PROFINET and MES Maintenance Operations

Guideline

for PROFINET

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Prepared by the PROFIBUS Working Group 7 “PROFINET and MES” in the Technical Committee 4 “System Integration”.

In this specification the following key words (in **bold** text) will be used:

may: indicates flexibility of choice with no implied preference.

should: indicates flexibility of choice with a strongly preferred implementation.

shall: indicates a mandatory requirement. Designers **shall** implement such mandatory requirements to ensure interoperability and to claim conformance with this specification.

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Revision Log

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TC4-05-0004-0	0.00.0	TC4-WG7	10.05.05	Initial. version
TC4-05-0004-9	0.90	TC4-WG7	23.03.06	Draft for PI review
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1 Management summary - purpose and scope of this document

PROFINET is a modern concept for distributed automation standards; it is based on Ethernet and integrates existing field bus systems (in particular PROFIBUS) simply and without change. Today PROFINET comprises specifications for diagnosis of the field bus system and its components.

The integration of Automation Systems, Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) is becoming more and more important for enterprise wide integrated information systems. While interfaces between MES and ERP have been defined within the IEC 62264, the definition of the interfaces between MES and the control / field level is still open.

The IEC 62264 subdivides MES into four basic domains:

- Production operations
- Quality operations
- Maintenance operations
- Inventory operations

Since the optimization of maintenance operations is an important task for many enterprises at process industries and discrete manufacturing industries the following guideline describes the interfaces from PROFINET devices and components to MES maintenance systems.

The scope of this document is mainly the definition and classification of the data to be exchanged between the devices / CBA components and MES maintenance systems.

The present document defines a common maintenance state model and describes the necessary extensions to the existing PROFINET IO diagnosis mechanisms and the PROFINET CBA interface.

2 List off affected patents

This profile guideline does not affect any patents known to the members of the working group.

3 Requirements for certification tests

This profile does not crate additional requirements for certification tests.

4 Related documents and references

The following documents and standards are references for the present guideline

[1] PNO PROFIBUS Profile Guideline, Part 3, “Diagnosis, Alarms and Time Stamping”, V1.0, July 2004. Order Number 3.522

[2] PNO PROFIBUS Profile Guideline Part 1: “Identification and Maintenance Functions” V1.1.1, March 2005. Order Number 3.502

[3] ISO / IEC 62264 / “Enterprise-control system integration” – Part 1:“Models and terminology”(2003-03); Part 2: “Object model attributes” (2004-07); ANSI/ISA 95.00.03 - 2005 – Part 3: ”Models of Manufacturing Operations Management”

[4] ISO TC 108 / 184 (Condition Monitoring Systems)

[5] NE107 / VDI/VDE 2650 „Anforderungen an Selbstüberwachung und Diagnose in der Feldinstrumentierung“ Blatt 1-4 (2004-11), Blatt 7 (2005-02)

[6] DIN / EN 13306 Maintenance Terminology (September 2001)

[7] DIN 31051 Instandhaltung – Begriffe und Maßnahmen (June 2003)

[8] PNO “PROFIBUS Specification, Amendment 2 to the PROFIBUS Profile for Process Control Devices” V3.01, Condensed Status and diagnostic messages, PROFIBUS-Nutzerorganisation (PNO), Karlsruhe, January 2005.

[9] NA 064: "Status Signals of Field Instruments", July 2002, NAMUR (www.namur.de)

[10] PNO PROFINET “PROFInet CBA - Architecture Description and Specification“ V2.02 (2004-12)

[11] PNO “GSDML Specification for PROFINET IO” V1.0 (2004-04)

[12] PNO “PROFINET Technology and Application - System Description” (2005-01)

[13] PNO “PROFIBUS/PROFINET Glossary” Version 0.91, January 2004, Order No 4.300

[14] PROFINET IO Application Layer Service Definition – Application Layer Protocol Specification V2.0 (2005-04) Doc. 2.332

5 Definitions and Abbreviations

Abbreviation	Term	Definition	Reference
	Asset	A production plant or machine or a subset of a plant or machine, e.g. a CBA component or a device, ...	
	Availability	Availability is the probability that an item, under the combined influence of its reliability, maintainability and maintenance support, will be able to fulfill its required function over a stated period of time, or at a given point in time. The operating context of a piece of equipment will determine its performance requirements. The definition of availability is: Availability = Uptime / (Downtime + Uptime) or Availability = MTBF / (MDT + MTBF) with MTBF = Mean Time Between Failure MDT = Mean Down Time (as the sum of meantime to repair and possibly mean logistic delay times)	[13]
CBA	Component Based Automation	Component based automation	
	CBA Component	PROFINET CBA Component is a type of device which includes the software-representation of a technological module with defined functionality. An automation solution consists of several PROFINET-Components. A PROFINET-Component contains in general one technological function and the assigned hardware device.	
	Condition Based Maintenance	Preventive maintenance based on performance and/or parameter monitoring and the subsequent actions.	[6]
	Condition Monitoring	Monitoring of assets for the purpose of early problem recognition.	
	Corrective Maintenance	Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function.	[6]
	Device	Entity that performs control, actuating and/or sensing	

