BS ISO 21111-5:2020

BSI Standards Publication

Road vehicles — In-vehicle Ethernet

Part 5: Optical 1-Gbit/s physical layer system requirements and test plans

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National foreword

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Part 5: Optical 1-Gbit/s physical layer system requirements and test plans

Véhicules routiers — Ethernet embarqué —

Partie 5: Exigences et plans de test du système de couche physique à 1-Gbit/s optique

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 31, *Data communication*.

A list of all parts in the ISO 21111 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The ISO 21111 series includes in-vehicle Ethernet requirements and test plans that are disseminated in other International Standards and complements them with additional test methods and requirements. The resulting requirement and test plans are structured in different documents following the Open Systems Interconnection (OSI) reference model and grouping the documents that depend on the physical media and bit rate used.

In general, the Ethernet requirements are specified in ISO/IEC/IEEE 8802-3. The ISO 21111 series provides supplemental specifications (e.g. wake-up, I/O functionality), which are required for in-vehicle Ethernet applications. In road vehicles, Ethernet networks are used for different purposes requiring different bit-rates. Currently, the ISO 21111 series specifies the 1-Gbit/s optical and 100-Mbit/s electrical physical layer.

The ISO 21111 series contains requirement specifications and test methods related to the in-vehicle Ethernet. This includes requirement specifications for physical layer entity (e.g. connectors, physical layer implementations) providers, device (e.g. electronic control units, gateway units) suppliers, and system (e.g. network systems) designers. Additionally, there are test methods specified for conformance testing and for interoperability testing.

Safety (electrical safety, protection, fire, etc.) and electromagnetic compatibility (EMC) requirements are out of the scope of the ISO 21111 series.

The structure of the specifications given in the ISO 21111 series complies with the Open Systems Interconnection (OSI) reference model specified in ISO/IEC 7498-1[1] and ISO/IEC 10731[3].

ISO 21111-1 defines the terms which are used in this series of standards and provides an overview of the standards for in-vehicle Ethernet including the complementary relations to ISO/IEC/IEEE 8802-3, the document structure, type of physical entities, in-vehicle Ethernet specific functionalities and so on.

ISO 21111-2 specifies the interface between reconciliation sublayer and physical entity including reduced gigabit media independent interface (RGMII), and the common physical entity wake-up and synchronized link sleep functionalities, independent from physical media and bit rate.

ISO 21111-3 specifies supplemental requirements to a physical layer capable of transmitting 1-Gbit/s over plastic optical fibre compliant with ISO/IEC/IEEE 8802-3, with specific application to communications inside road vehicles, and a test plan for physical entity conformance testing.

ISO 21111-4 specifies the optical components requirements and test methods for 1-Gbit/s optical in-vehicle Ethernet.

This document specifies, for 1-Gbit/s optical in-vehicle Ethernet, requirements on the physical layer at system level, requirements on the interoperability test set-ups, the interoperability test plan that checks the requirements for the physical layer at system level, requirements on the device-level physical layer conformance test set-ups, and device-level physical layer conformance test plan that checks a set of requirements for the OSI physical layer that are relevant for device vendors.

ISO 21111-6 specifies advanced features of an ISO/IEC/IEEE 8802-3 in-vehicle Ethernet physical layer (often also called transceiver), e.g. for diagnostic purposes for in-vehicle Ethernet physical layers. It specifies advanced physical layer features, wake-up and sleep features, physical layer test suite, physical layer control requirements and conformance test plan, physical sublayers test suite and physical sublayers requirements and conformance test plan.

ISO 21111-7 specifies the implementation for ISO/IEC/IEEE 8802-3:2017/Amd 1:2017, which defines the interface implementation for automotive applications together with requirements on components used to realize this Bus Interface Network (BIN). ISO 21111-7 also defines further testing and system requirements for systems implemented according to the system specification. In addition, ISO 21111-7 defines the channels for tests of transceivers with a test wiring harness that simulates various electrical communication channels.

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ISO 21111-8 specifies the transmission media, the channel performance and the tests for ISO/IEC/IEEE 8802-3 in-vehicle Ethernet.

ISO 21111-9 specifies the data link layer requirements and conformance test plan. It specifies the requirements and test plan for devices and systems with bridge functionality.

ISO 21111-10 specifies the application to network layer requirements and test plan. It specifies the requirements and test plan for devices and systems that include functionality related with OSI layers from 3 to 7.

Figure 1 shows the parts of the ISO 21111 series and the document structure.

