100G SWDM4 MSA Technical Specifications

Optical Specifications

Participants

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Revisions

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0.1	March 7, 2017	Initial Release
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TABLES

FIGURES

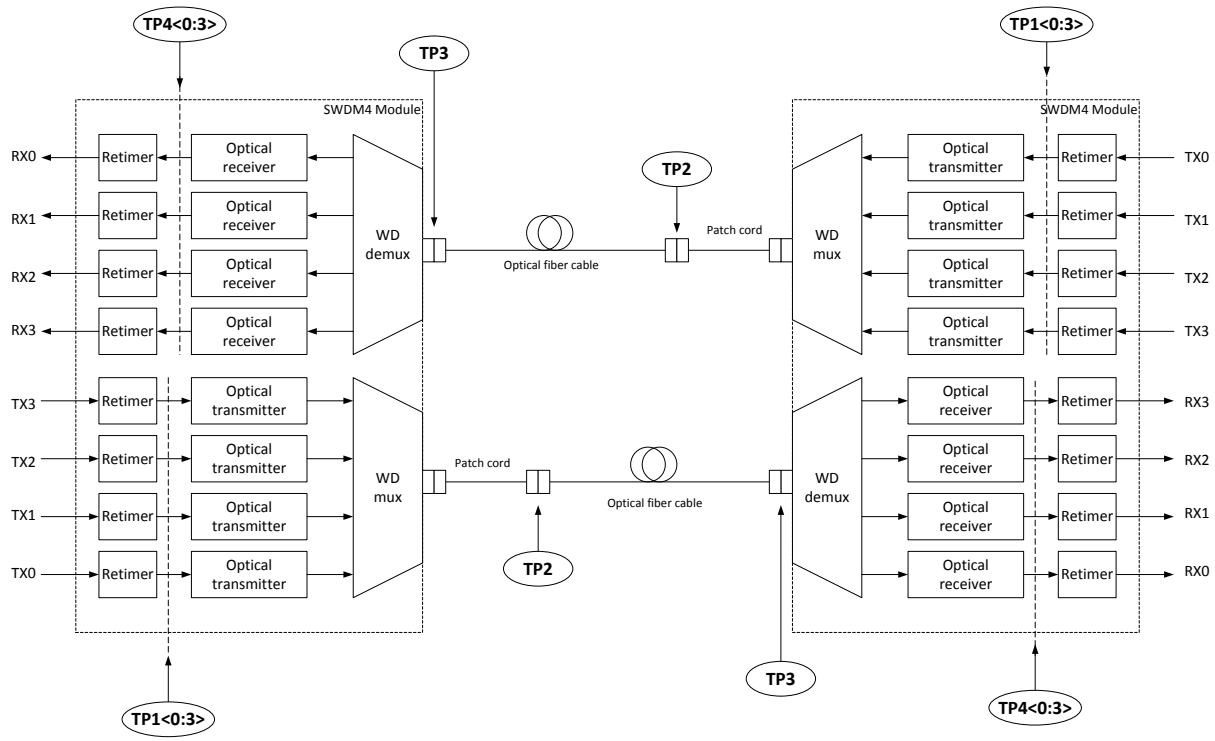
1 GENERAL

1.1 SCOPE

This Multi-Source Agreement (MSA) defines 4 x 25 Gbps Short Wavelength Division Multiplex (SWDM) optical interfaces for 100 Gbit/s optical transceivers for Ethernet applications including 100 GbE. Forward error correction (FEC) is required to be implemented by the host in order to ensure reliable system operation. Two transceivers communicate over multimode fibers (MMF) of length from 2 meters to 150 meters. The transceiver electrical interface is not specified by this MSA but can have, for example, four lanes in each direction with a nominal signaling rate of 25.78125 Gbps per lane.

Different form factors for the transceivers are possible. Initial implementations are expected to use the QSFP28 module form factor. Other form factors are possible and are not precluded by this MSA.

1.2 SWDM4 MODULE BLOCK DIAGRAM



WD = Wavelength division

NOTE – Specification of the retime function is beyond the scope of this MSA.

