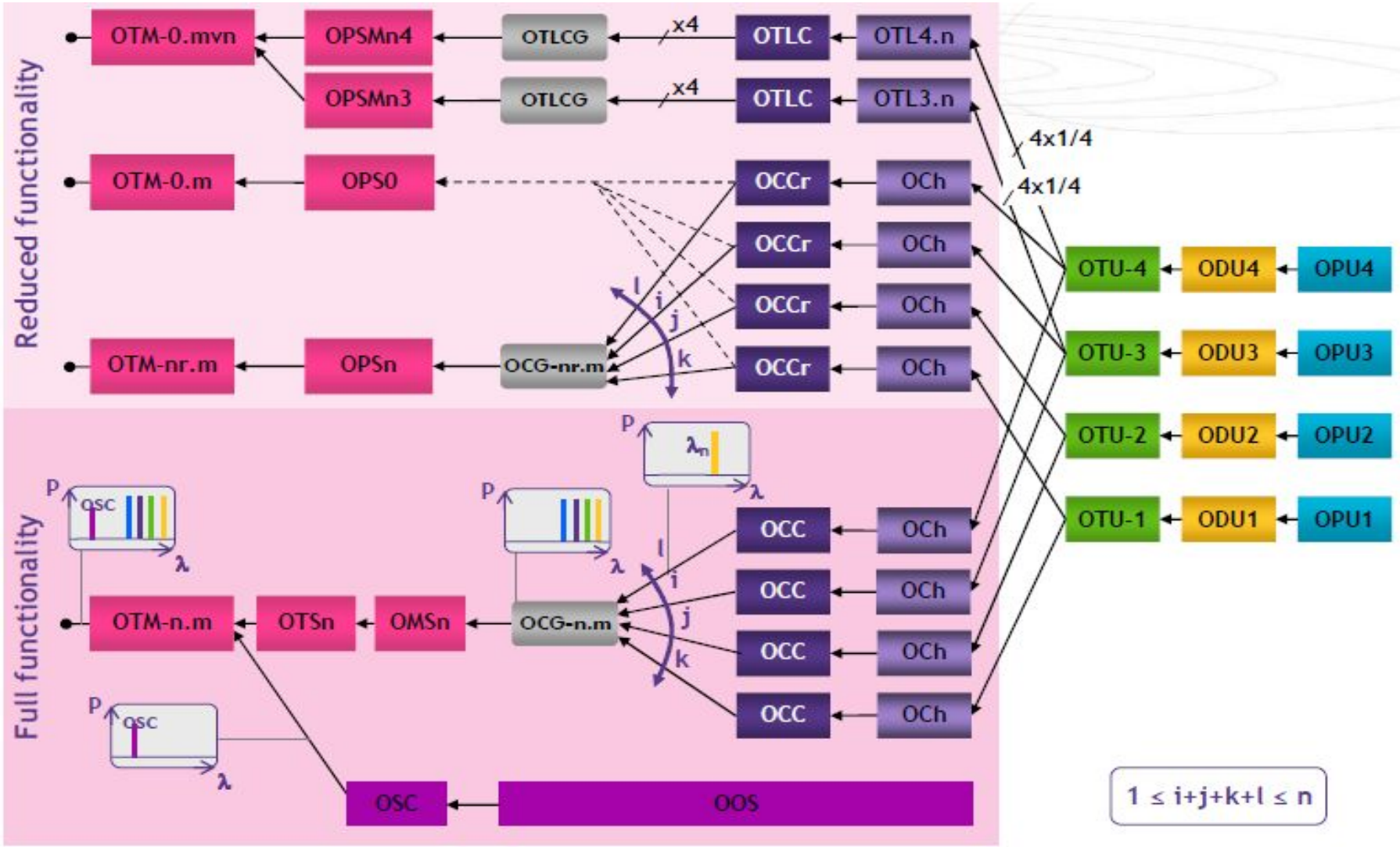
In **the OTM-0.m** the “0” refers to a special case of reduced functionality: In this case **no WDM** functionality is supported, therefore only a single optical channel is transmitted. So the value “m” can only identify one single OTU level: OTU-1 to OTU-4.

**The OTM-4r.m** refers to the reduced functionality, so again no OSC is generated in this case. WDM function is supported. The OTM in this example carries four optical channels. Any mixture of different OTU levels is possible.