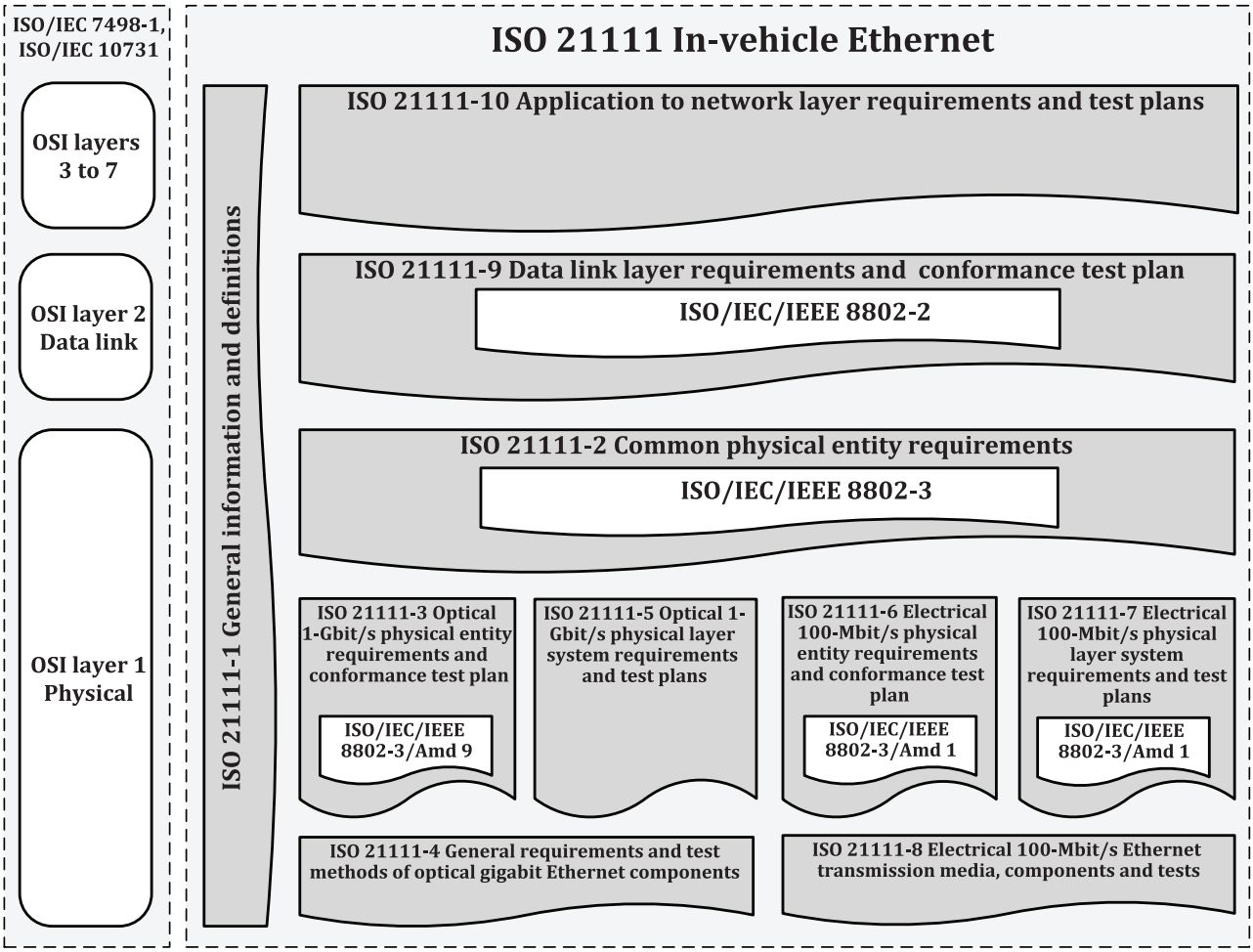

Figure 1 — In-vehicle Ethernet document reference according to OSI model

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Part 5: Optical 1-Gbit/s physical layer system requirements and test plans

1 Scope

This document specifies:

— requirements on the physical layer at system level,

— requirements on the interoperability test set-ups,

— interoperability test plan that checks the requirements for the physical layer at system level,

— requirements on the device-level physical layer conformance test set-ups, and

— device-level physical layer conformance test plan that checks a set of requirements for the OSI physical layer that are relevant for device vendors.

The interoperability test plan checks the physical layer system requirements specified in this document and in ISO/IEC/IEEE 8802-3:2017/Amd 9.

This test plan is structured in four different test groups, attending to the kind of system requirements that covers:

— link status, that includes the tests that check the status of the link by using the content of the available registers and its accuracy with the real status of the link,

— link-up, that includes the tests that check the time that the IUT reaches a reliable link status from certain state,

— channel quality, that includes the tests that check the quality of the optical channel by using the content of the available registers and its accuracy with the real quality of the optical channel, and

— wake-up and sleep, that include tests that check that the transmission and reception of the wake-up and sleep events.

The device-level conformance test plan checks the device-level requirements specified in the ISO 21111 series and in ISO/IEC/IEEE 8802-3:2017/Amd 9.

This test plan is structured in four different test groups, attending to the test set-up required:

— high-attenuation channel,

— low-attenuation channel,

— optical IUT transmitter measurements, and

— wake-up and synchronised link sleep.

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2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 21111-1[1)], *Road vehicles — In-vehicle Ethernet — Part 1: General information and definitions*

ISO 21111-2[2)], *Road vehicles —In-vehicle Ethernet — Part 2: Common medium-independent interface specifications*

ISO 21111-3, *Road vehicles — In-vehicle Ethernet — Part 3: Optical 1-Gbit/s physical layer specification and conformance test plan*

ISO 21111-4, *Road vehicles — In-vehicle Ethernet — Part 4: Optical 1-Gbit/s component requirements and test methods*

ISO/IEC/IEEE 8802-3, *Standard for Ethernet*

ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, *Physical Layer Specifications and Management Parameters for 1000 Mb/s Operation over Plastic Optical Fiber*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC/IEEE 8802-3, ISO 21111-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
network system
two or more devices connected bi-directionally through a physical medium

Note 1 to entry: Physical medium is defined in ISO 7498-1:1994.

3.2
GEPOF link status
reliability or unreliability of the bidirectional communication between two GEPOF physical entities as signalled by bit 2 of MDIO register 1.1 specified in ISO/IEC/IEEE 8802-3:2017/Amd 9

3.3
device-level physical layer conformance test plan
set of conformance test cases that covers physical layer requirements relevant for the device provider

3.4
cable plug
POF cable plug that fulfils the specification in ISO 21111-4

3.5
cable socket
POF cable socket that fulfils the specification in ISO 21111-4

1) Under preparation. Stage at the time of publication: ISO/DIS 21111-1:2020.

2) Under preparation. Stage at the time of publication: ISO/DIS 21111-2:2020.

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3.6
in-line connector
connector resulting of the match of a *cable plug* (3.4) and a *cable socket* (3.5)

4 Symbols and abbreviated terms

4.1 Symbols

For the purposes of this document, the symbols of ISO 21111-1 and the following apply.