Figure 1-1: Block diagram for SWDM4 transmit/receive paths

1.3 FUNCTIONAL DESCRIPTION

SWDM4 modules comply with the requirements of this document and have the following common features: four optical transmitters; four optical receivers with signal detect; wavelength division multiplexer and demultiplexer; and a duplex optical connector for multi-mode fiber. The optical connector type is vendor specific but can include LC types.

1.4 HARDWARE SIGNALING PINS

Hardware signaling pins are specified in the respective module form factor MSAs.

1.5 MODULE MANAGEMENT INTERFACE

The contents of the various ID registers shall comply with the requirements of the module MSA and the respective standards. In the case of QSFP28 modules, the management interface complies with SFF-8636.

1.6 HIGH SPEED ELECTRICAL CHARACTERISTICS

The detailed high speed electrical characteristics are not defined by this MSA. 100GE modules could be implemented in compliance with IEEE-Std™ 802.3 Annex 83E, CAUI-4 chip-to-module, or OIF CEI-28G-VSR or other interfaces to be defined.

1.7 FEC REQUIREMENTS

The optical link is specified to operate at an uncorrected bit error ratio (BER) of 5×10^{-5}. The host system is required to enable RS(528,514) FEC in accordance with IEEE-Std 802.3 clause 91. The option to bypass the Clause 91 RS-FEC correction function is not supported.

1.8 MECHANICAL DIMENSIONS

Mechanical dimensions are defined in the module form factor MSA specifications. QSFP28 is defined in SFF-8661.

1.9 OPERATING ENVIRONMENT

All specified minimum and maximum parameter values shall be met when the host system maintains the operating case temperature and supply voltages within the module vendor specified operating ranges. All minimum and maximum limits apply over the operating life of the system.

1.10 POWER SUPPLIES AND POWER DISSIPATION

Module vendors shall specify the module power supply requirements in accordance with the module MSA.

2 SWDM4 OPTICAL SPECIFICATIONS

2.1 WAVELENGTH-DIVISION-MULTIPLEXED LANE ASSIGNMENTS

The wavelength range for each lane of the SWDM PMD is defined in Table 2-1. The center wavelengths are spaced at 30 nm.

Table 2-1: Wavelength-division-multiplexed lane assignments

Lane	Center wavelength	Wavelength range	Module electrical lane
L_0	850 nm	844 to 858 nm	Tx0, Rx0
L_1	880 nm	874 to 888 nm	Tx1, Rx1
L_2	910 nm	904 to 918 nm	Tx2, Rx2
L_3	940 nm	934 to 948 nm	Tx3, Rx3

2.2 OPTICAL SPECIFICATIONS

The operating range for a 100G-SWDM4 PMD is defined in Table 2-2. An SWDM4 compliant PMD operates on multi-mode fibers according to the specifications defined in The channel insertion loss is given in Table 4-1. A channel may contain additional connectors as long as the optical characteristics of the channel (such as attenuation, modal dispersion, reflections and losses of all connectors and splices) meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with IEC 61280-4-1:2009. As OM4 and OM5 (TIA-492AAAE) optical fiber meet the requirements for OM3, a channel compliant to the "OM3" column may use OM4 or OM5 (TIA-492AAAE) optical fiber, or a combination of OM3, OM4 and OM5 (TIA- 492AAAE). The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term *channel* is used here for consistency with generic cabling standards.

Table 4-1 and characteristics in 4.2.1. A PMD that exceeds the required operating range while meeting all other optical specifications is considered compliant (e.g., operating at 200 m on OM5 fiber meets the operating range requirement of 2 m to 150 m).

Table 2-2: 100G-SWDM4 operating range

MMF type	Required operating range
OM3	2 to 75 m
OM4	2 to 100 m
OM5	2 to 150 m

2.2.1 100G-SWDM4 transmitter optical specifications

The SWDM4 transmitter shall meet the specifications defined in Table 2-3.

