TAI Workshop

Attribute Enhancement

2021/6/16

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Phoenix

NTT

- A 400G Capable layer 1 white box device based on open and disaggregated architecture for exiting metro/backhaul, Backbone network and Data Center Interconnection
- Disaggregated components (HW and SW from different technology providers)

Image of Phoenix

Line Interfaces

- 60km to 1750km with 100KM increments
- C&L Band
- 100/200G BPSK, QPSK
- 8/16/32/64 QAM
- 200/300/400G 16 QAM

OFC2021 Open Networking Summit:
Data Plane Compatibility

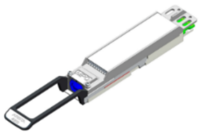
List of Interconnection Modes

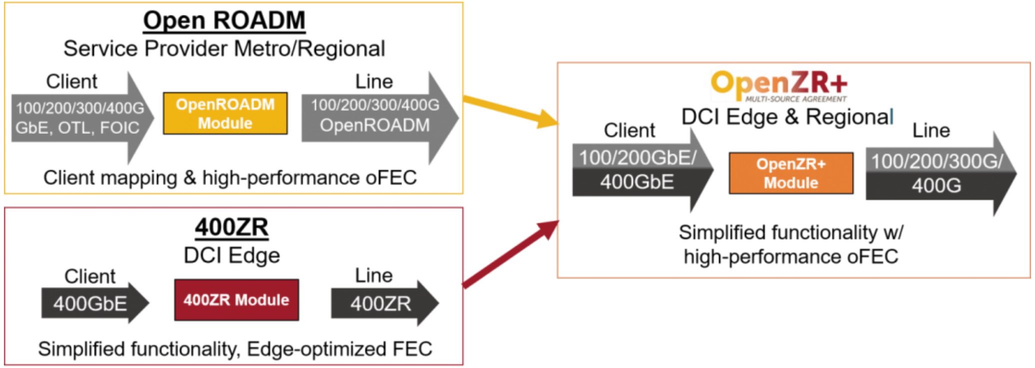
Capacity [bps]	100G	200G	300G	400G	
Modulation format	DP-QPSK	DP-QPSK	DP-8QAM	DP-16QAM	DP-16QAM
FEC type	SC-FEC	oFEC	oFEC	CFEC	oFEC
FEC OH [%]	7	15	15	15	15
FEC NCG[a] [dB]	9.3	11.1	11.6	10.8	11.6
Interoperability	CableLabs Open ROADM ITU-T IEEE802.3ct[b]	CableLabs Open ROADM	Open ROADM	OIF ITU-T IEEE802.3cw[b]	Open ROADM ITU-T

[a] Net coding gain, SNR.
[b] Project underway.

Standardized

Data signal
(Standard FEC/flame mapping)