IDD_{device}	device current consumption
IDD_{min}	minimum device current consumption in operation
IDD_{max}	maximum device current consumption in operation
IDD_DIS_{min}	minimum device current consumption in sleep power state
IDD_DIS_{max}	maximum device current consumption in sleep power state
T	climatic chamber temperature
T_{device}	device climatic chamber temperature
T_{LP}	link partner climatic chamber temperature
T_{min}	minimum operating temperature
T_{max}	maximum operating temperature
T_{typ}	typical operating temperature
U	supply voltage
U_{device}	device supply voltage
U_{LP}	link partner supply voltage
U_{min}	minimum supply voltage
U_{max}	maximum supply voltage
U_{typ}	typical supply voltage

4.2 Abbreviated terms

For the purposes of this document, the abbreviated terms of ISO 21111-1 and the following apply.

AOP	average optical power
ER	extinction ratio
GESST	GEPOF entity stress test tool
IUT	implementation under test
LP	link partner
LT	lower tester

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POF	plastic optical fibre
RIN	relative intensity noise
RMS	root mean square
TC	test coordinator
UT	upper tester

5 Physical layer system requirements and interoperability test setups requirements

5.1 General

Clause 5 specifies the physical layer system requirements and the interoperability test setup requirements.

The physical layer system requirements are structured by the functionality that they cover:

— The GEPOF link status comprises the physical layer system requirements related with the time and accuracy the network system signals a new status in the GEPOF link (see 5.2),

— The GEPOF link-up time comprises the physical layer system requirements related with the time the network system signals a reliable GEPOF link status from a given initial power state of the two physical entities involved in the GEPOF link (see 5.3),

— The channel quality comprises the physical layer system requirements related with the time and accuracy the network system signals a change of the channel quality in the GEPOF link (see 5.4),

— The communication reliability comprises the physical layer system requirements related with the communication reliability when the devices in the network system are under certain climatic loads and the communication channel is set (see 5.5).

The reference network system used to specify the physical layer system requirements is shown in Figure 2.

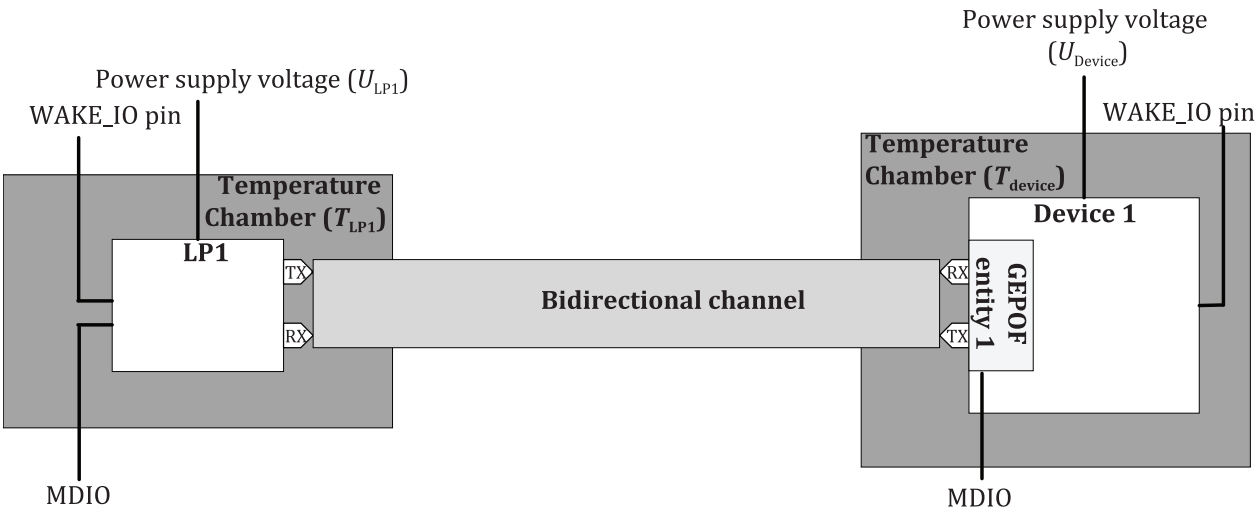

Figure 2 — Reference network system for physical layer system requirements definition

The interoperability test set-ups requirements are specified in 5.6. They include requirements on the channels that are used in the test set-ups and requirements on the device and LP used in the test set-ups.

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5.2 GEPOF link status requirements

5.2.1 IOP_GEPOF_REQ_LINK_STATUS_1

REQ	1.1 PHY — IOP_GEPOF_REQ_LINK_STATUS_1
The time measured from the instant when the GEPOF link status changes to "bidirectional reliable link is established" till the reception of the first Ethernet frame in the device shall be lower than 0,5 ms when Ethernet frames are sent continuously from the LP.	

5.2.2 IOP_GEPOF_REQ_LINK_STATUS_2

REQ	1.2 PHY — IOP_GEPOF_REQ_LINK_STATUS_2
The time measured from the instant when the GEPOF link becomes unreliable till the GEPOF link status changes to "bidirectional unreliable link" shall be lower than 5 ms.	

5.3 GEPOF link-up requirements

5.3.1 IOP_GEPOF_REQ_LINK_UP_1

REQ	1.3 PHY — IOP_GEPOF_REQ_LINK_UP_1
The time measured from the instant when the GEPOF entity 1 receives a PHY_WakeUp.request from the data link layer as specified in ISO 21111-2 till the GEPOF link status in GEPOF entity changes to "bidirectional reliable link is established" shall be lower than 100 ms. The initial power state of the GEPOF entity in device 1 and its LP to measure this time shall be Sleep as defined in ISO 21111-2.	

5.3.2 IOP_GEPOF_REQ_LINK_UP_2

REQ	1.4 PHY — IOP_GEPOF_REQ_LINK_UP_2
The time measured from the instant when the GEPOF entity 1 receives a WakeUp_request event as specified in ISO 21111-2 till the GEPOF link status in GEPOF entity 1 changes to "bidirectional reliable link is established" shall be lower than 100 ms. The initial power state of the GEPOF entity 1 to measure this time shall be Sleep as defined in ISO 21111-2. The initial power state of the LP to measure this time shall be Normal as defined in ISO 21111-2.	