Abbreviation	Term	Definition	Reference
		functions and interfaces to other such entities within an automation system. See also PROFINET IO Device and CBA Component	
ERP	Enterprise Resource Planning System	ERP systems depict the business processes of a company. End-to-end integration and omitting stand-alone solutions result in a re-centralized system. In this system, resources can be managed enterprise-wide. Typical ERP software function areas are: • Materials management (procurement, stock keeping, planning and scheduling, evaluation) • Manufacturing, production • Finances and accounting • Controlling • Human resources management • Research and development • Sales and marketing • Master data administration	
	Failure	The nonperformance of a system to achieve its intended function within its performance constraints. Failures are events that occur and some point in time, leading to a failed condition (state) e.g. due to hardware defects.	[13]
	Fault	(1) A fault is an unsatisfactory system condition. Thus, failure states and errors are different kinds of faults. See "Failure" and "Error". (2) Within "Intrinsically Safe Systems": A defect or electrical breakdown of any component, spacing, or insulation that alone or in combination with other defects or breakdowns may adversely affect the electrical or thermal characteristics of the intrinsically safe system. If a defect or breakdown leads to defects or breakdowns in other components, the primary and subsequent defects and breakdowns are considered to be single fault. Certain components may be considered not subject to fault when analyses or tests for intrinsic safety are made.	[13]
	Fault diagnosis	Actions taken for fault recognition, fault localization and cause identification.	[6]
	Fault localization	Actions taken to identify the faulty item at the appropriate indenture level.	[6]
	Inspection	Check for conformity by measuring, observing, testing or gauging the relevant characteristics of an item.	[6]
I&M	I&M Functions	Identification and Maintenance Functions according to the PROFIBUS guideline	[2]
	Item	Any part, component, device, subsystem, functional unit, equipment or system that can be individually considered.	[6]
	Improvement	Combination of all technical, administrative and managerial actions, intended to ameliorate the dependability of an item, without changing its required function.	[6]
KPI	Key performance indicator	The Key Performance Indicator is a business management term. It refers to key figures, based on which the progress and degree of fulfillment with regard to important targets or critical success factors within an organization can be measured and/or determined (e.g. → OEE).	
	Maintenance	Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function.	[6]
MDT	Mean Down Time	Mean Down Time (as the sum of meantime to repair and possibly mean logistic delay times)	
MES	Manufacturing Execution System	Manufacturing Execution Systems according to IEC 62264 (ISA S95)	[3]
MLDT	Mean logistic delay time	Mean accumulated time during which maintenance cannot be carried out due to the necessity to acquire maintenance resources, excluding any administrative	

Abbreviation	Term	Definition	Reference
		delay. NOTE: Logistic delays can be, for example, due to travelling to unattended installations, pending arrival of spare parts, specialists, test equipment and information and unsuitable environmental conditions.	
MTBF	Mean time between failures	Mathematical expectation of the time between failures.	[6]
	Monitored entity	Part of the maintained equipment which is monitored by a monitoring function regarding its modification of certain properties (e.g. degree of degradation)	
MTTR	Mean time to repair	Mean part of active corrective maintenance time during which repair is carried out on an item.	
OEE	Overall equipment effectiveness	Key performance indicator (KPI) that compares the actual machine utilization with the degree of machine utilization that is theoretically possible.	
OPC	OLE for Process Control	The OPC Specification is a non-proprietary technical specification that defines a set of standard interfaces based upon Microsoft's OLE/COM technology. The application of the OPC standard interface makes possible interoperability between automation/control applications, field systems/devices and business/office applications.	[13]
	Preventive Maintenance	Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item.	[6]
	Predictive Maintenance	Condition based maintenance carried out following a forecast derived from the analysis and evaluation of the significant parameters of the degradation of the item.	[6]
	PROFINET	PROFINET is the Ethernet-based automation standard of PROFIBUS International for the implementation of an integrated and consistent automation solution based on Industrial Ethernet. PROFINET supports the integration of simple distributed field devices and time-critical applications in (switched) Ethernet communication (PROFINET IO), as well as the integration of component-based distributed automation systems (PROFINET CBA) for vertical and horizontal integration of networks.	[13]
	PROFINET CBA	Part of the PROFINET technology focusing on component based automation (→ CBA)	
	PROFINET Controller	PROFINET controllers are directly connected to Ethernet. They may be hosted by a PLC or an intelligent field device.	[12], [13]
	PROFINET IO	Part of the PROFINET technology focusing on IO data transmission.	
	PROFINET IO Device	PROFINET device which acts as server for IO operation.	[12]
	PROFINET IO Supervisor	Engineering device which manages commissioning and diagnosis of an IO system	[12]
	Scheduled Maintenance	Preventive maintenance carried out in accordance with an established time schedule or established number of units of use.	[6]
	Status	Indication of the condition of a plant or part of a plant	

Table 5-1 Definitions and abbreviations

6 Introduction and overview

6.1 Maintenance tasks and strategies

Maintenance is a generic term which describes the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function.

Different maintenance strategies have been established over the years. The strategies shown in Figure 1 Major maintenance strategies are the most important ones. They have been derived from EN 13306 [6]. Please refer to chapter 5 for definitions of the maintenance strategies.

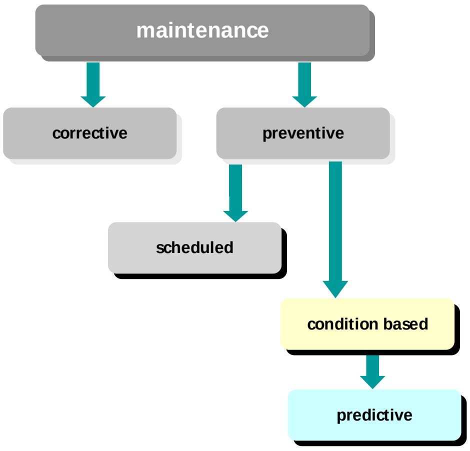


Figure 1 Major maintenance strategies

Especially the condition based maintenance and predictive maintenance have been proved to minimize failure caused shutdowns of plants. In the past the required determination of the condition data was done off-line via inspections of the equipment. During the last years the online monitoring of the equipment condition became more and more a topic for the plant maintenance due to the increasing capabilities of equipment and communication.