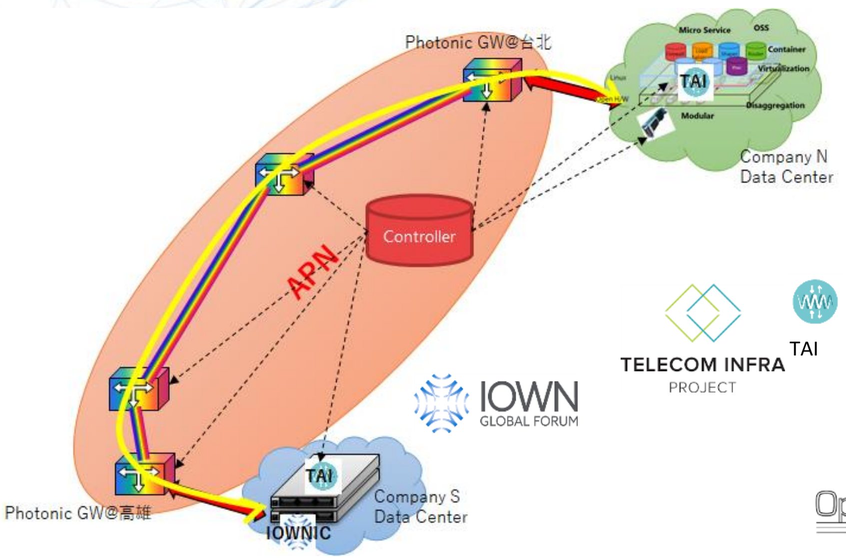


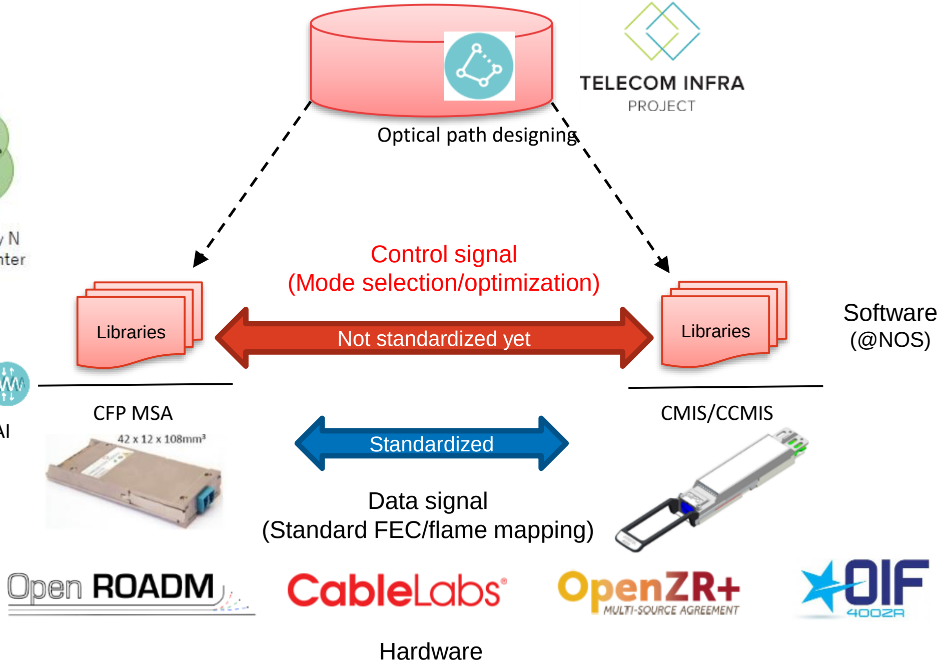
Open ZR+ (Source: https://openzrplus.org/)

OFC2021 Open Networking Summit:
Future work: End-to-end lambda connection

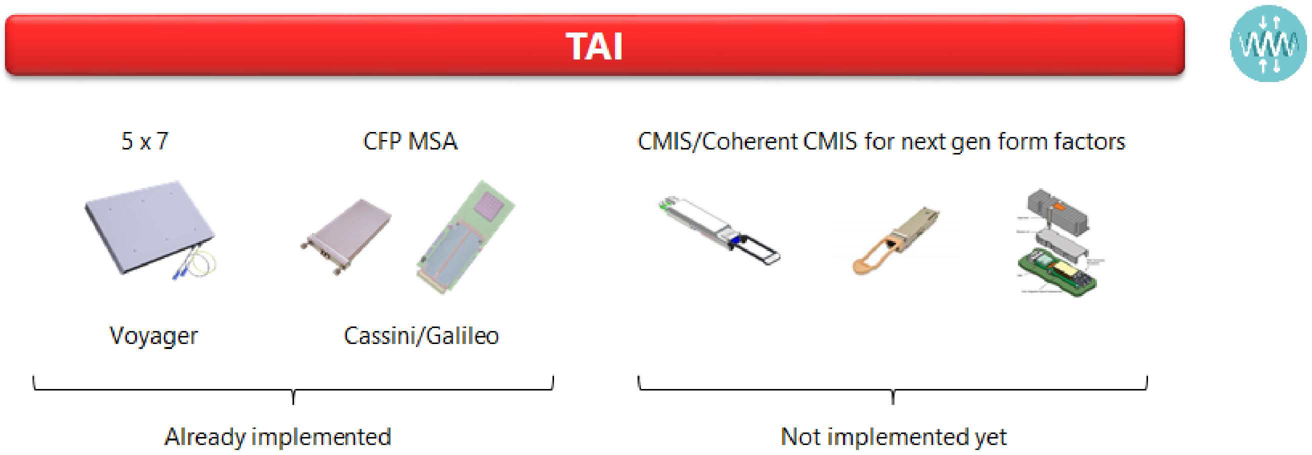
- Carrier networks in the future must be able to accommodate user terminals that have various coherent form factor/NOS,
- and then manage/optimize the end-to-end optical path for customer premises “transponders”.