5.3.3 IOP_GEPOF_REQ_LINK_UP_3

REQ	1.5 PHY — IOP_GEPOF_REQ_LINK_UP_3
The time measured from the instant when the GEPOF entity 1 is reset till the GEPOF link status in GEPOF entity 1 changes to "bidirectional reliable link is established" shall be lower than 100 ms. The initial power state of the GEPOF entity 1 to measure this time shall be Normal as defined in ISO 21111-2. The initial power state of the LP to measure this time shall be Normal as defined in ISO 21111-2.	

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5.3.4 IOP_GEPOF_REQ_LINK_UP_4

REQ	1.6 PHY — IOP_GEPOF_REQ_LINK_UP_4
The time measured from the instant when the LP is reset till the GEPOF link status in GEPOF entity 1 changes to "bidirectional reliable link is established" shall be lower than 100 ms. The initial power state of the GEPOF entity 1 to measure this time shall be Normal as defined in ISO 21111-2. The initial power state of the LP to measure this time shall be Normal as defined in ISO 21111-2.	

5.3.5 IOP_GEPOF_REQ_LINK_UP_5

REQ	1.7 PHY — IOP_GEPOF_REQ_LINK_UP_5
The time measured from the instant when the GEPOF entity 1 receives a WakeUp_request event as specified in ISO 21111-2 till the GEPOF link status in GEPOF entity 1 changes to "bidirectional reliable link is established" shall be lower than 100 ms. The initial power state of the GEPOF entity 1 to measure this time shall be Normal as defined in ISO 21111-2. The initial power state of the LP to measure this time shall be Normal as defined in ISO 21111-2.	

5.4 Channel quality requirements

5.4.1 IOP_GEPOF_REQ_CH_QLTY_1

REQ	1.8 PHY — IOP_GEPOF_REQ_CH_QLTY_1
The GEPOF entity 1 shall indicate the channel quality decrease for a channel with decreasing quality.	

5.4.2 IOP_GEPOF_REQ_CH_QLTY_2

REQ	1.9 PHY — IOP_GEPOF_REQ_CH_QLTY_2
The GEPOF entity 1 shall indicate the channel quality increase for a channel with increasing quality.	

5.5 Communication reliability under climatic loads requirements

5.5.1 IOP_GEPOF_REQ_RELIABILITY_TEMP_1

REQ	1.10 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_1
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{max}, — the LP is located in an oven with temperature set to T_{min}, and — the communication channel between them is set as bidirectional high attenuation as specified in REQ 1.20 and REQ 1.21.	

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5.5.2 IOP_GEPOF_REQ_RELIABILITY_TEMP_2

REQ	1.11 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_2
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{min}, — the LP is located in an oven with temperature set to T_{max}, and — the communication channel between them is set as bidirectional high attenuation as specified in REQ 1.20 and REQ 1.21.	

5.5.3 IOP_GEPOF_REQ_RELIABILITY_TEMP_3

REQ	1.12 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_3
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{min}, — the LP is located in an oven with temperature set to T_{min}, and — the communication channel between them is set as bidirectional high attenuation as specified in REQ 1.20 and REQ 1.21.	

5.5.4 IOP_GEPOF_REQ_RELIABILITY_TEMP_4

REQ	1.13 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_4
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{max}, — the LP is located in an oven with temperature set to T_{max}, and — the communication channel between them is set as bidirectional high attenuation as specified in REQ 1.20 and REQ 1.21.	

5.5.5 IOP_GEPOF_REQ_RELIABILITY_TEMP_5

REQ	1.14 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_5
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{max}, — the LP is located in an oven with temperature set to T_{min}, and — the communication channel between them is set as bidirectional low attenuation as specified in REQ 1.22 and REQ 1.23.	

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5.5.6 IOP_GEPOF_REQ_RELIABILITY_TEMP_6

REQ	1.15 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_6
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{min}, — the LP is located in an oven with temperature set to T_{max}, and — the communication channel between them is set as bidirectional low attenuation as specified in REQ 1.22 and REQ 1.23.	

5.5.7 IOP_GEPOF_REQ_RELIABILITY_TEMP_7

REQ	1.16 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_7
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{min}, — the LP is located in an oven with temperature set to T_{min}, and — the communication channel between them is set as bidirectional low attenuation as specified in REQ 1.22 and REQ 1.23.	

5.5.8 IOP_GEPOF_REQ_RELIABILITY_TEMP_8

REQ	1.17 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_8
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{max}, — the LP is located in an oven with temperature set to T_{max}, and — the communication channel between them is set as bidirectional low attenuation as specified in REQ 1.22 and REQ 1.23.	

5.5.9 IOP_GEPOF_REQ_RELIABILITY_TEMP_9

REQ	1.18 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_9
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{device}, — the LP is located in an oven with temperature set to T_{LP}, — the communication channel between them is set as bidirectional high attenuation as specified in REQ 1.20 and REQ 1.21, — the initial temperature of T_{device} is equal to T_{min} and is increased linearly till it reaches T_{max} in 30 min, and — the initial temperature of T_{LP} is equal to T_{max} and is decreased linearly till it reaches T_{min} in 30 min.	

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5.5.10 IOP_GEPOF_REQ_RELIABILITY_TEMP_10

REQ	1.19 PHY — IOP_GEPOF_REQ_RELIABILITY_TEMP_10
The communication between GEPOF entity 1 and its LP shall be reliable as specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 when: — the device that includes the GEPOF entity 1 is located in an oven with temperature set to T_{device}, — the LP is located in an oven with temperature set to T_{LP}, — the communication channel between them is set as bidirectional low attenuation as specified in REQ 1.22 and REQ 1.23, — the initial temperature of T_{device} is equal to T_{min} and is increased linearly till it reaches T_{max} in 30 min, and — the initial temperature of T_{LP} is equal to T_{max} and is decreased linearly till it reaches T_{min} in 30 min.	