Table 2-3: 100G-SWDM4 transmit characteristics

Description	Value			Unit
Signaling rate, each lane (range) 100GE	25.78125 ± 100 ppm			GBd
Lane wavelengths (range)	L0	844 to 858		nm
	L1	874 to 888		
	L2	904 to 918		
	L3	934 to 948		
RMS spectral width (max) [1]	0.59			nm
Average launch power, each lane (max)	[2]			dBm
Average launch power, each lane (min)	-7.5			dBm
Optical Modulation Amplitude (OMA), each lane (max)	3			dBm
Optical Modulation Amplitude (OMA), each lane (min) [3]	-5.5			dBm
Difference in launch power between any two lanes (OMA) (max)	4.5			dB
Launch power in OMA minus TDEC, each lane (min)	L0	-7		dBm
	L1	-7		
	L2	-7.4		
	L3	-7.7		
Transmitter and dispersion eye closure (TDEC) and measured TDEC (TDECm), each lane (max) [4]		TDECm	TDEC	dB
	L0	3.2	4	
	L1	3.2	4	
	L2	3.2	4.4	
	L3	3.2	4.8	
Average launch power of OFF transmitter, each lane (max)	-30			dBm
Extinction ratio (min)	2			dB
Optical return loss tolerance (max)	12			dB
Encircled flux [5]	≥ 86% at 19 μm ≤ 30% at 4.5 μm			
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3} Hit ratio 1.5×10^{-3} hits per sample	{0.3, 0.38, 0.45, 0.35, 0.41, 0.5}			

Notes:

1. RMS spectral width is the standard deviation of the spectrum.
2. Average launch power, each lane (max) shall be the lower of Average receive power (max) or, a value that in combination with all other lanes is less than class 1M eye safety limits per IEC 60825.
3. The normative lowest value of OMA for a compliant transmitter is 'Launch power in OMA minus TDEC, each lane (min)' plus the actual value of 'TDEC', but with a value of at least 'OMA, each lane (min)'.
4. TDEC is calculated from the measured TDECm using the methods in 3.6. TDECm is measured following the method in IEEE 802.3 clause 95.8.5 using a 12.6 GHz bandwidth reference receiver for all lanes.
5. If measured into type A1a.2 or type A1a.3 50 μm fiber in accordance with IEC 61280-1-4.

2.2.2 100G-SWDM4 receive optical specifications

The SWDM4 receiver shall meet the specifications defined in Table 2-4.

Table 2-4: 100G-SWDM4 receive characteristics

Description	Value		Unit
Signaling rate, each lane (range) 100GE	25.78125 ± 100 ppm		GBd
Lane wavelengths (range)	L0	844 to 858	nm
	L1	874 to 888	
	L2	904 to 918	
	L3	934 to 948	
Damage threshold, each lane (min) [1]	3.8		dBm
Average receive power, each lane (max)	2.4		dBm
Average receive power, each lane (min) [2]	L0	-9.5	dBm
	L1	-9.4	
	L2	-9.4	
	L3	-9.4	
Receive power, each lane (OMA) (max)	3		dBm
Difference in receive power between any two lanes (OMA) (max)	5		dB
Receiver reflectance (max)	-12		dB
Stressed receiver sensitivity (OMA), each lane (max) [4]	TBD		dBm
Conditions of stressed receiver sensitivity test [5]			
Stressed eye closure (SEC), lane under test	L0	4	dB
	L1	4	
	L2	4.4	
	L3	4.8	
Stressed eye J2 Jitter, lane under test	0.39		UI
Stressed eye J4 Jitter, lane under test	0.53		UI
OMA of each aggressor lane relative to lane under test	+5		dB
Stressed receiver eye mask definition { X1, X2, X3, Y1, Y2, Y3} Hit ratio $5x10^{-5}$ hits per sample	{0.28, 0.5, 0.5, 0.33, 0.33, 0.3}		

Notes:

1. The receiver shall be able to tolerate, without damage, continuous exposure to an optical signal having this average power level
2. Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
3. Measured with conformance test signal at TP3 (see 3.9) for BER = $5x10^{-5}$.
4. Vertical eye closure penalty, stressed eye J2 Jitter, stressed eye J4 Jitter, and SRS eye mask definition are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

2.2.3 100G-SWDM4 illustrative link power budget

An illustrative power budget and penalties for 100G-SWDM4 are shown in Table 2-5.