EtoE λ Connection use case



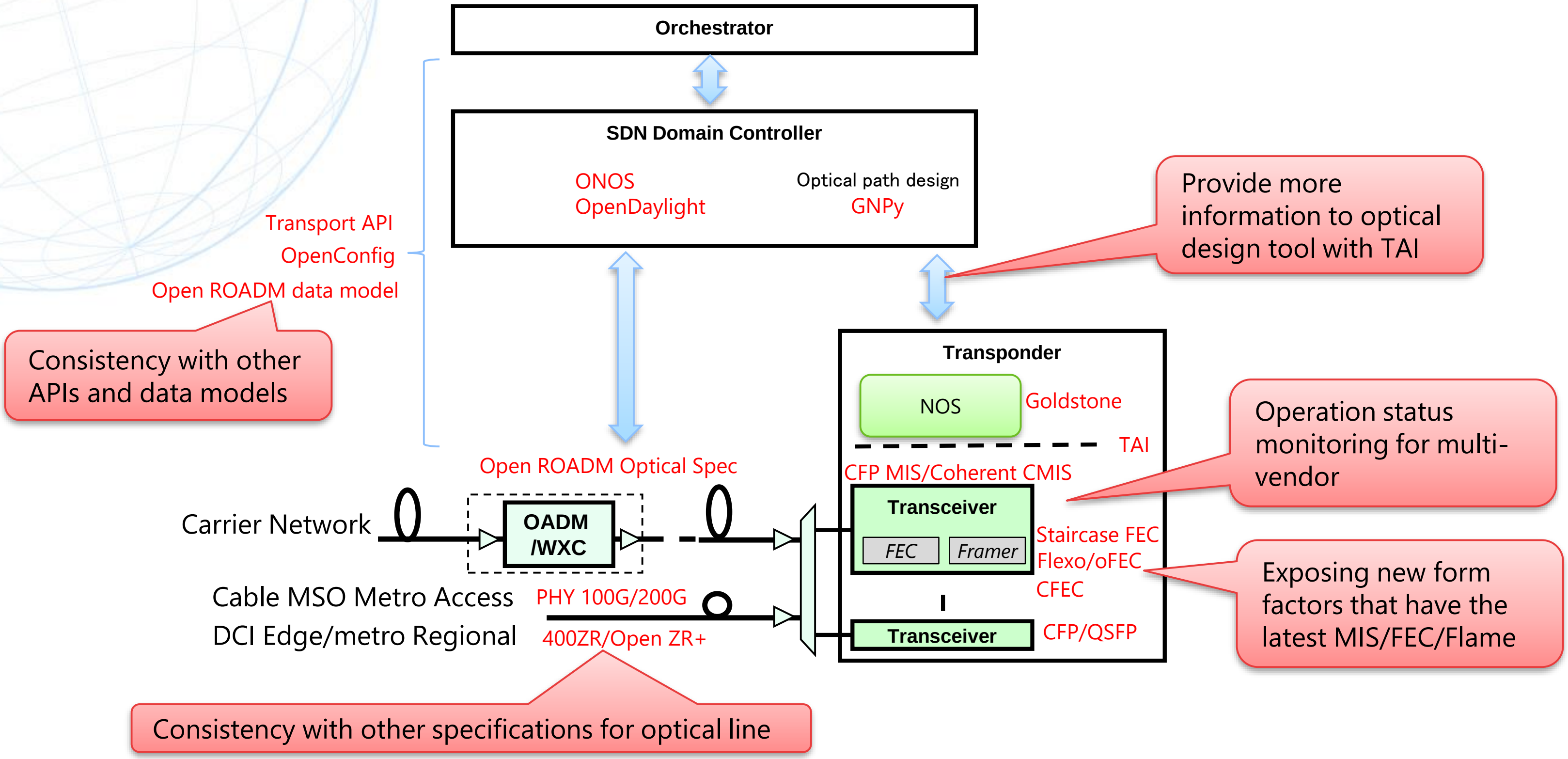


How to expose CMIS/C-CMIS specific features via TAI?



Discussion: What we need to add on TAI?

- Your contributions are highly appreciated.