6.2 Maintenance workflow

Maintenance activities follow a basic workflow which starts with the request for maintenance action. This request can be created by the operators of a machine or plant or by the equipment itself. The request must be evaluated by the maintenance planner and if necessary a maintenance work order will be created. The work order has to be scheduled considering its priority for the plant availability and the requirements of the plant operators. The work order will then be executed. Finally the completion of the work will be reported to the plant operators and to the maintenance planner.

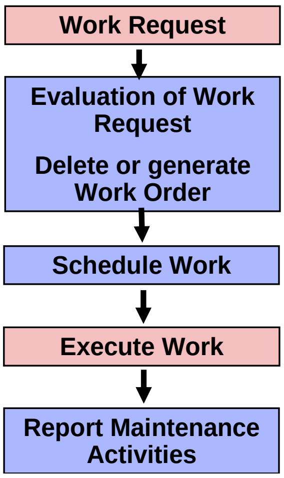


Figure 2 Simplified maintenance workflow

6.3 Maintenance functionalities within the different automation levels

In order to describe the automation of a plant, an appropriate model has been tried and tested for a long time which divides the functions to be executed and the required systems and components into control levels within a pyramid. A different number of levels exist depending on the environment in which the model is used. One common model uses four levels:

ERP (Enterprise Resource Planning), MES (Manufacturing Execution Systems), Controls and Field level.

This model can also be used for the description of the processes related to the maintenance of production plants within an enterprise. Maintenance functionalities are spread over all levels of the pyramid – from local functions in the field up to enterprise wide maintenance planning and management functionalities within the enterprise resource planning level.

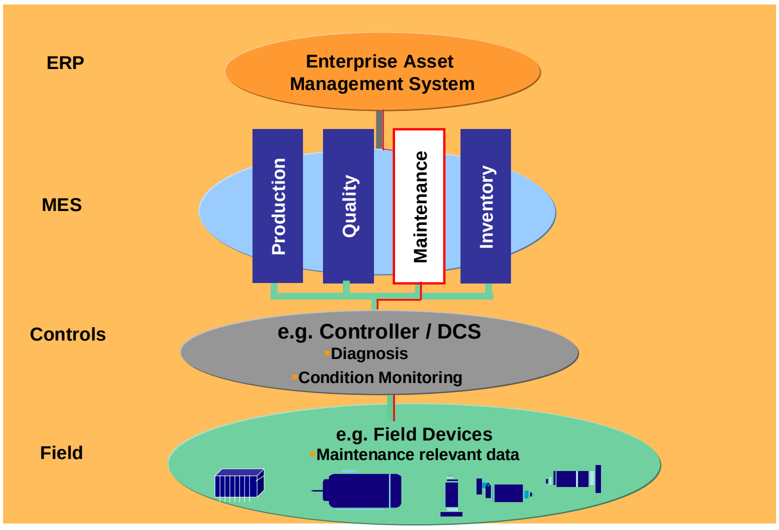


Figure 3 Maintenance functions within the automation pyramid

Local data with relevance for maintenance are being collected in the lower automation levels and forwarded to the upper automation levels for further processing. In the upper levels the local data are combined with each other and with other data to gain maintenance information for technological modules and units. Algorithms and / or expert know how is used to condense data to maintenance information and maintenance knowledge.

6.3.1 ERP level maintenance functions

The ERP level comprises maintenance functions for the administration of maintenance resources as maintenance personnel, spare parts stock and tools. The overall maintenance strategies and work instructions are defined within the ERP level. Further tasks of ERP based maintenance systems are the enterprise wide planning of maintenance activities e.g. plant revisions and the accounting of maintenance expenditure.

6.3.2 MES level maintenance functions

The Manufacturing Execution Systems are located between the ERP and the controls level of the automation pyramid. MES not only provides a layer of communication between Business and Control, they also represent a set of coordinated functions capable of optimizing plant activity in all phases of production. If unexpected maintenance must be done, the MES level is in charge to perform corrective actions and to coordinate the maintenance activity with the production requirements (e.g. production rescheduling in order to reduce the disadvantages as much as possible).

The MES level according to the specification of IEC/ISO 62264 comprises the maintenance operations management which is responsible for the detailed planning and administration of maintenance activities. MES maintenance operations receive global planning information from the ERP system and assign it to the units and cells of the manufacturing plant.

MES maintenance operations include the definition and management of maintenance strategies and maintenance tasks which defines how maintenance will be done within the plant. A major task of MES is conversion of the overall maintenance schedules into detailed schedules for a certain plant and its units and modules. MES dispatches the maintenance activities for execution, tracks the activities until completion and reports the results back to the ERP system. MES maintenance operations also collect data for analysis. Typical outputs of MES are key performance indicators (KPI) as for instance the overall equipment efficiency (OEE) or the mean time between failures (MTBF) which can be used for optimization of the plant.