5.6 Test set-up requirements

5.6.1 General

5.6 specifies the requirements of the test set-ups that are used in the interoperability test plan.

Most of the test set-ups involve a communication channel between a device and its LP. Different types of communication channels are specified in 5.6 and examples of realization are given.

The requirements on the device and LP for the test set-ups are specified in 5.6.3.

5.6.2 Channel requirements

5.6.2.1 Bidirectional high attenuation channel

5.6.2.1.1 Bidirectional high attenuation channel requirements

REQ	1.20 PHY — Bidirectional high attenuation channel requirement — Bidirectional channel structure
The bidirectional high attenuation channel type shall be composed of two unidirectional high attenuation channels. Each of the unidirectional high attenuation channels shall comply with REQ 1.21.	

REQ	1.21 PHY — Bidirectional high attenuation channel requirement — Unidirectional channel requirements
The unidirectional high attenuation channel shall have an insertion loss measured at 0 Hz between 6 dB and 7 dB. The normalized frequency response of the unidirectional high attenuation channel shall be between the normalized frequency response specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 for channel type III and 0,2 dB more for the frequency range from 0 MHz to 162,5 MHz. The insertion loss and transfer function requirement shall be fulfilled at (23 ± 2) °C.	

5.6.2.1.2 Example for bidirectional high attenuation channel implementation.

Figure 3 shows an example for a bidirectional high attenuation channel implementation. The simplex POF cable, in-line connector and cable plug fulfil the requirements given in ISO 21111-4. The two-parallel simplex POF cables can be substituted by a single duplex POF cable.

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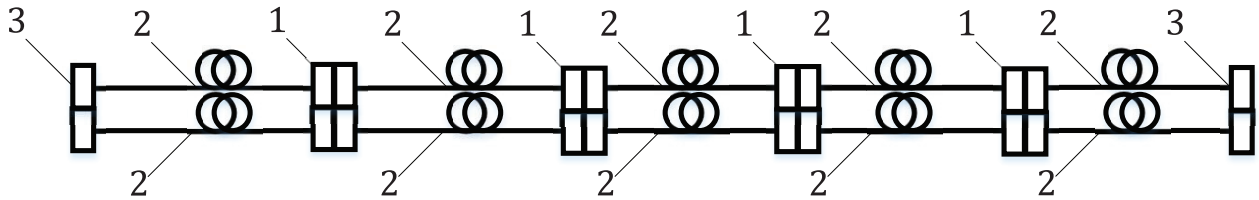


Key

1 in-line connector

2 3-m simplex POF cable

3 cable plug

Figure 3 — Example for bidirectional high attenuation channel implementation

5.6.2.2 Bidirectional low attenuation channel

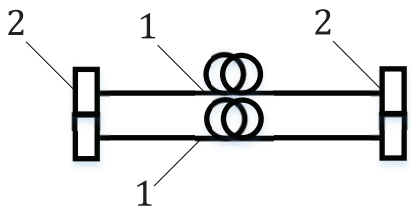
5.6.2.2.1 Bidirectional low attenuation channel requirements

REQ	1.22 PHY — Bidirectional low attenuation channel requirement — Bidirectional channel structure
The bidirectional low attenuation channel type shall be composed of two unidirectional low attenuation channels. Each of the unidirectional low attenuation channels shall comply with REQ 1.23.	

REQ	1.23 PHY — Bidirectional low attenuation channel requirement — Unidirectional channel requirements
The unidirectional low attenuation channel type shall have an insertion loss measured at 0 Hz between 2,5 dB and 3 dB. The lower limit for transfer function magnitude shall be −0,25 dB for the frequency range from 0 Hz to 160 MHz. The upper limit for transfer function magnitude shall be 0 dB for the frequency range from 0 Hz to 160 MHz. The insertion loss and transfer function requirement shall be fulfilled at (23 ± 2) °C.	

5.6.2.2.2 Example for bidirectional low attenuation channel implementation

Figure 4 shows an example for a bidirectional low attenuation channel implementation. The simplex POF cable and cable plug fulfil the requirements given in ISO 21111-4. The two-parallel simplex POF cables can be substituted by a single duplex POF cable.



Key

1 0,5-m simplex POF cable

2 cable plug

Figure 4 — Example for bidirectional low attenuation channel implementation

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5.6.2.3 Variable attenuation channel

5.6.2.3.1 Variable attenuation channel requirements

REQ	1.24 PHY — Variable attenuation channel requirements — Bidirectional channel structure
The variable attenuation channel type shall be composed of one unidirectional variable attenuation channel that shall comply with REQ 1.25 and one unidirectional low attenuation channel that shall comply with REQ 1.23. The unidirectional variable attenuation channel shall connect the upper-left and upper-right ports of the variable attenuation channel. The unidirectional low attenuation channel shall connect the lower-left and lower-right ports of the variable attenuation channel.	

REQ	1.25 PHY — Variable attenuation channel requirements — Unidirectional channel requirements
The variable attenuation channel type shall have an insertion loss measured at 0 Hz programmable between 3 dB and 10 dB. The lower limit for transfer function magnitude shall be the requirement specified in ISO/IEC/IEEE 8802-3:2017/Amd 9 for channel type III for the frequency range from 0 Hz to 160 MHz. The upper limit for transfer function magnitude shall be 0 dB for the frequency range from 0 Hz to 160 MHz. The insertion loss and transfer function requirement shall be fulfilled at (23 ± 2) °C and for all the programmable insertion loss measured at 0 Hz.	

5.6.2.3.2 Example for variable attenuation channel implementation

Figure 5 shows an example for a variable attenuation channel implementation. The simplex POF cable and cable plug fulfil the requirements given in ISO 21111-4. Note that the unidirectional variable attenuation channel is implemented only in one communication direction.