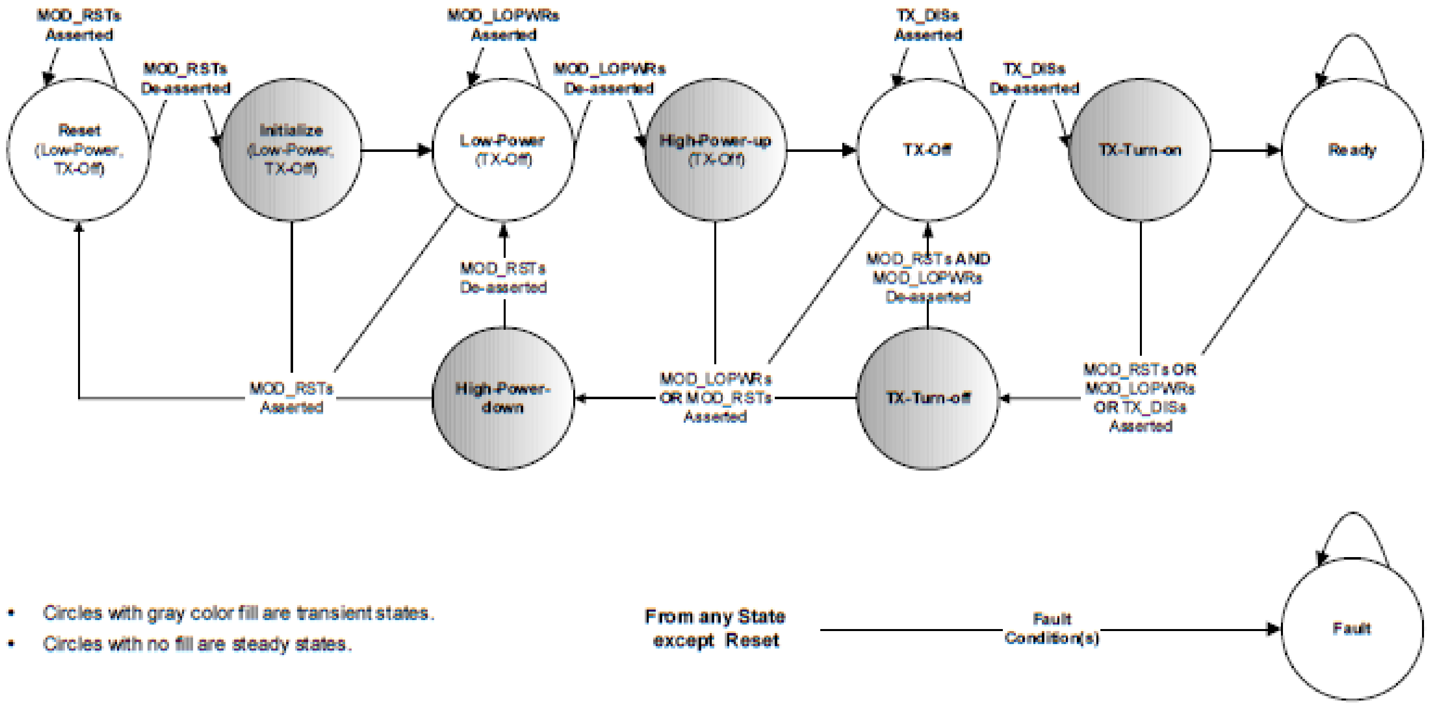
Operation status

- The ability to monitor the operation status must be essential for multi-vendor interconnection.
- We have defined status on TAI with CFP MSA's definition.
- Next Step: adapt to CMIS.