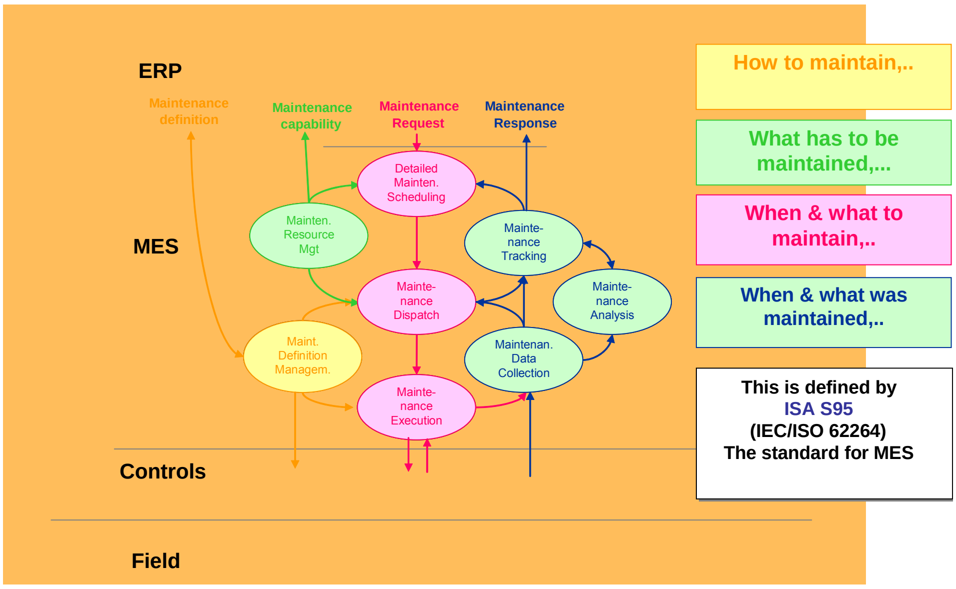


Figure 4 Four questions to be answered by MES maintenance

MES is focused onto production plants and their technological subunits down to the level of units. In the context of maintenance operations a lot of the data needed within MES is originated at field level. This data needs to be made available for MES. Figure 5 MES and PROFINET indicates the context of PROFINET / PROFIBUS field devices, PROFINET CBA components and MES.

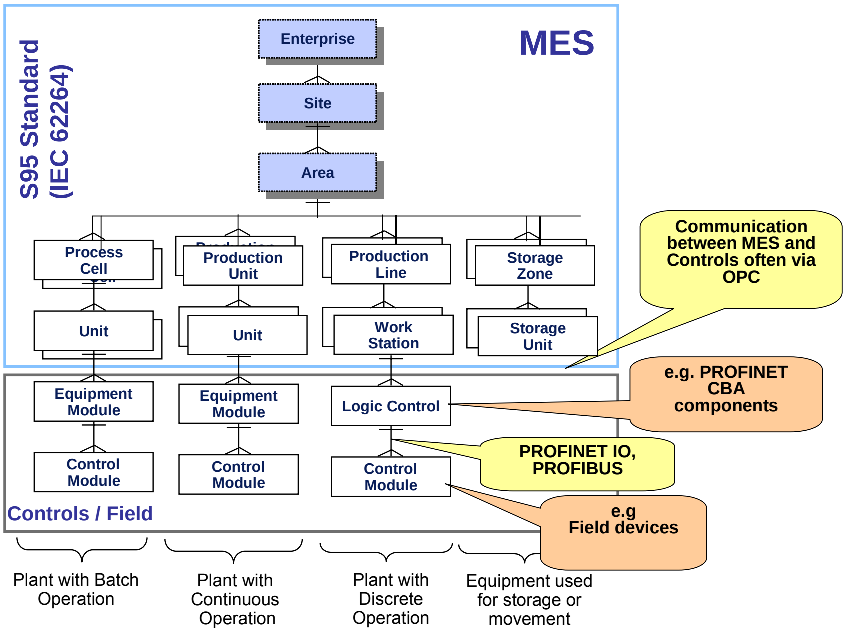


Figure 5 MES and PROFINET / PROFIBUS

6.4 Maintenance functions in control and field level

6.4.1 Control level maintenance functions

The controls level provides functions which are required for efficient maintenance. Beside the diagnosis data of the control modules diagnostic data can be obtained from process monitoring. Especially the monitoring of equipment modules which consist of several control modules (e.g. field devices) and mechanic modules is done within the control or higher level. The controllers have also to provide data which may be required especially for preventive maintenance and are not available within field devices e.g. counters for operating hours, switching cycles etc.

6.4.2 Field level maintenance functions

Field level functionality includes vital maintenance functions and data. Examples are diagnostics and condition monitoring data for the devices itself and for adjacent control modules or mechanical modules. These data are either generated within or collected by the field devices and have to be forwarded to the upper layers of the automation pyramid. The data which identify the field devices itself are also of importance for maintenance. These data are available on physical name plates, in the plant documentation or directly within the devices.
Note: today’s PROFINET IO devices can be part of the field or the control level.

6.5 Maintenance data processing

The maintenance relevant data from field devices (including maintenance specific data and relevant process data) need interpretation and further processing to increase the quality of information and to gain guidelines for required maintenance activities for the devices and for the technological units where the devices belong to (please refer to Figure 6 Maintenance relevant data). Beside the maintenance data from the field devices other data as historical data or maintenance instructions from the device documentation may be required. The maintenance data processing uses algorithms, models and rules to process the data according to the business rules. Also expert knowledge can be employed for maintenance data processing.