Table 2-5: 100G-SWDM4 illustrative power budget

Parameter	OM5				OM4				OM3				Unit
	L0	L1	L2	L3	L0	L1	L2	L3	L0	L1	L2	L3	
Effective modal bandwidth (min) [1]	4190	3700	2880	2500	4520	3076	2329	1859	2000	1667	1426	1243	MHz.km
Power budget at max TDEC	6.0	6.2	6.4	6.7	6.0	6.2	6.4	6.7	6.0	6.2	6.4	6.7	dB
Operating distance	0.5 to 150				0.5 to 100				0.5 to 75				m
Channel insertion loss (max) [2]	2.0	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.7	dB
Allocation for penalties (max TDEC) [3]	4.0	4.1	4.4	4.8	3.2	3.2	3.5	3.9	3.3	3.5	3.8	4.2	dB
Additional insertion loss allowed	0.0	0.2	0.1	0.0	0.9	1.1	1.1	1.0	0.9	0.9	0.8	0.8	dB

Notes:

1. Per IEC 60793-2-10
2. The channel insertion loss is calculated using the maximum distance specified in Table 2-2 and cabled fiber attenuation of 3.5 dB/km at 850 nm plus an allocation for connection and splice loss given in 4.2.3.
3. Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

3 DEFINITION OF OPTICAL PARAMETERS AND MEASUREMENT METHODS

All optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

3.1 TEST PATTERNS FOR OPTICAL PARAMETERS

Table 3-1: Patterns for optical parameter testing

Parameter	Pattern	Sub-clause [1]
Wavelength, spectral width	PRBS31	3.3
Average optical power	PRBS31	3.4
Optical modulation amplitude (OMA)	Square wave	3.5
Transmitter and dispersion eye closure (TDEC)	PRBS31	3.6
Extinction ratio	PRBS31	3.7
Transmitter optical waveform	PRBS31	3.8
Stressed receiver sensitivity	PRBS31	3.9
Stressed eye closure (SEC), calibration	PRBS31	3.9

Notes:
1. These sub-clauses make reference to relevant clauses of IEEE Std 802.3™.
2. Note that the PRBS pattern generator and pattern checker are defined in IEEE Std 802.3 clauses 49.2.9 and 49.2.12 respectively.

3.1.1 Square wave pattern definition

A pattern consisting of eight ones followed by an equal run of zeroes may be used as a square wave.

3.2 SKEW AND SKEW VARIATION

Refer to IEEE Std 802.3™ Clause 87.8.2. SWDM4 MSA transceivers shall comply with the skew and skew variation limits of clause 88.3.2.

3.3 WAVELENGTH AND SPECTRAL WIDTH

Measure per TIA/EIA-455-127-A or IEC 61280-1-3.

3.4 AVERAGE OPTICAL POWER

Measure using the methods given in IEC 61280-1-1 with all channels not being measured turned off.

3.5 OPTICAL MODULATION AMPLITUDE (OMA)

Refer to IEEE Std 802.3 Clause 52.9.5. OMA is measured with a square wave (8 ones, 8 zeros) test pattern. Each lane may be tested individually with all other lanes turned off, or by using an optical filter as defined in 3.6 if the other lanes are active.

3.6 TRANSMITTER AND DISPERSION EYE CLOSURE (TDEC)

TDEC shall be as defined in IEEE Std 802.3 Clause 95.8.5 with the exception that each optical lane is tested individually using an optical filter to separate the lane under test from the others.

The optical filter pass band ripple shall be limited to 0.5 dB peak-to-peak and the isolation is chosen such that the ratio of the power in the lane being measured to the sum of the powers of all the other lanes is greater than 20 dB (see ITU-T G.959.1 Annex B). The lanes not under test shall be operating with PRBS31 bit streams.