https://github.com/Telecominfraproject/oopt-tai/blob/master/inc/tainetworkif.h

```
/**
 * @brief Operational states of the network interface
 */
typedef enum _tai_network_interface_oper_status_t
{
    TAI_NETWORK_INTERFACE_OPER_STATUS_UNKNOWN,          /**< Unknown */
    TAI_NETWORK_INTERFACE_OPER_STATUS_RESET,            /**< Reset */
    TAI_NETWORK_INTERFACE_OPER_STATUS_INITIALIZE,       /**< Initialize */
    TAI_NETWORK_INTERFACE_OPER_STATUS_LOW_POWER,        /**< Low Power */
    TAI_NETWORK_INTERFACE_OPER_STATUS_HIGH_POWER_UP,    /**< High Power Up */
    TAI_NETWORK_INTERFACE_OPER_STATUS_TX_OFF,           /**< TX Off */
    TAI_NETWORK_INTERFACE_OPER_STATUS_TX_TURN_ON,       /**< TX Turn On */
    TAI_NETWORK_INTERFACE_OPER_STATUS_READY,            /**< Ready */
    TAI_NETWORK_INTERFACE_OPER_STATUS_TX_TURN_OFF,      /**< TX Turn Off */
    TAI_NETWORK_INTERFACE_OPER_STATUS_HIGH_POWER_DOWN,  /**< High Power Down */
    TAI_NETWORK_INTERFACE_OPER_STATUS_FAULT,            /**< Fault */
    TAI_NETWORK_INTERFACE_OPER_STATUS_MAX,              /**< Number of states */
} tai_network_interface_oper_status_t;
```

Reference: CFP MSA MIS



- Circles with gray color fill are transient states.
- Circles with no fill are steady states.