5.6.3 Device and LP requirements for interoperability test plan

REQ	1.26 PHY — Device and LP requirements for interoperability test plan — GEPOF entities requirements
Each of the GEPOF entities in the device and LP shall fulfil the requirements in ISO 21111-3 and ISO/IEC/IEEE 8802-3:2017/Amd 9.	

REQ	1.27 PHY — Device and LP requirements for interoperability test plan — MDIO interface
The device and the LP shall include at least one accessible MDIO interface as specified in ISO/IEC/IEEE 8802-3 that allows the individual access to each set of MDIO registers of each GEPOF entity in the device or LP.	

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REQ	1.28 PHY — Device and LP requirements for interoperability test plan — Access and control of PHY service interface and neighbour service interface
If the device or the LP implements the wake-up and synchronized link sleep functionality as specified in ISO 21111-3, it shall include a way to access and control PHY service interface and neighbour service interface, as specified in ISO 21111-2.	

REQ	1.29 PHY — Device and LP requirements for interoperability test plan — Ethernet interface
The device and the LP shall include at least one Ethernet physical layer capable of 1 Gbit/s in addition to the one provided by the GEPOF entity.	

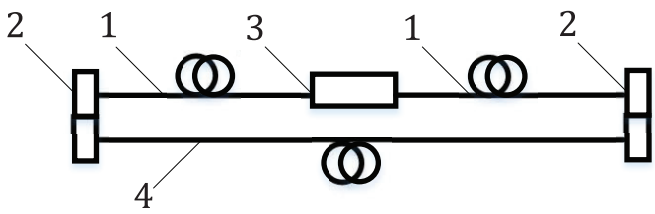
The link status has two possible states:

— "bidirectional reliable link is established" when the MDIO register 1.1 is equal to 1_2, and

— "bidirectional unreliable link" when the MDIO register 1.1 is equal to 0_2.

REQ	1.30 PHY — Device and LP requirements for interoperability test plan — Access to link status
The device shall include constant access to the MDIO register 1.1 that contains the current link status.	

REQ	1.31 PHY — Device and LP requirements for interoperability test plan — PMD_TXPWR.request(tx_pwr) control
The device and the LP shall include a mechanism to control the generation of the request PMD_TXPWR.request(tx_pwr) with a controlled value of the tx_pwr parameter as specified in ISO/IEEE/IEC 8802-3:2017/Amd 9:2018, 115.6.1.3.	



Key

1 0,5-m simplex POF cable

2 cable plug

3 optical variable attenuator

4 1-m simplex POF cable

Figure 5 — Example for variable attenuation channel implementation

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6 Interoperability test plan set-ups

6.1 General

The objective of the interoperability test plan is to verify the physical layer system requirements that need a set-up with at least two GEPOF entities. These test set-ups are relevant for the network system designer.

The IUT for this test plan is the complete network system that includes two or more GEPOF physical entities implemented in, at least, one device and its LP. The interoperability test set-up determines the IUT that is used in each test case.

The IUT and the UT are controlled by the TC. The TC implements the functionality of the test coordination procedure specified in ISO/IEC 9646-1.

The IUT has communication with the UT. The UT is able to generate and analyse data from the IUT and check if the result complies with the IUT requirements, as specified in ISO/IEC 9646-1.

Figure 6 shows the relationship between the IUT, the UT and the TC.

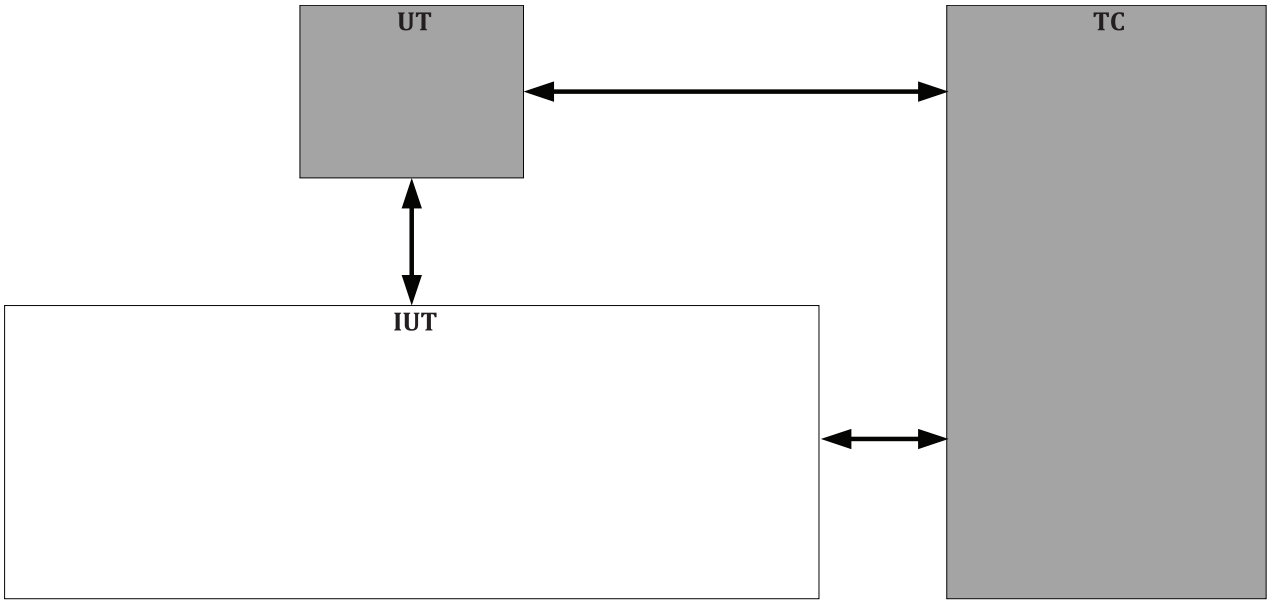

Figure 6 — Interoperability test environment

6.2 Interoperability test set-up 1

The interoperability test set-up 1 is composed of one device and its LP connected by one bidirectional channel that fulfils the requirements for the bidirectional high attenuation channel type specified in 5.6.2.1.