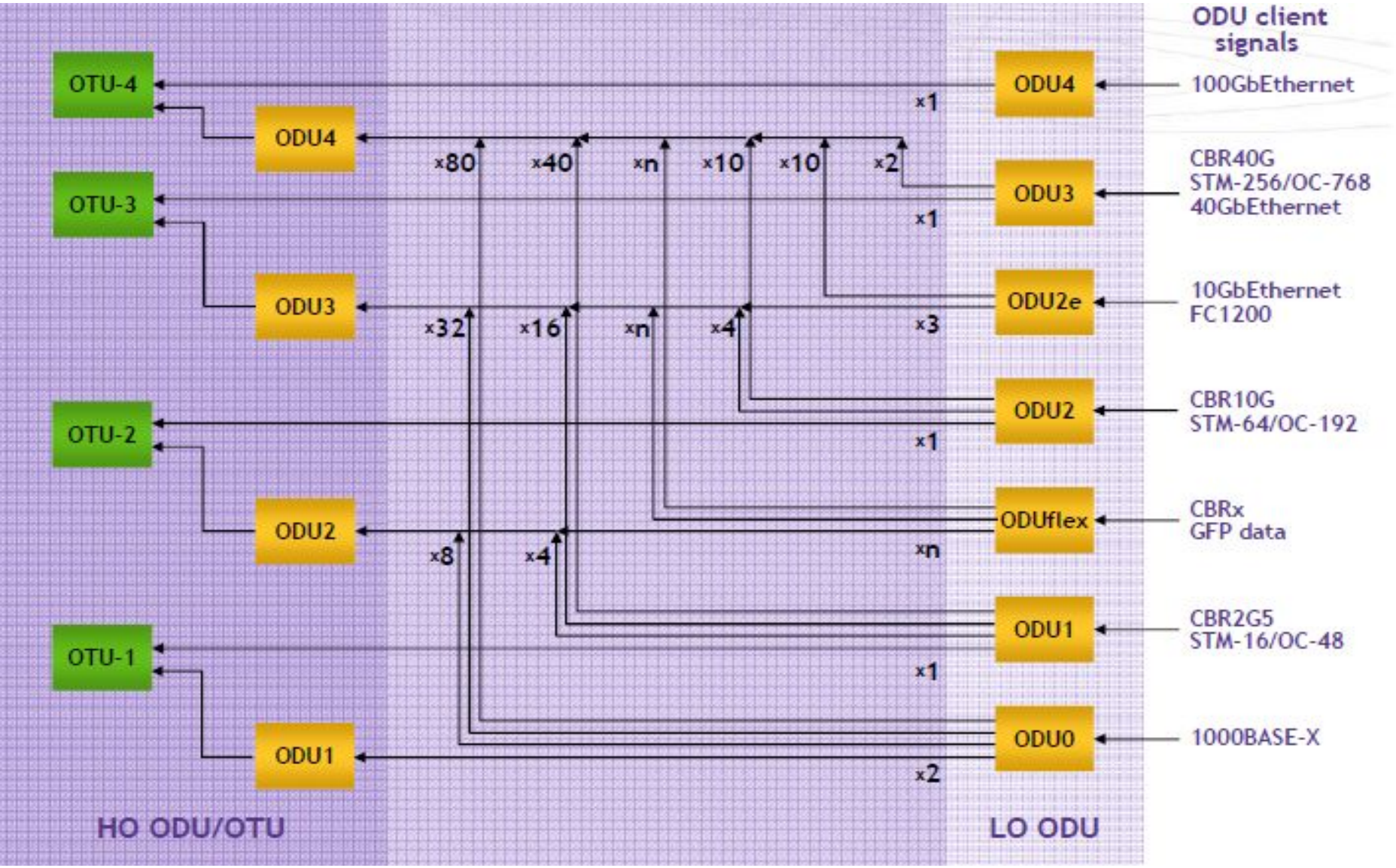
The **OTM-n.m** refers to the general and complete OTH signal. It supports WDM functionality t carry several optical channels and the generation of the OSC. The number of channels included in the OTM is given by value “n”. “m” refers to the OTU levels multiplexed in the OTM.

In case of the **OTM-0.mvn** a multilane optical signal is supported. It is only available for OTUk levels 3 and 4. This OTM carries four optical channels over which the OTUk is distributed in a virtually concatenated manner. No OSC is created in this case.