Reference: CMIS

NTT

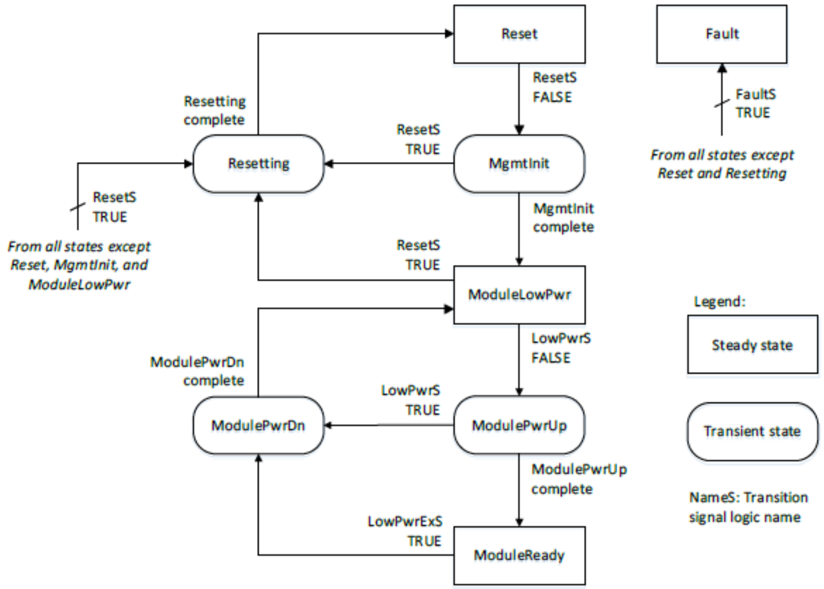


Figure 6-3 Module State Machine, paged memory modules

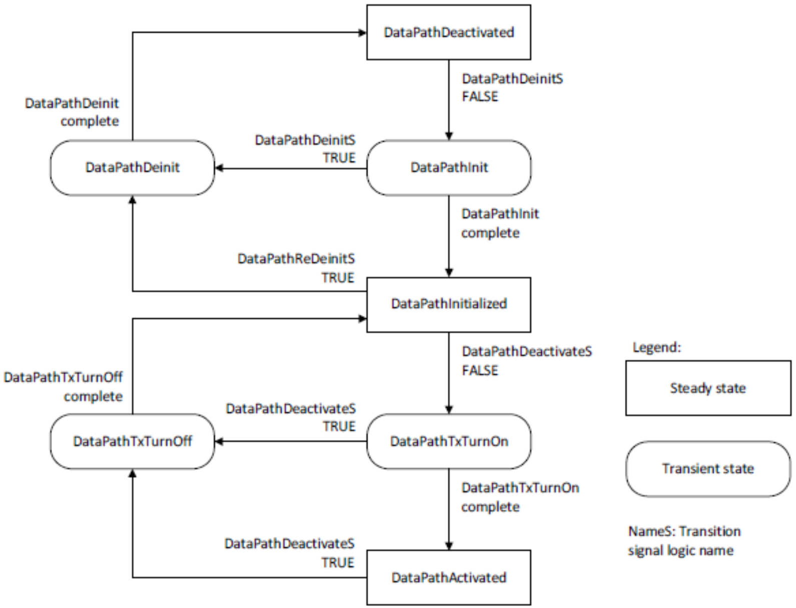


Figure 6-5 Data Path State Machine

(QSFP-DD-CMIS-rev4p0.pdf)

Coherent monitors

(IA OIF-C-CMIS-01.0)

Table 7: Identifiers for Coherent Monitors

Identifier	Description	Data Type	LSB Scaling	Unit
128	Modulator Bias X/I	U16	100/65,535	%
129	Modulator Bias X/Q	U16	100/65,535	%
130	Modulator Bias Y/I	U16	100/65,535	%
131	Modulator Bias Y/Q	U16	100/65,535	%
132	Modulator Bias X_Phase	U16	100/65,535	%
133	Modulator Bias Y_Phase	U16	100/65,535	%
134	CD – high granularity, short link	S16	1	Ps/nm
135	CD – low granularity, long link	S16	20	Ps/nm
136	DGD	U16	0.01	Ps
137	SOPMD	U16	0.01	Ps^2
138	PDL	U16	0.1	dB
139	OSNR	U16	0.1	dB
140	eSNR	U16	0.1	dB
141	CFO	S16	1	MHz
142	EVM_modem	U16	100/65,535	%
143	Tx Power	S16	0.01	dBm
144	Rx Total Power	S16	0.01	dBm
145	Rx Signal Power	S16	0.01	dBm
146	SOP ROC	U16	1	krad/s
147	MER	U16	0.1	dB

Grid spacing

- OIF has defined 75GHz spacing for 64GBaud mode in DCI, supported by hyper scalars.
- ITU-T has started to describe 75GHz and 87.5 GHz spacing as appendix.

```
/** @brief The transmit channel grid spacing */
typedef enum _tai_network_interface_tx_grid_spacing_t
{
    TAI_NETWORK_INTERFACE_TX_GRID_SPACING_UNKNOWN,
    TAI_NETWORK_INTERFACE_TX_GRID_SPACING_100_GHZ,
    TAI_NETWORK_INTERFACE_TX_GRID_SPACING_50_GHZ,
    TAI_NETWORK_INTERFACE_TX_GRID_SPACING_33_GHZ,
    TAI_NETWORK_INTERFACE_TX_GRID_SPACING_25_GHZ,
    TAI_NETWORK_INTERFACE_TX_GRID_SPACING_12_5_GHZ,
    TAI_NETWORK_INTERFACE_TX_GRID_SPACING_6_25_GHZ,
    TAI_NETWORK_INTERFACE_TX_GRID_SPACING_MAX
} tai_network_interface_tx_grid_spacing_t;
```

Reference: ITU-T G.694.1

Appendix I

Use of the flexible grid

(This appendix does not form an integral part of this Recommendation.)