3.6.1 TDEC conformance test setup

Refer to IEEE Std 802.3 Cl. 95.8.5.1. The combination of the O/E and the oscilloscope used to measure the optical waveform has fourth-order Bessel-Thomson filter response with a bandwidth of 12.6 GHz. That value was selected to model the effective bandwidth of the worst case fiber used for 100GBASE-SR4 at the specified wavelengths for that PMD. Since the 12.6 GHz bandwidth is built into commercial test equipment, the 100G-SWDM4 PMD can use the same bandwidth and correct the results for the actual properties of the fibers used.

3.6.2 Test procedure

The test procedure is as defined in IEEE Std 802.3 Cl. 95.8.5.2. Each lane is tested individually using an optical filter to separate the lane under test from the others, and the BER of 5×10^{-5} is for the lane under test on its own. The measured value is equal to TDECm and the final value of TDEC is obtained by conversion as follows:

TDEC = TDECm + TDEC(OM5-OM4)

Where TDEC(OM5-OM4) is the increase in maximum TDEC for 150m of worst case OM5 fiber compared to 100m of worst case OM4 fiber as per Table 3-2.

Table 3-2: TDEC(OM5-OM4) versus optical lane

Lane	TDEC(OM5-OM4)
L0	0.8
L1	0.9
L2	0.9
L3	0.9

3.7 EXTINCTION RATIO

Extinction ratio is measured using the methods specified in IEC 61280-2-2, with the lanes not under test turned off.

3.8 TRANSMITTER OPTICAL WAVEFORM (TRANSMIT EYE)

Refer to IEEE Std 802.3 Cl. 95.8.7.

3.9 STRESSED RECEIVER SENSITIVITY

Use the method of IEEE Std 802.3 Cl. 95.8.8 with the following exceptions:

- The limits and test conditions for stressed receiver sensitivity are in Table 2-4.
- The attenuated stressed receiver conformance test signal for the lane under test and the three aggressor lanes are combined using a 4:1 optical multiplexer before application to the PMD receiver under test at TP3.

4 FIBER OPTIC CABLING MODEL

4.1 FIBER OPTIC CABLING MODEL

The fiber optic cabling model is shown in Figure 4-1.

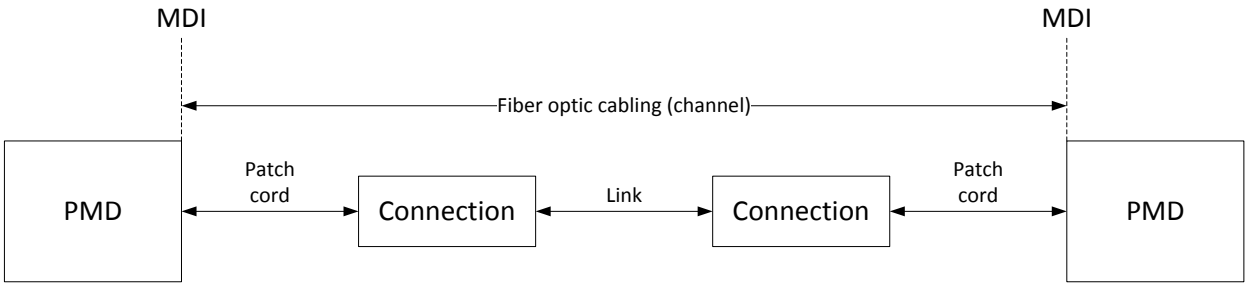


Figure 4-1: Fiber optic cabling model

The channel insertion loss is given in Table 4-1. A channel may contain additional connectors as long as the optical characteristics of the channel (such as attenuation, modal dispersion, reflections and losses of all connectors and splices) meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with IEC 61280-4-1:2009. As OM4 and OM5 (TIA-492AAAE) optical fiber meet the requirements for OM3, a channel compliant to the "OM3" column may use OM4 or OM5 (TIA-492AAAE) optical fiber, or a combination of OM3, OM4 and OM5 (TIA-492AAAE). The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term *channel* is used here for consistency with generic cabling standards.