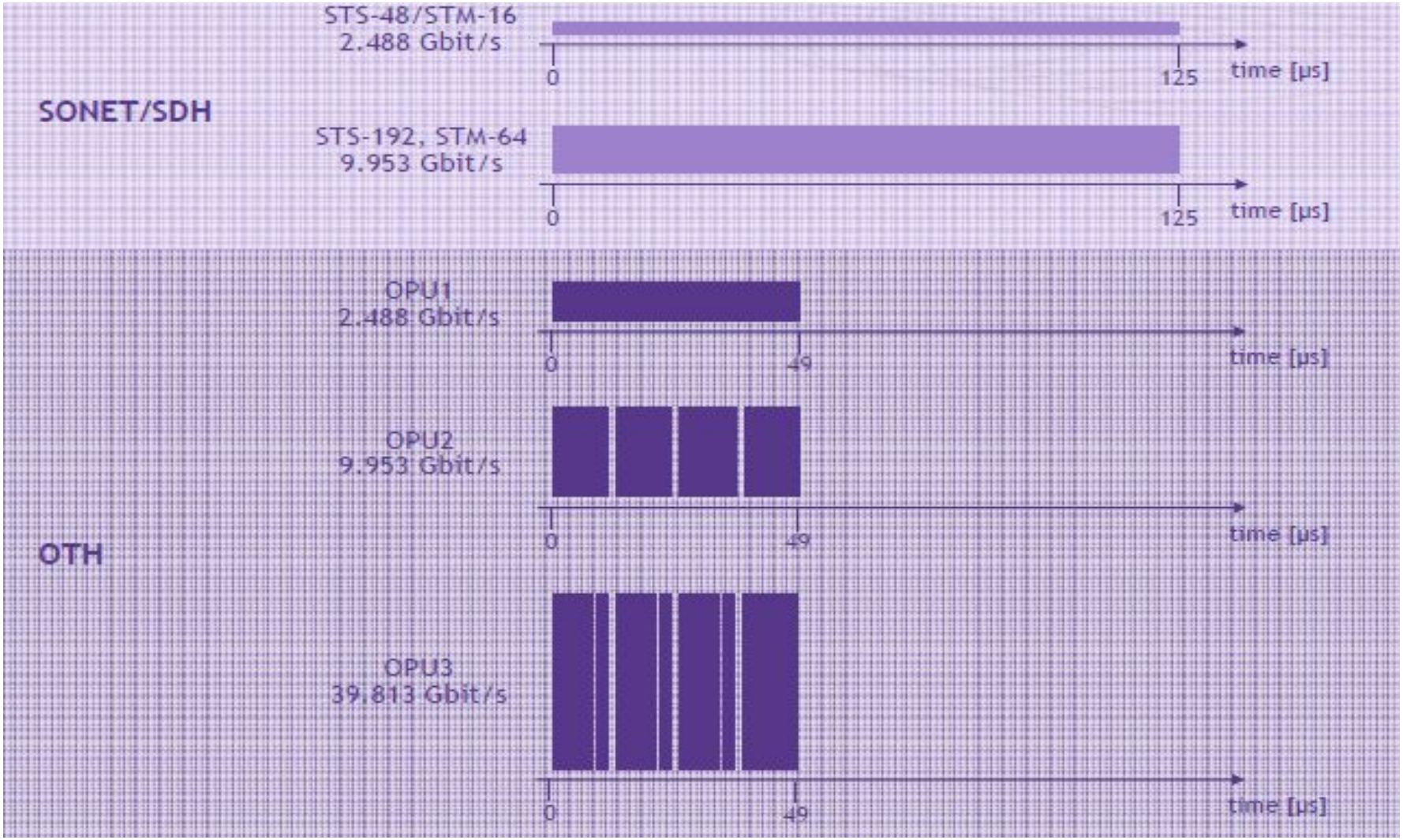
# Схема мультиплексирования OTM



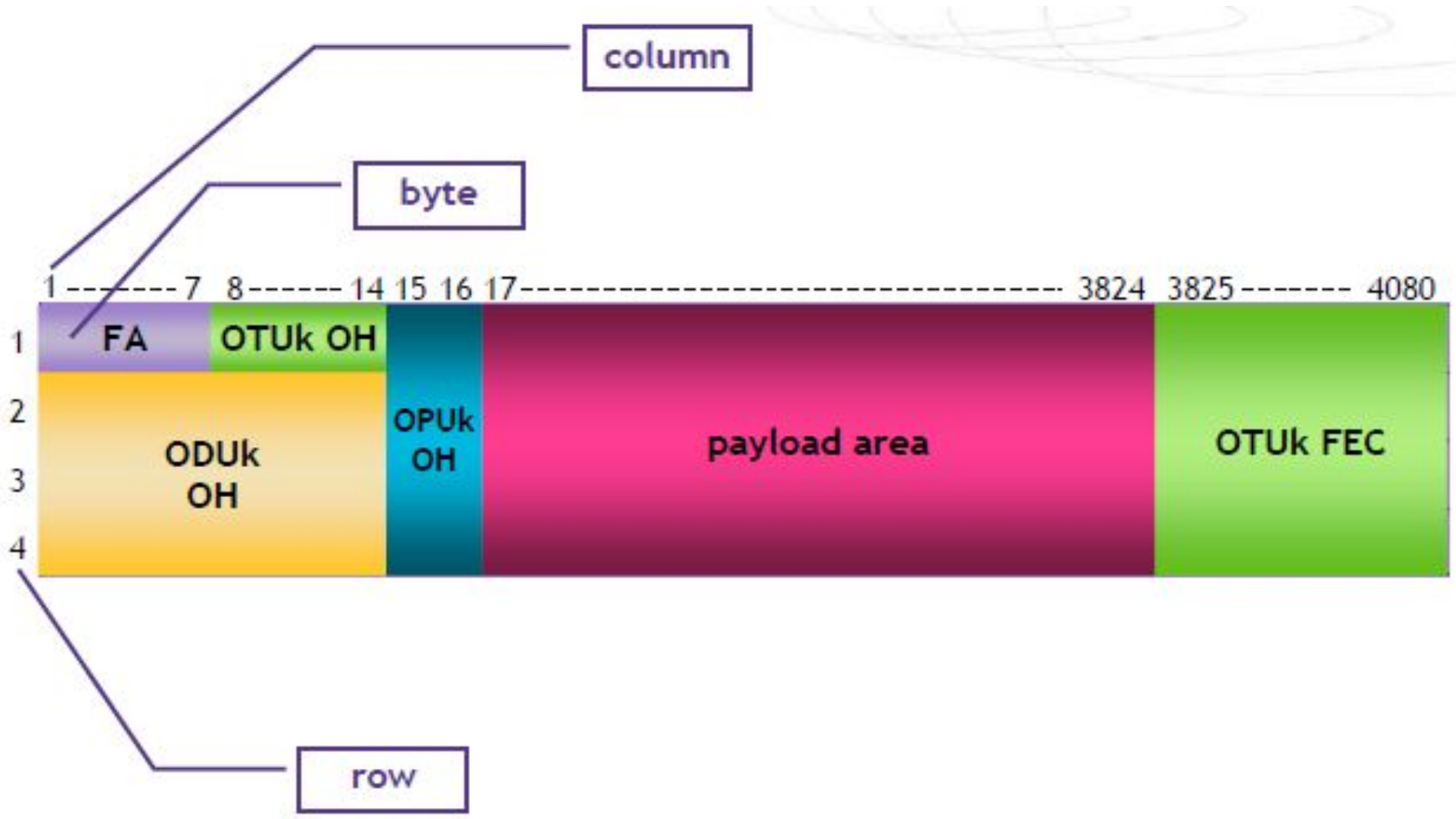