The device is placed inside a temperature chamber set to a controlled temperature T_{device}.

The device is powered by a controlled power supply voltage U_{device}.

The LP is placed inside a temperature chamber set to a controlled temperature T_{LP}.

The LP is powered by a controlled power supply voltage U_{LP}.

The device, LP1 and LP2 may include a wake I/O block connected to a WAKE_IO pin as specified in ISO 21111-2:—, 6.6.

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For the test cases that use this test set-up, to power up the device or LP means to set the power_off_entity variable specified in ISO 21111-2 to FALSE for the GEPOF entity included in the device or LP.

Symmetrically, to power down the device or LP means to set the power_off_entity variable specified in ISO 21111-2 to TRUE for the GEPOF entity included in the device or LP.

REQ	1.32 PHY —Interoperability test plan set-ups — Interoperability test set-up 1
The interoperability test setup 1 shall include the elements and the placement specified in Figure 7.	

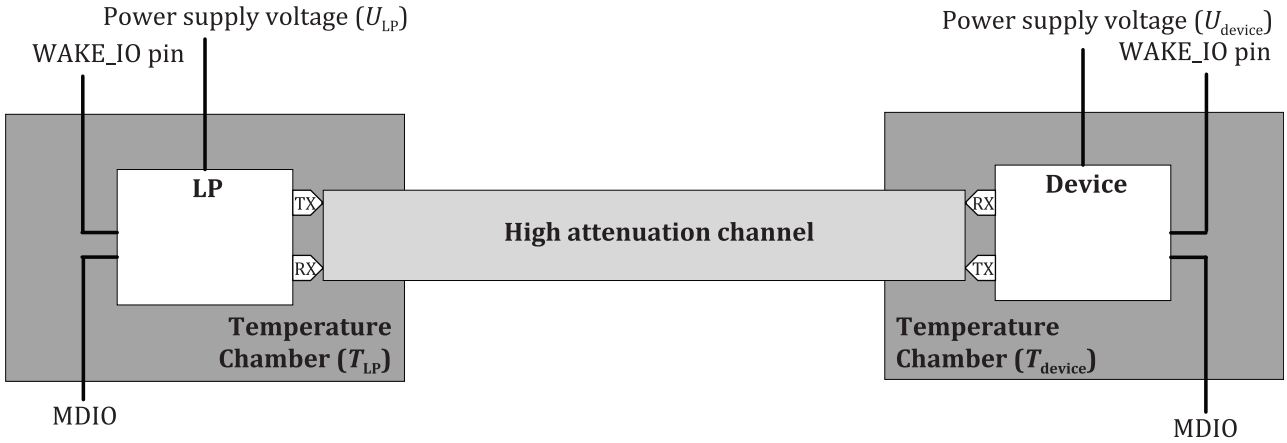

Figure 7 — Interoperability test set-up 1

6.3 Interoperability test set-up 2

The interoperability test set-up 2 is composed by one device and its LP connected by the variable attenuation channel type specified in 5.6.2.3.

The variable attenuation channel implies that the unidirectional channel between the LP transmission and the device reception fulfils REQ 1.25 and that the unidirectional channel between the device transmission and the LP reception fulfils REQ 1.23.

The device is placed inside a temperature chamber set to a controlled temperature T_{device}.

The device is powered by a controlled power supply voltage U_{device}.

The device, LP1 and LP2 may include a wake I/O block connected to a WAKE_IO pin as specified in ISO 21111-2:—, 6.6.

For the test cases that use this test set-up, to power up the device or LP means to set the power_off_entity variable specified in ISO 21111-2 to FALSE for the GEPOF entity included in the device or LP.

Symmetrically, to power down the device or LP means to set the power_off_entity variable specified in ISO 21111-2 to TRUE for the GEPOF entity included in the device or LP.

The LP is placed inside a temperature chamber set to a controlled temperature T_{LP}.

The LP is powered by a controlled power supply voltage U_{LP}.

REQ	1.33 PHY — Interoperability test plan set-ups — Interoperability test set-up 2
The interoperability test setup 2 shall include the elements and the placement specified in Figure 8.	

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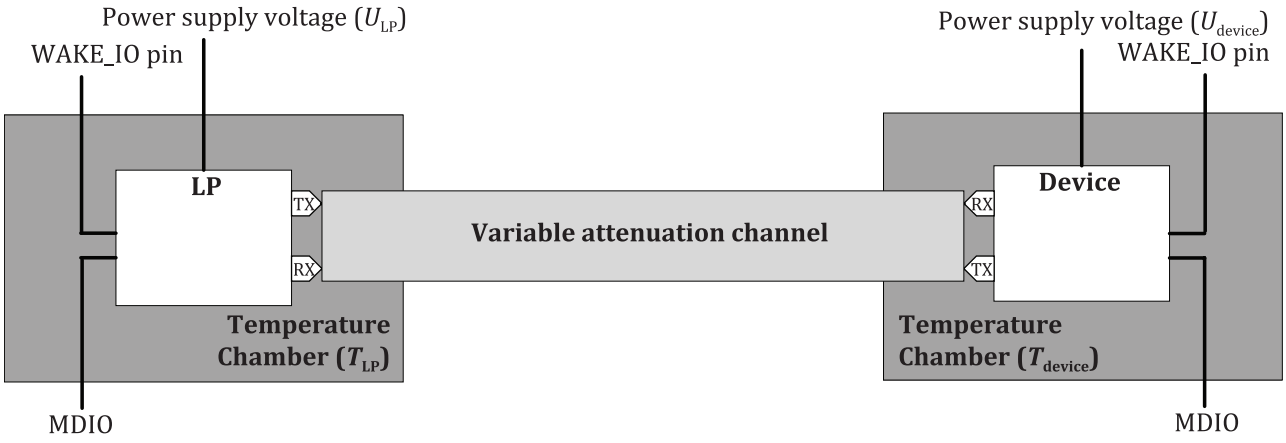

Figure 8 — Interoperability test set-up 2

6.4 Interoperability test set-up 3

The interoperability test set-up 3 is composed of one device that includes at least two GEPOF entities and two LPs connected each one with each of the two GEPOF entities in the device by means of two bidirectional channels.