Table 4-1: Fiber optic cabling (channel) characteristics for 100G-SWDM4

Description	OM3	OM4	OM5	Unit
Operating distance (max)	75	100	150	m
Channel insertion loss[a] (max)	1.8	1.9	2.0	dB
Channel insertion loss (min)	0			dB

a) These channel loss values include cable loss plus 1.5 dB allocated for connection and splice loss over the wavelength range 844 to 948 nm.

4.2 CHARACTERISTICS OF THE FIBER OPTIC CABLING (CHANNEL)

The SWDM4 fiber optic cabling shall meet the specifications defined in The channel insertion loss is given in Table 4-1. A channel may contain additional connectors as long as the optical characteristics of the channel (such as attenuation, modal dispersion, reflections and losses of all connectors and splices) meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with IEC 61280-4-1:2009. As OM4 and OM5 (TIA-492AAAE) optical fiber meet the requirements for OM3, a channel compliant to the "OM3" column may use OM4 or OM5 (TIA-492AAAE) optical fiber, or a combination of OM3, OM4 and OM5 (TIA- 492AAAE). The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term *channel* is used here for consistency with generic cabling standards.

Table 4-1. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together.

4.2.1 Optical fiber cable

The fiber contained within the fiber optic cabling shall comply with the specifications and parameters of Table 4-2. A variety of multimode cable types may satisfy these requirements, provided the resulting channel also meets the specifications of Table 4-1.

Table 4-2: Optical fiber and cable characteristics

Description	OM3[a]	OM4[b]	OM5[c]	Unit
Nominal core diameter	50			μm
Nominal fiber specification wavelength	850			nm
Effective modal bandwidth (min)[d]	2000	4700		MHz.km
Cabled optical fiber attenuation (max)	3.5			dB/km
Zero dispersion wavelength (λ_0)	$1295 \leq \lambda_0 \leq 1340$		$1297 \leq \lambda_0 \leq 1328$	nm
Chromatic dispersion slope (max) (S_0)	0.105 for $1295 \leq \lambda_0 \leq 1310$ and $0.000375 \times (1590 - \lambda_0)$ for $1310 \leq \lambda_0 \leq 1340$		$-412/(840(1-(\lambda_0/840)^4)$	ps/nm^2km

a IEC 60793-2-10 type A1a.2

b IEC 60793-2-10 type A1a.3

c TIA-492AAAE

d When measured with launch conditions in Table 2-3

4.2.2 Optical fiber connection

An optical fiber connection, as shown in Figure 4-1, consists of a mated pair of optical connectors.

4.2.3 Connection insertion loss

The maximum link distance is based on an allocation of 1.5 dB total connection and splice loss. For example, this allocation supports three connections with an average insertion loss per connection of 0.5 dB. Connections with lower loss characteristics may be used provided the requirements of Table 4-1 are met. However, the loss of a single connection shall not exceed 0.75 dB.

4.2.4 Maximum discrete reflectance

The maximum discrete reflectance shall be less than -20 dB.

4.3 MEDIUM DEPENDENT INTERFACE (MDI)

The 100G-SWDM4 PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" (as shown in Figure 4-1). Examples of an MDI include the following:

a) PMD with a connectorized fiber pigtail plugged into an adapter,
b) PMD receptacle

NOTE---Transmitter compliance testing is performed at TP2 i.e. after a 2-5 meter patch cord, not at the MDI.

4.3.1 MDI requirements for 100G-SWDM4

The MDI shall optically mate with the compatible plug on the fiber optic cabling. For 100G-SWDM4 when the MDI is a connector plug and receptacle connection, it shall meet the interface performance specifications of IEC 61753-1 and IEC 61753-022-2 for performance grade Bm/2m.

5 SWDM4 MODULE COLOR CODING

Transceiver modules compliant to the SWDM4 MSA Specifications use a color code to indicate the application. This color code can be on a module bail latch, pull tab, or other visible feature of the module when installed in a system. The color code scheme is specified in Table 5-1.

Table 5-1: SWDM4 Module Color Coding

Color Code	Application
Gray	100 Gb/s SWDM4

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