# Структура мультиплексирования OTU



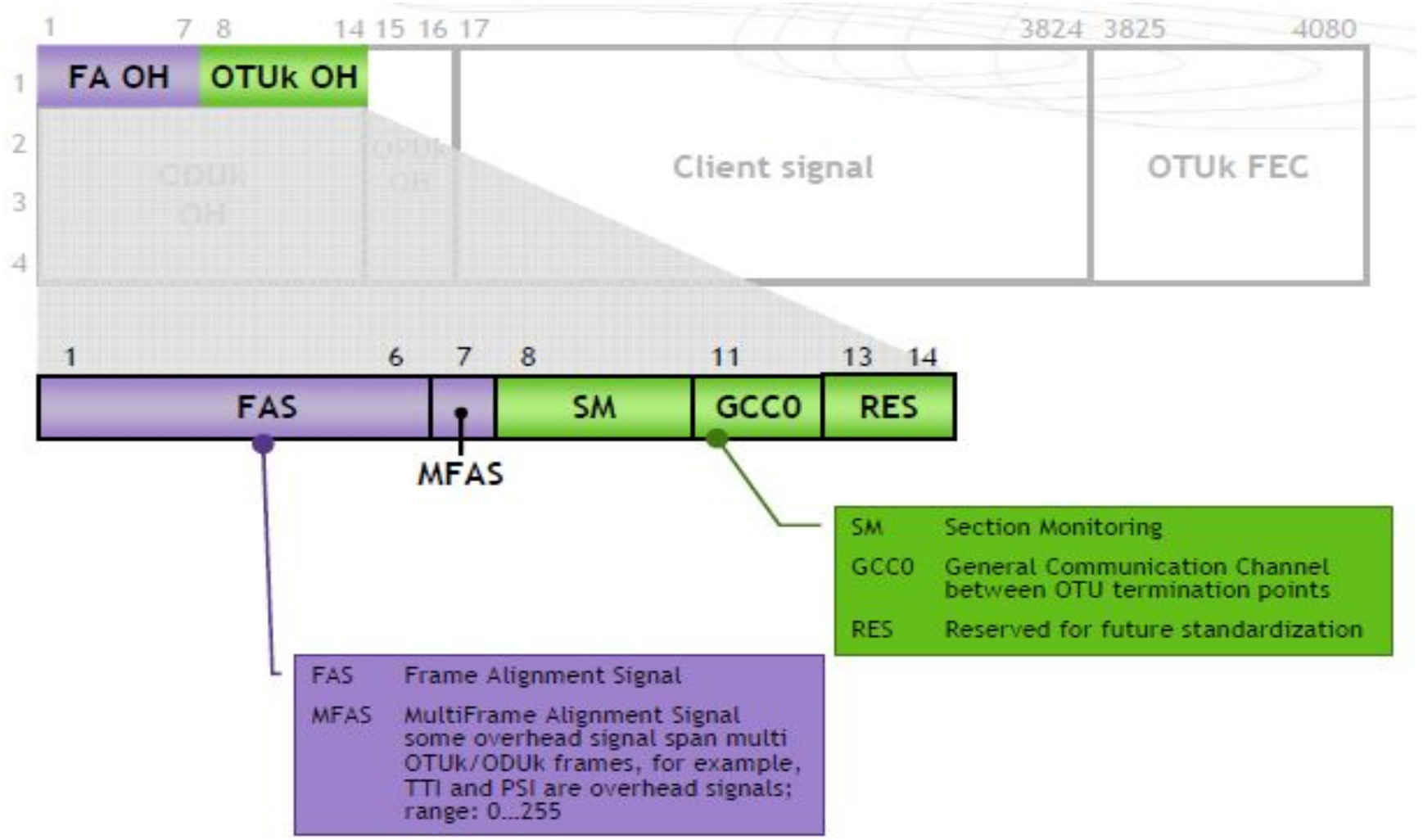
# Передача кадров в OTH