The bidirectional channel between each LP and the device fulfils the requirements for the bidirectional low attenuation channel type specified in 5.6.2.2.

The device, LP1 and LP2 may include a wake I/O block connected to a WAKE_IO pin as specified in ISO 21111-2:—, 6.6.

For the test cases that use this test set-up, to power up the device means to set the power_off_entity variable specified in ISO 21111-2 to FALSE for each of the GEPOF entities that are included in the device.

REQ	**1.34 PHY — Interoperability test plan set-ups — Interoperability test set-up 3**
The interoperability test setup 3 shall include the elements and the placement specified in Figure 9.	

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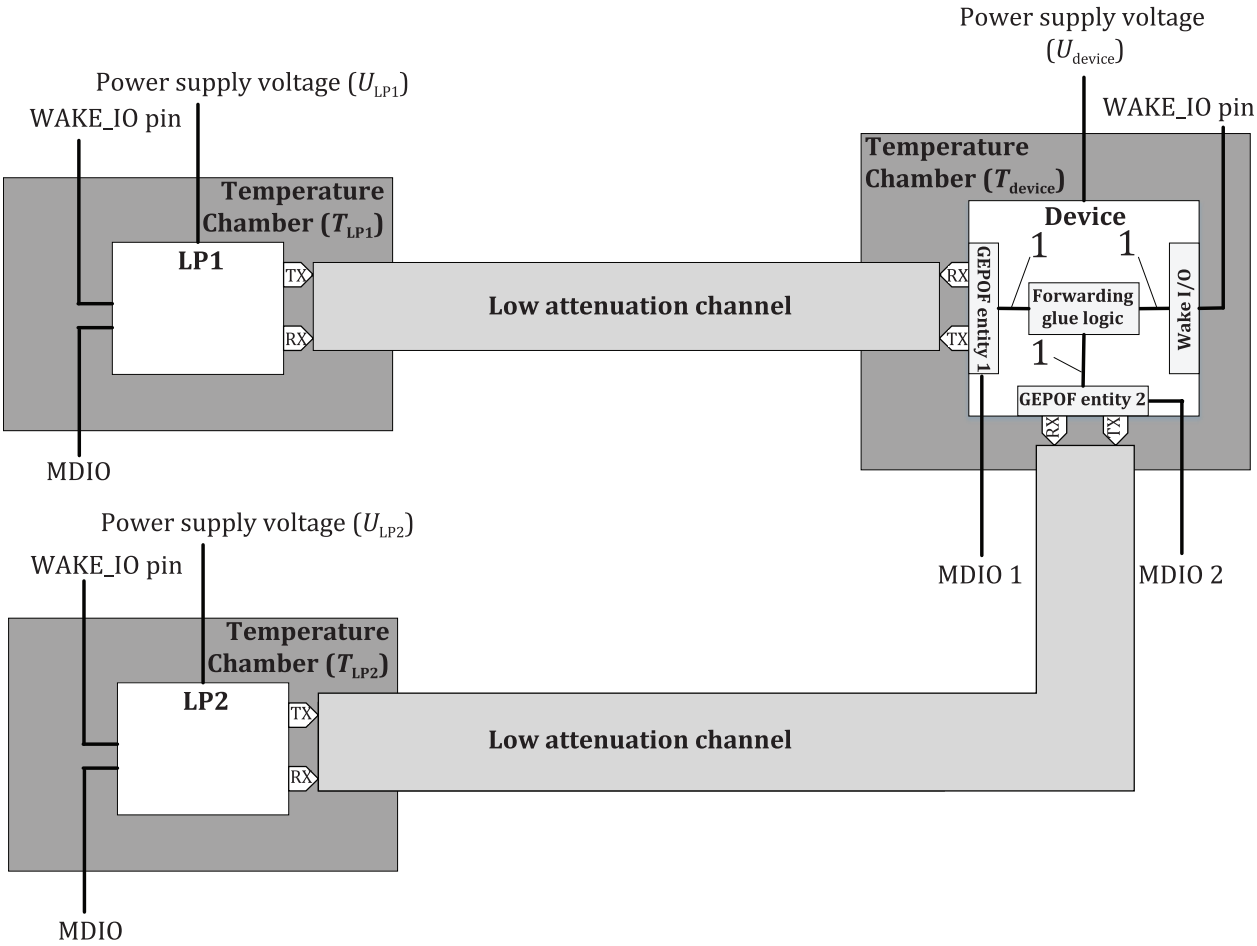

Key

1 NPHY service interface as specified in ISO 21111-2

Figure 9 — Interoperability test set-up 3

6.5 Interoperability test set-up 4

The interoperability test set-up 4 is composed of one device that includes at least two GEPOF entities and two LPs. One LP is connected with one of the two GEPOF entities in the device by means of a bidirectional channel.

The LP1 may include a wake I/O block connected to a WAKE_IO pin as specified in ISO 21111-2:—, 6.6.

The device and LP2 include a wake I/O block connected to a WAKE_IO pin as specified in ISO 21111-2:—, 6.6.

The bidirectional channel between LP1 and the device fulfils the requirements for the bidirectional low attenuation channel type specified in 5.6.2.2.

The LP2 is connected to the device by means of the WAKE_IO pin specified in ISO 21111-2.

For the test cases that use this test set-up, to power up the device means to set the power_off_entity variable specified in ISO 21111-2 to FALSE for each of the GEPOF entities that are included in the device.

REQ	1.35 PHY — Interoperability test plan set-ups — Interoperability test set-up 4
The interoperability test setup 4 shall include the elements and the placement specified in Figure 10.	

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