I.1 Flexible grid examples

In addition to the fixed spacing dense wavelength division multiplexing (DWDM) grids defined in clause 6, a newer flexible DWDM grid has been introduced in clause 7. One of the motivations for the flexible grid is to allow a mixed bit rate or mixed modulation format transmission system to allocate frequency slots with different widths so that they can be optimized for the bandwidth requirements of the particular bit rate and modulation scheme of the individual channels. Because of the complexity of defining multi-vendor interoperable transmission systems containing mixed bit rates or modulation formats, there are currently no DWDM optical interface Recommendations that make use of this grid.

An example use of the flexible DWDM grid is shown in Figure I.1, where two 50 GHz slots are shown together with two 75 GHz slots. For each slot in the figure, the values of n and m in the formulae defining the slot parameters in clause 7 are also given. The frequency range between 193.125 THz and 193.18125 THz is shown unallocated. This range could be left as a "guard band" between the two sets of channels or it could subsequently be allocated to an additional slot with a width of 50 GHz (n=8, m=4), leaving 6.25 GHz unallocated, or other alternatives (e.g., two 25 GHz slots n=6, m=2 and n=10, m=2).

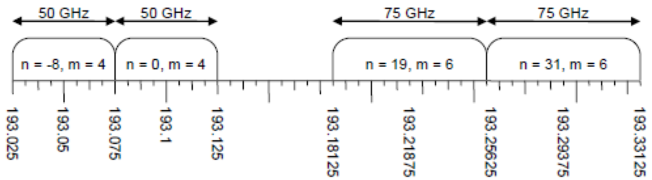


Figure I.1 – An example of the use of the flexible grid

The granularity of the nominal central frequency and slot width parameters for the flexible DWDM grid have been chosen so that any of the fixed spacing DWDM grids defined in clause 6 can also be described via suitable choices of slots in the flexible DWDM grid. For example, the 50 GHz fixed spacing DWDM grid is shown in Figure I.2 represented using the DWDM flexible grid.

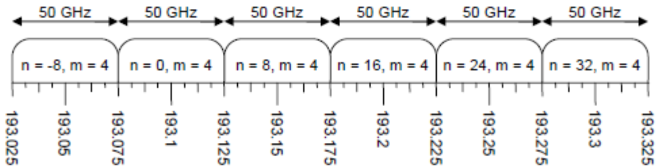


Figure I.2 – The 50 GHz fixed spacing grid represented using the flexible grid

Since the smallest spacing fixed grid is 12.5 GHz, the slot width granularity needs to be 12.5 GHz. In order to be able to place a slot that has a width that is an even multiple of 12.5 GHz next to one with a width that is an odd multiple of 12.5 GHz without a gap, the nominal central frequency granularity needs to be 6.25 GHz. An example of this is shown in Figure I.3.

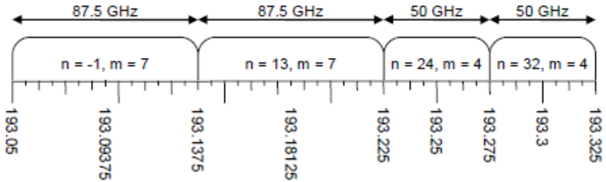


Figure I.3 – Example showing the need for 6.25 GHz nominal central frequency granularity

I.2 Flexible grid compliance

The flexible DWDM grid defined in clause 7 has a nominal central frequency granularity of 6.25 GHz and a slot width granularity of 12.5 GHz. However, devices or applications that make use of the flexible grid may not have to be capable of supporting every possible slot width or position. In other words, applications may be defined where only a subset of the possible slot widths and positions are required to be supported.

For example, an application could be defined where the nominal central frequency granularity is 12.5 GHz (by only requiring values of n that are even) and that only requires slot widths as a multiple of 25 GHz (by only requiring values of m that are even).