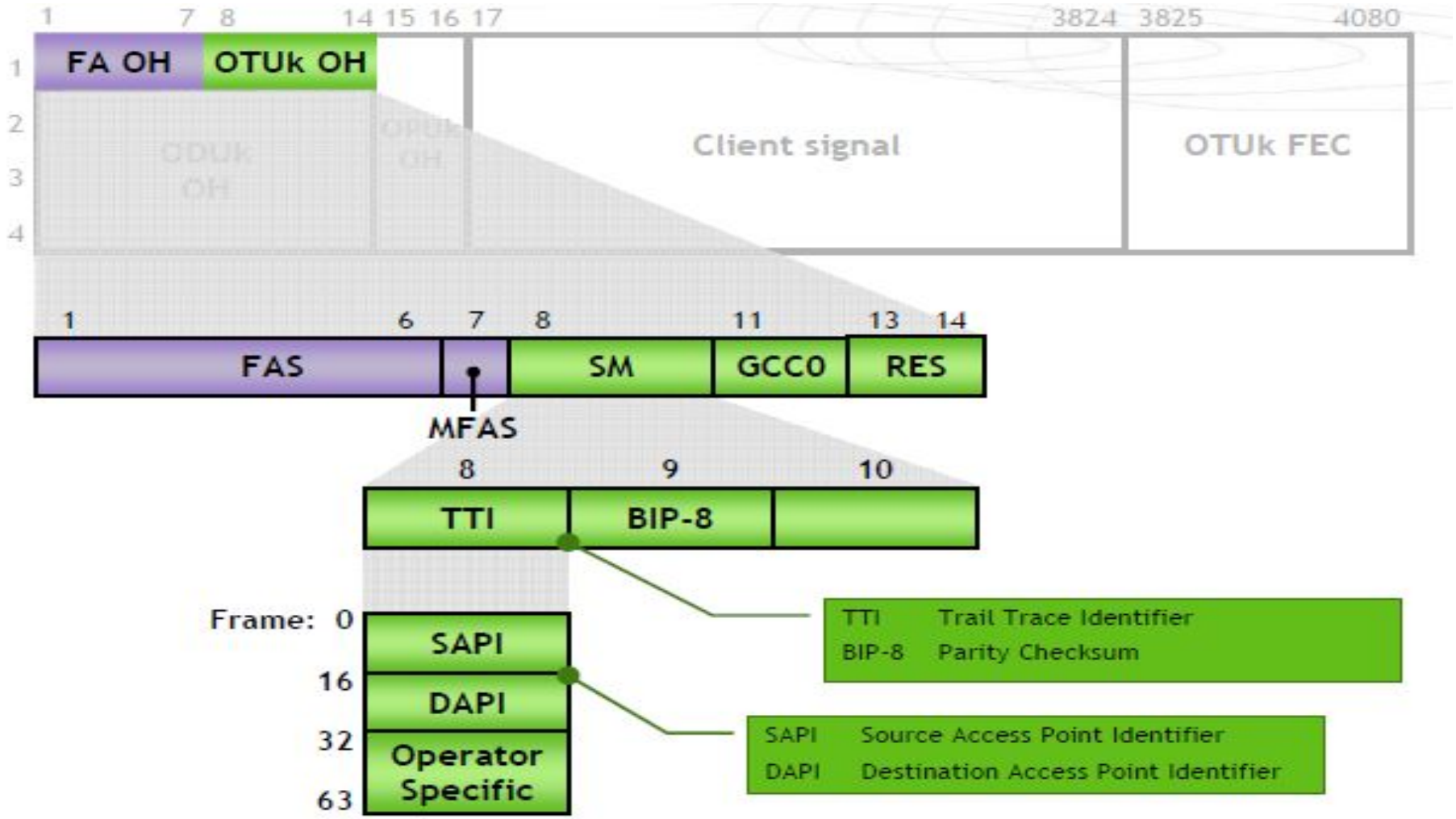
# Структура кадра OTH



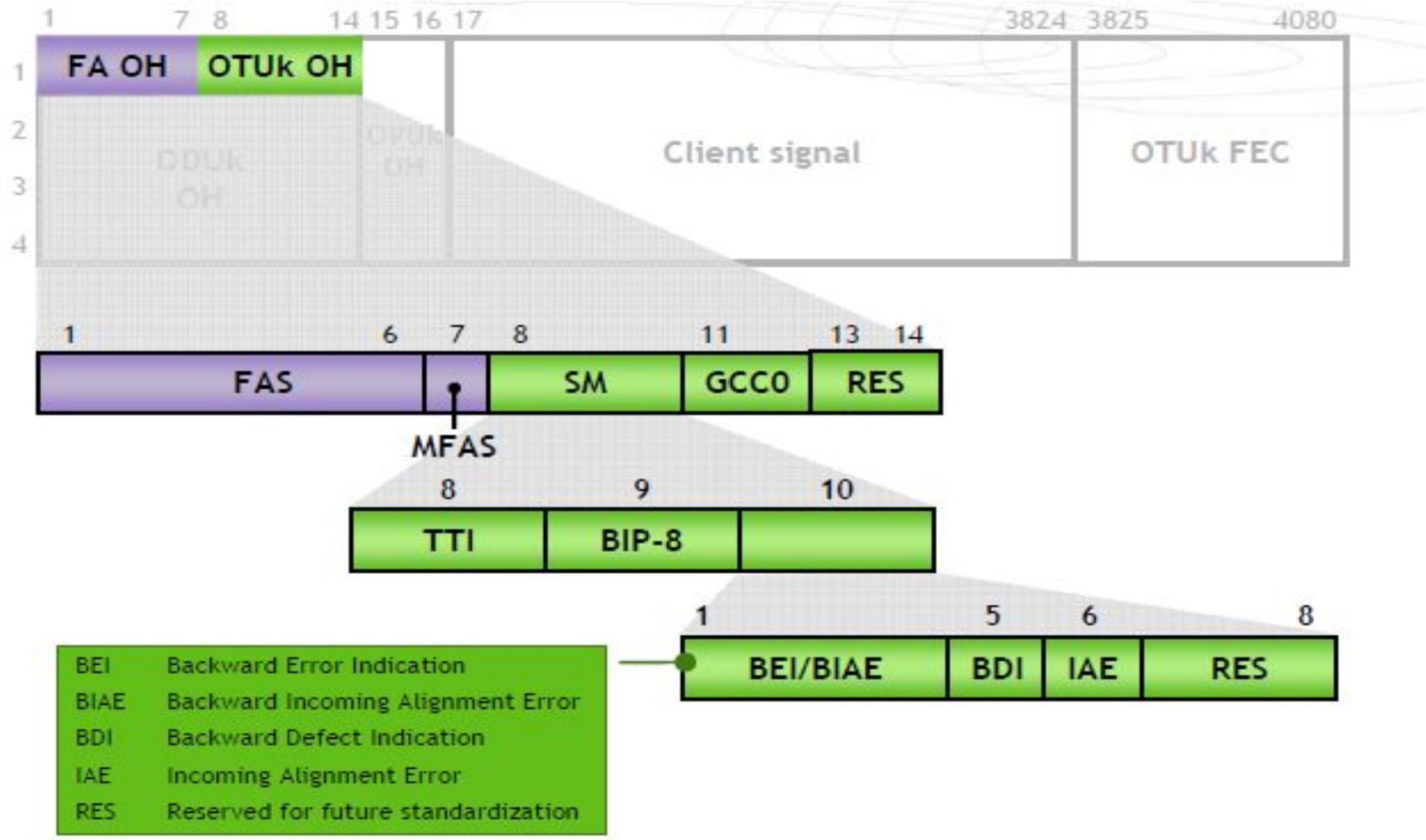
# Структура заголовка OTUk(1)