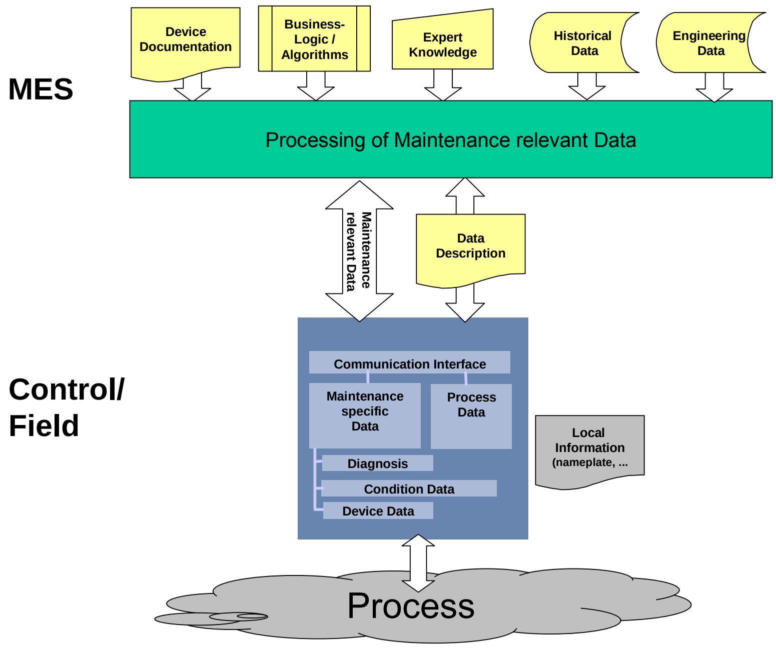


Figure 6 Maintenance relevant data

6.6 Reference architectures

The following figures illustrate the major system configurations and their information flows. Figure 7 Reference architecture 1 “communication via control system”, Figure 8 Reference architecture 2 “data communication via stand alone tool” and Figure 9 Reference architecture 3 “data and event communication via stand alone tool” show configurations which are typical for process industry plants. Figure 10 Reference architecture 4 “communication via PLC” is a typical architecture of a factory automation plant.

The chronological sequence of the information flow is indicated by numbers 1 – 6. Numbers 1 – 4 refer to the event driven communication of the maintenance state. Numbers 5 – 6 refer to the communication of the detailed maintenance data.

In Figure 7 Reference architecture 1 “communication via control system” the maintenance state events and the detailed maintenance data are both handled by the control system which includes a supervisor / master class 2 for handling of the detailed maintenance data. The control system acts as the maintenance information provider for the MES system.

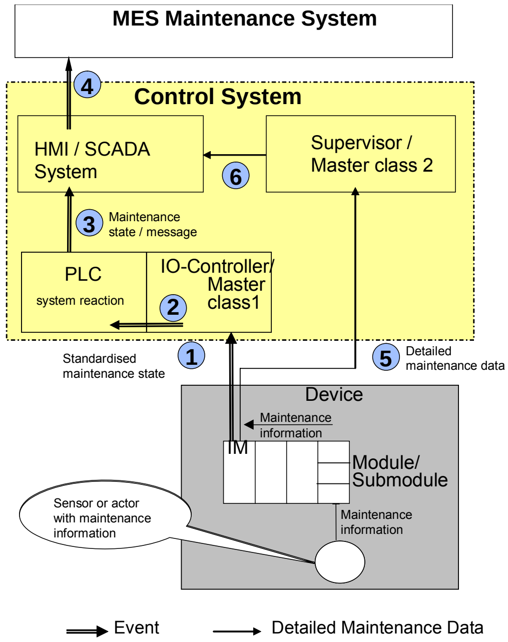


Figure 7 Reference architecture 1 “communication via control system”

In Figure 8 Reference architecture 2 “data communication via stand alone tool” the detailed maintenance data are handled by a stand alone maintenance tool which acts in the PROFINET / PROFIBUS context as a supervisor / master class 2. The maintenance state events are handled in both examples by the control system which includes the IO controller / master class 1 and the SCADA system.

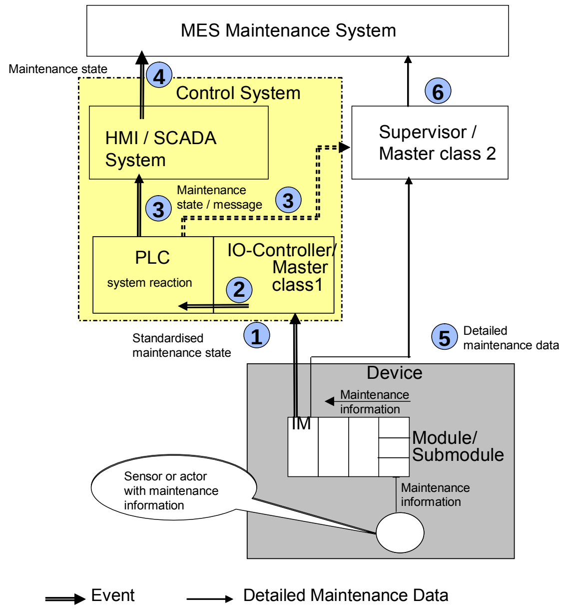


Figure 8 Reference architecture 2 “data communication via stand alone tool”

In Figure 9 Reference architecture 3 “data and event communication via stand alone tool” the detailed maintenance data and the maintenance events are handled by a stand alone maintenance tool which acts in the PROFINET / PROFIBUS context as a supervisor / master class 2.

As an option the PLC may inform the supervisor / master class 2 about the maintenance state event. The specification of PLC blocks for the event communication to the supervisor is not within the scope of this version of the profile guideline.