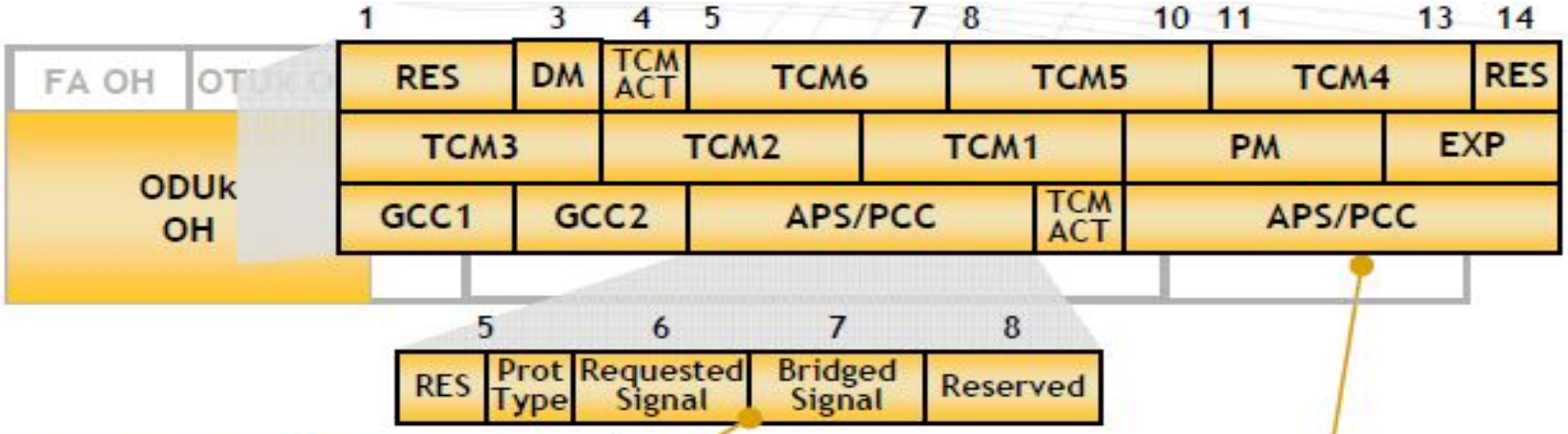
# Структура заголовка OTUk(2)



# Структура заголовка OTUk(3)



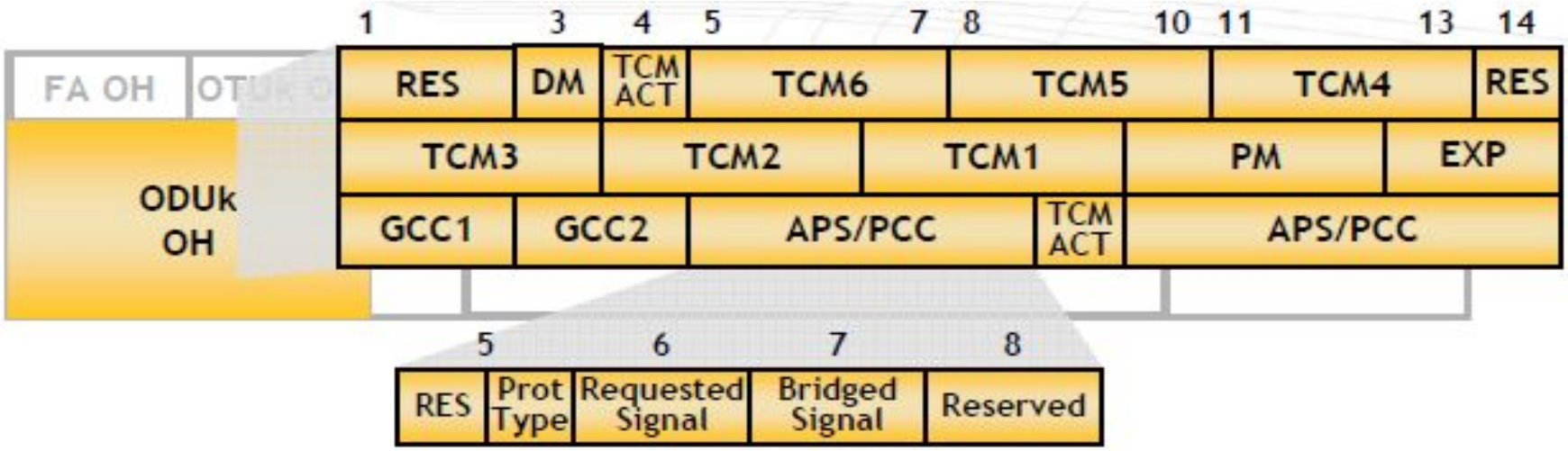
# Структура заголовка ODU (1)

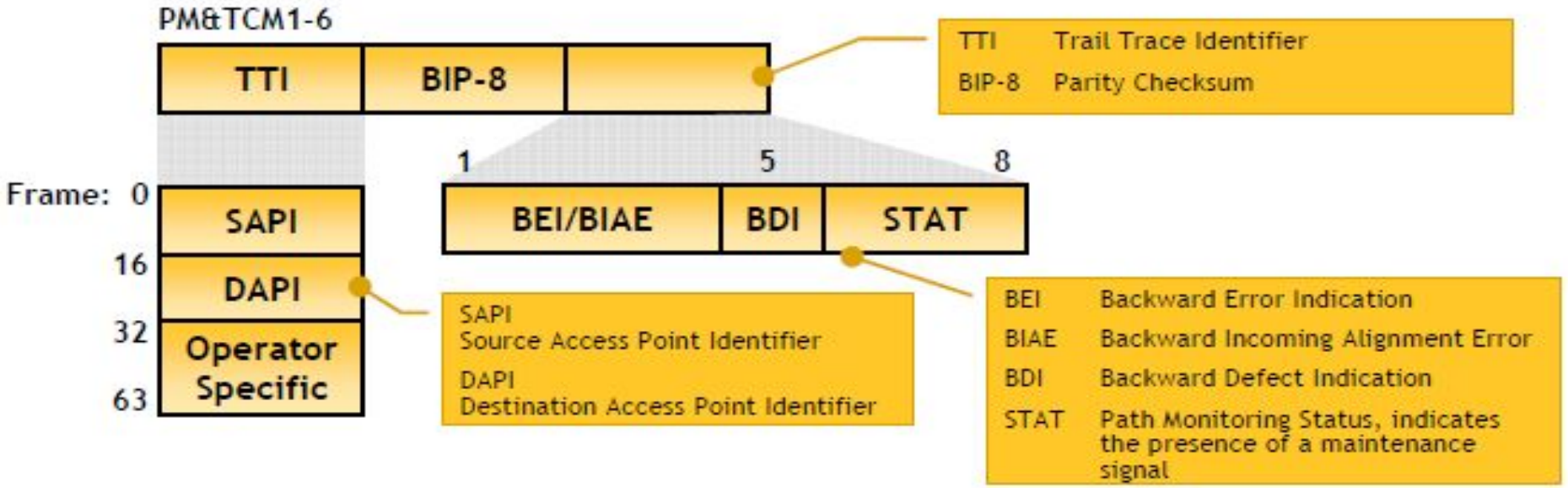



| | |
|---|---|
| APS | Automatic Protection Switching coordination channel; 8 APS channel available for ODUk path and section and 6 TCM level monitoring |

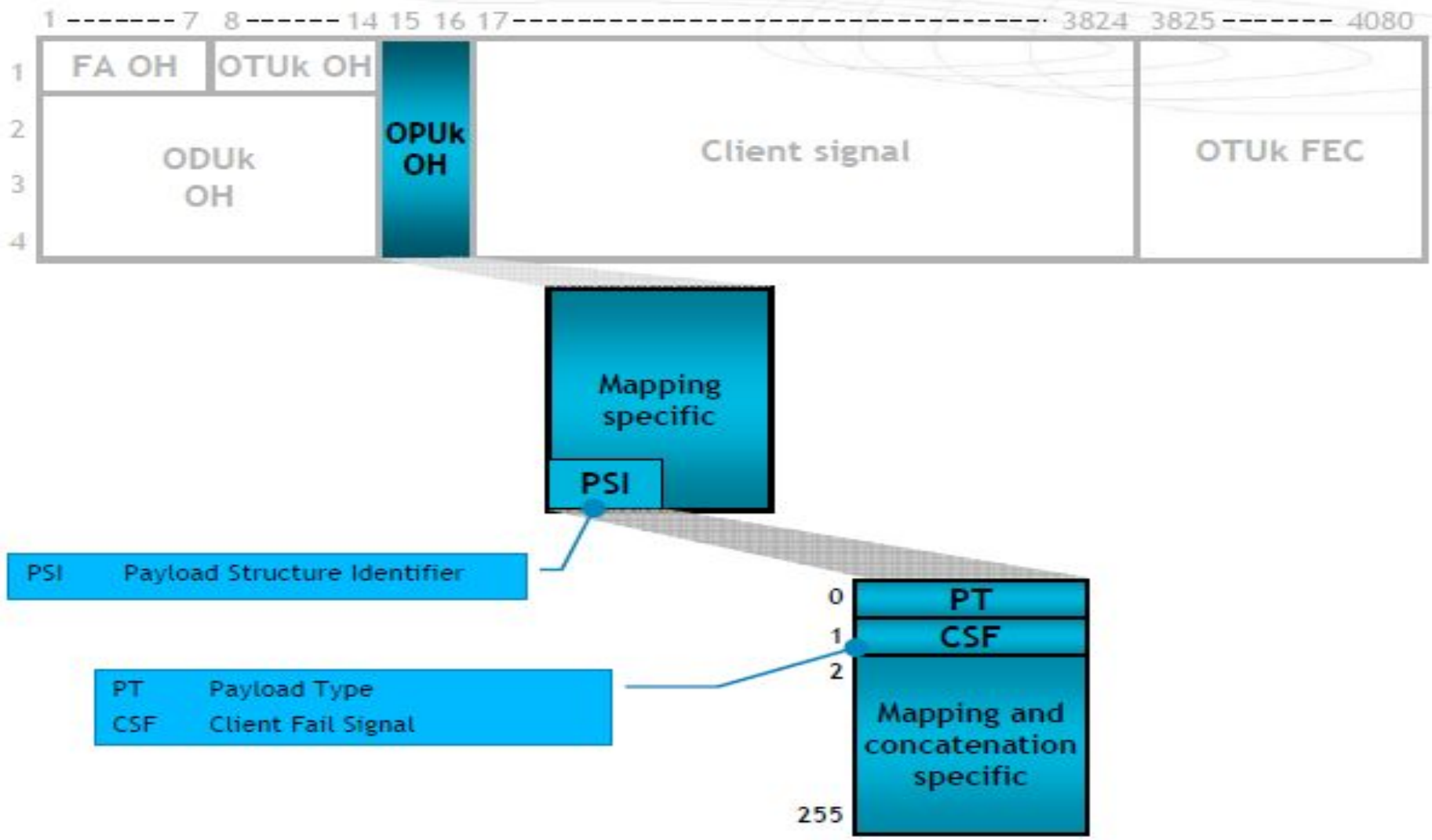
| | |
|---|---|
| RES | Reserved for future standardization |
| DM | Delay Measurements for ODUk path or tandem connection |
| TCMACT | Activation/deactivation control channel |
| TCM | Tandem Connection Monitoring |
| PM | Path Monitoring |
| EXP | Experimental |
| GCC | General Communication Channel (clear channel) |
| PCC | Protection Communication Control channel |