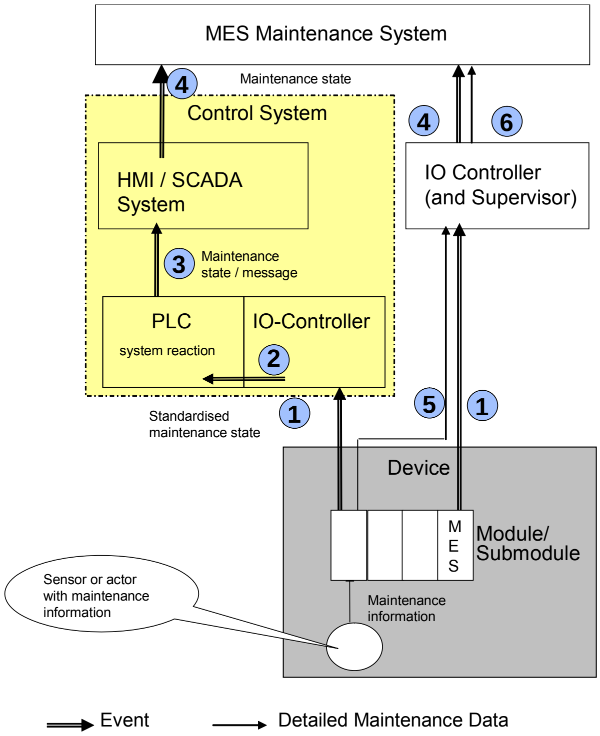


Figure 9 Reference architecture 3 “data and event communication via stand alone tool”

The above shown reference architecture 3 is only applicable for PROFINET IO systems. The device has an additional MES submodule that is dedicated to handle MES related events. In case of an MES related event this dedicated MES submodule generates an alarm towards the MES system / asset management tool acting as an IO controller.
The alarms from the MES submodule to the supervisor are acknowledged by the supervisor. The device design has to make sure that a missing acknowledges does not affect the device behavior towards the IO controller.
The technical details of reference architecture 3 are not covered by this version of the guideline and have to be defined in a later version.

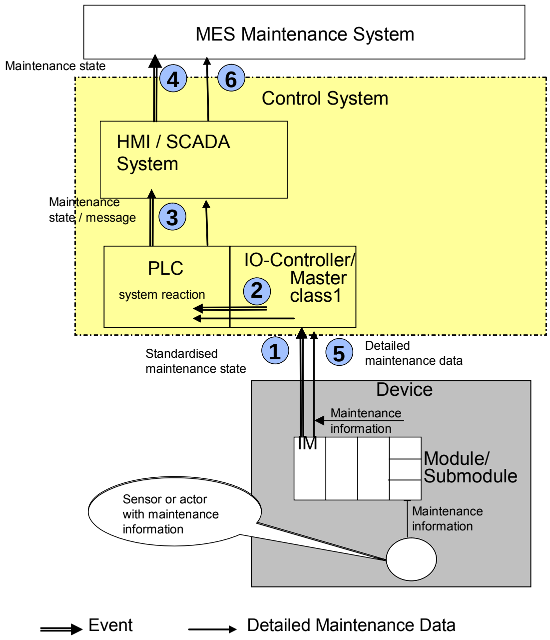


Figure 10 Reference architecture 4 "communication via PLC"

7 Use Cases

The following use cases shall provide an overview about common maintenance tasks which have to be considered within the present specification.

7.1 Use Case 1: Identification of devices

For the purpose of plant maintenance a clear identification of devices is indispensable. Device identification means in maintenance terms the acquisition of all data which are relevant for the selection of a spare part. The following data are required for the identification:

- Manufacturer
- Device type (order number)
- Hardware release
- Software / firmware release

The described data are today available locally outside the device (device inscription, name plate) or within the documentation. The provision of the described data in electronic form directly out of the device would optimize this use case and would save manual action.

7.2 Use Case 2: Determination of the designation of devices

The designation of a device needs to be determined for maintenance purpose. A clear assignment of devices to the technological structure of the plant is necessary for analysis purposes and for the assessment of the impact of device failures onto the system. The localization designation is needed to simply find a device within the plant.

Data needed:

- Function designation / plant designation
- Location designation

As of today the described data are provided as physical labels which are attached to or beside the device. The provision of the described data in electronic form directly out of the device would optimize this use case and would save manual action.

7.3 Use Case 3: Set Up and synchronization of MES asset databases

MES maintenance systems often include asset databases. These databases have to be filled with information at the time of the system setup and have to be kept up to date during operation of the system. The device information within the asset database has to be consistent with the devices which are physically installed in the plant. This use case can be fulfilled much easier if the device information can be read out of the devices.

Data needed:

- See use case 1 and 2
- Installation date
- Last maintenance date
- End of warranty
- Inventory id
- Cost center

7.4 Use Case 4: Indication of the maintenance state

Maintenance measures have to be scheduled for a plant or for a certain area of the plant. The state of all devices subject to wear & tear, consumption, pollution etc. needs to be determined for the purpose of preventive maintenance planning.

Information needed:

- Standardized maintenance state indication and differentiation.

7.5 Use Case 5: Determination of maintenance relevant condition data

Maintenance relevant condition data of devices are needed within the MES maintenance system for the evaluation of maintenance measures.

This use case has to distinguish between:

- Collection of condition data during normal operation
- Collection of data under predefined conditions or with special test profiles. This can be achieved by test runs which may be triggered from outside the device e.g. by a controller, MES or other devices.

The required data / functions may be presented within certain devices today but a high engineering effort is needed to make use of these data.

8 Requirements

The following requirements can be derived from the use cases of chapter 7.

Requirement number	Description	Reference
1.	**Identification**	
1.1.	Devices shall provide data for clear identification of the device as already specified within the "PROFIBUS Profile Guideline Identification and Maintenance Functions" (I&M).	[2]
2.	**Maintenance State**	
2.1.	Devices which are subject to preventive maintenance shall provide a standardized maintenance state. The maintenance state shall be in addition to the diagnostic information. The maintenance state shall initialize an event in case of a status change.	
2.2.	The device maintenance state shall include a basic set of states which is standardized and common for all devices	
2.3	The information about the supported maintenance states must be provided by the device or the data description	
2.4	The basic maintenance state should provide facilities to distinguish between arising problems which need short term maintenance attendance from those which can be handled on a long or medium term basis.	
2.5	In addition to the common state the maintenance information should provide additional profile and manufacturer specific information.	
2.6.	The basic maintenance state of devices shall have the same syntax and semantic.	
2.7.	The limits used for the determination of the maintenance state should be adjustable if necessary and useful e. g. for different applications.	
3.	**Detailed Maintenance Data**	
3.1	The maintenance state of a device is the result of one or several monitored entities of the device. Examples of monitored entities are cycle counting, current monitoring or pressure difference monitoring.	
3.2	The monitored entities shall provide detailed maintenance data in addition to the maintenance state for evaluation by skilled maintenance personnel or a superior maintenance management system. The detailed maintenance data shall be linked to the corresponding monitored entities.	
3.3	Some monitored entities e.g. cycle counters or maintenance timers may need manual setting to a defined state after performance of maintenance activities. Facilities are to be prepared for this purpose.	
3.4	A standardized way for triggering of test runs is required	

Table 8-1 Requirements

9 Maintenance state and data

MES maintenance needs condition information from the level 1/2 equipment for determination of the required maintenance tasks. According to chapter 8 requirement number 2.x devices which are subject to preventive maintenance shall provide a standardized maintenance state.

The NE107 / VDI/VDE 2650 [5] defines the device state "maintenance required". Maintenance required indicates that maintenance attendance is needed within a certain time span e.g. 7

days. The state maintenance demanded indicates an imminent problem which requires maintenance action within a shorter time span e.g. 24h.

9.1 Maintenance state model

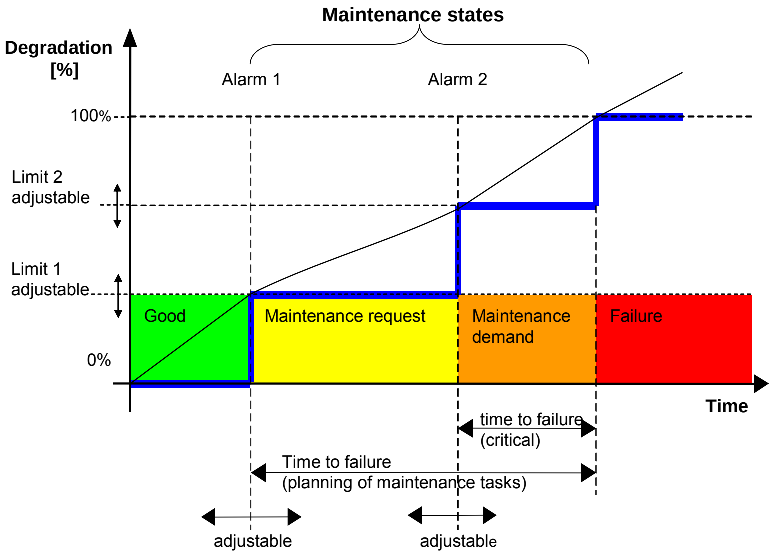


Figure 11 Maintenance state model for devices

(Remark to figure 11: the colors are only for better overview not for visualization purpose)

A device may be subject to wear, fouling, or other effects which degrade the function after a certain period of time and lead at the end to a failure of the device. The progression of the degradation depends on time / operating time or frequency, load, the device design, environmental conditions, etc. It is vital information to know the current degree of wear, fouling, etc. of the device and thus being able to plan adequate measures to prevent the breakdown. For better overview and simple communication it is advised to assign the device condition to a common maintenance state model which is shown in Figure 11 Maintenance state model for devices .

The status model provides beside the states “good” and “failure” the maintenance states “maintenance required” and “maintenance demanded”. The maintenance state changes if the degradation of the device reaches a certain limit value. The change of the maintenance state shall be communicated to the systems of the superordinated automation levels. The limits between the different maintenance states shall be adjustable to allow different times to failure. It is advised to adjust the limit values of all devices in a way which results in common times to failure (e.g. 7days and 24hours). However application specific adjustments of the limit values must be possible to cope with the special operating and environmental conditions of the end users plant.

The described model represents the superset of the possible maintenance states. The devices can adopt the described model according to their capabilities. A specific device may only be able to support the subset “maintenance required” or “maintenance demanded”.

9.2 Device maintenance state

A device can have one or more entities for monitoring of device internal or external functions, characteristics or values. Each monitored entity may follow its own degrading function and may need its own limit values. It can also support different states of the maintenance state model.

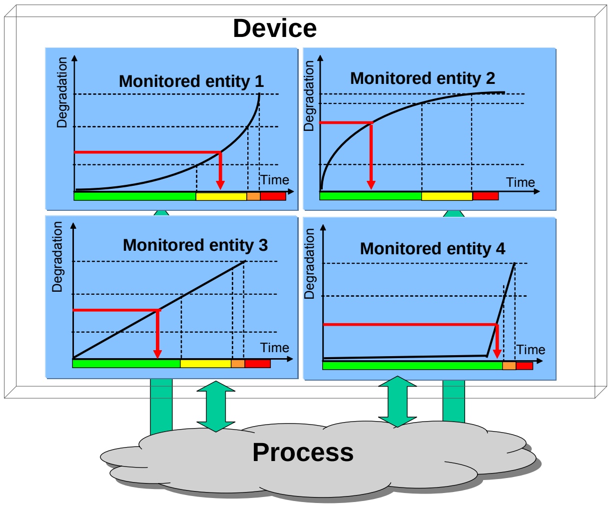


Figure 12 Device with monitored entities

The maintenance state of the device is made up by the maintenance states of the monitored entities. The device does not determine a collective maintenance state but communicates the maintenance states of its monitored entities. Any change of a monitored entity state shall be communicated independently. This means that a state change of a monitored entity will be communicated even if another monitored entity of the same device has already communicated the same or a higher prior maintenance state. The limit values of the monitored entities have to be set as part of the device engineering. Reasonable default values have to be provided by the device manufacturer.