# Структура заголовка ODU (2)

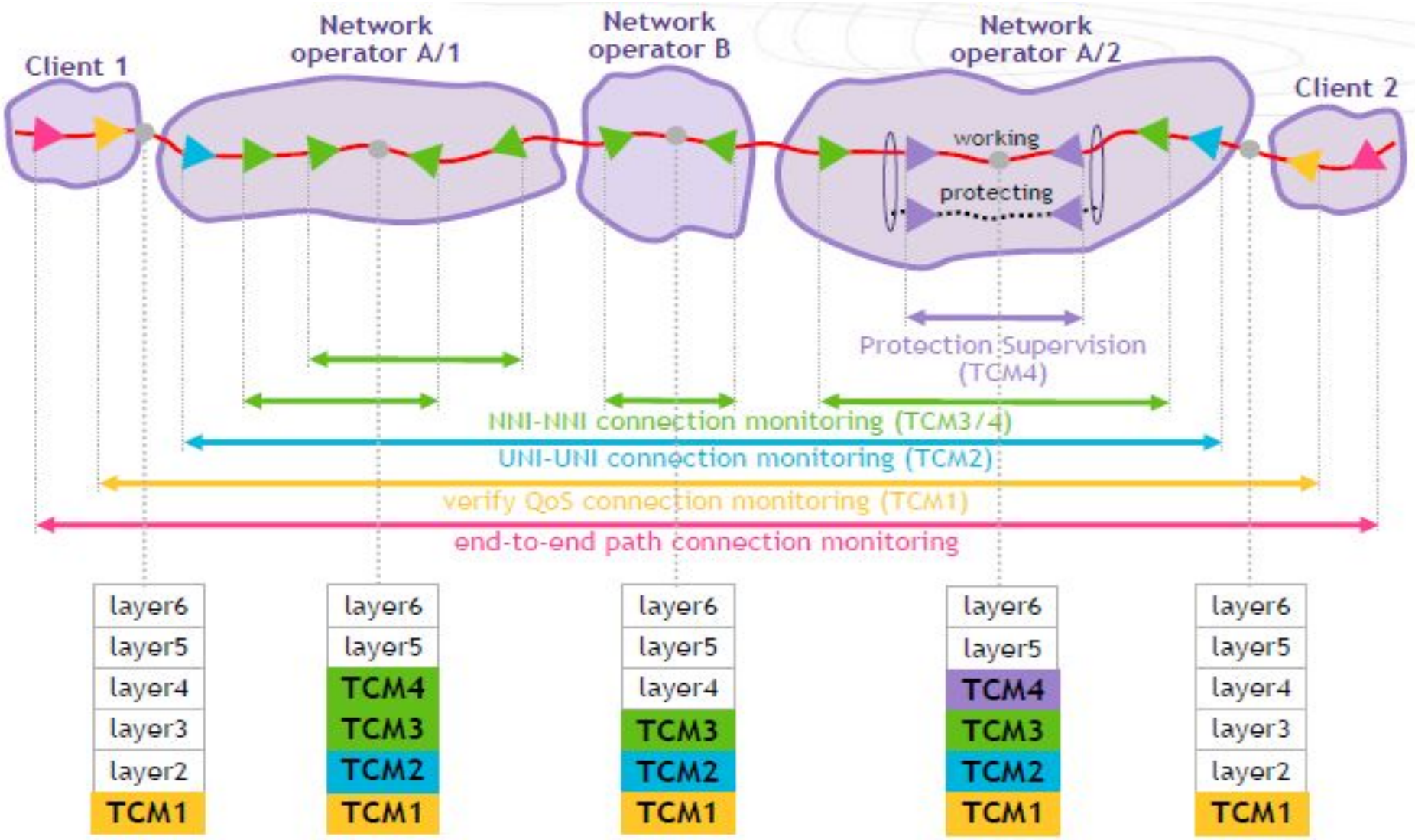


# Структура заголовка OPU



# Уровни контроля модемных соединений TCM



# Проверочное поле FEC


## FEC functions

- Reed-Solomon RS
- Identify transmission errors
- Correct transmission errors
- Up to 32 bit errors correctable

## FEC benefits

- Reduction of 3R regenerators
- Using higher bandwidth
- Gain in power level
- Early warning tool

# Размещение кодовых слов RS в кадре OTH