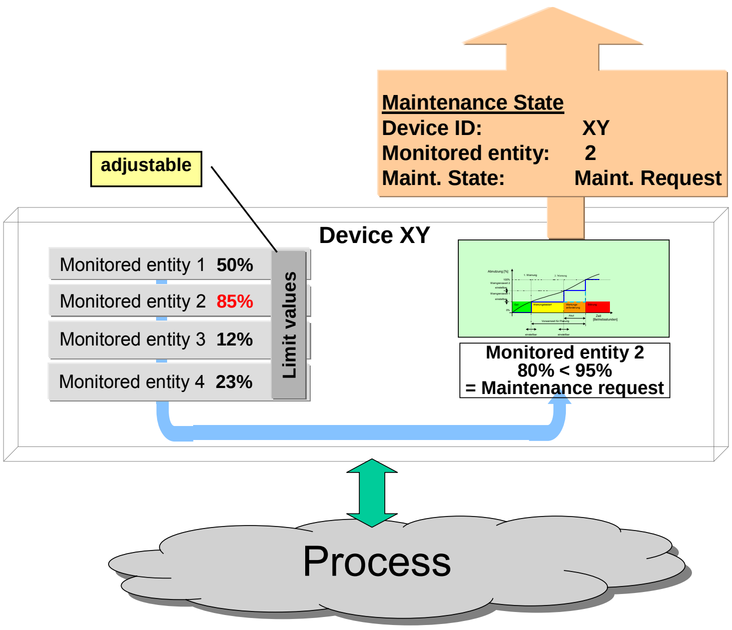


Figure 13 Device maintenance state

Figure 13 Device maintenance state shows a device with four monitored entities whereby the maintenance state of entity 2 just reached the limit value for the change to the “maintenance required” state. The change of the maintenance state is communicated by an alarm which indicates the device ID, the relevant monitored entity and the maintenance state of the monitored entity.

Beside the maintenance state of the monitored entities it shall be possible to fetch detailed maintenance data from the monitored entities of a device. These data may include beside the states of all monitored entities of the device also associated values, e.g. the limit values.

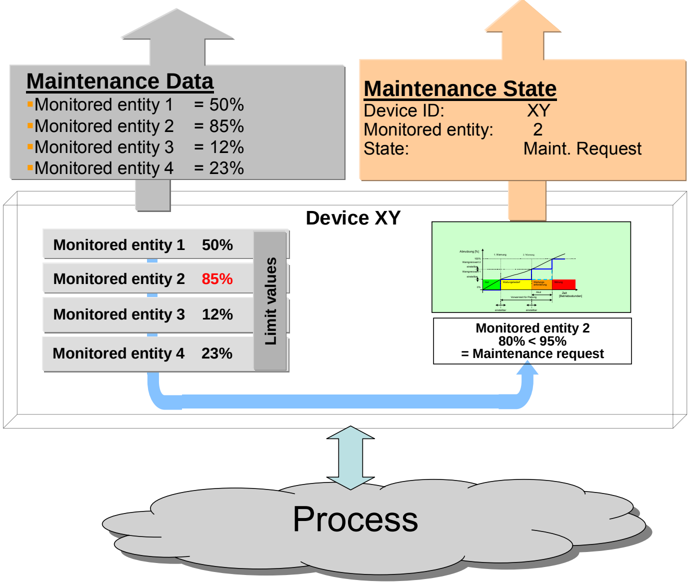


Figure 14 Device maintenance data

The maintenance data are defined by the device manufacturer. It is necessary to provide facilities for the interpretation of the maintenance data.
In addition to the manufacturer specific maintenance data it should be aimed to establish sets of common maintenance data for the devices which are designed according to application profiles. However the definition of such application profile specific maintenance data is the responsibility of the concerning profile working groups and will not be detailed within this guideline.

9.3 Monitored Entities

A Monitored Entity is always able to generate a Maintenance State based on a current value. The function for generating the Maintenance State in the Monitored Entity and the data sources are not described in this Guideline. They can be defined in application profiles or by the device manufacturer.
The Monitored Entities of a device, together with its structure and associated parameters and data, are to be described in a device description.
The Detailed Maintenance Data are based on the Maintenance State and it is very well possible that they are required for further processing, e.g. the determination of cross-device Maintenance States in MES.
The Detailed Maintenance Data must be able to be communicated and interpreted. They can be read out via the acyclic access paths defined by PI (see also Section 6.5).

9.3.1 Description of Monitored Entities

The following is required for the interpretation of a Monitored Entity:

- Identifier / name of the Monitored Entity
- Assignment of the Monitored Entity to a submodule and channel
- Limit Value Maintenance Required

- Limit Value Maintenance Demanded
- Limit Value Maintenance Failure
- References to the raw data (formats, units, addressing)

10 Identification and Maintenance Functions

I&M functions are described in a separate Profile Guideline [2] and are therefore not described in this document.

11 PROFINET IO mechanisms for communication of maintenance state and data

11.1 Architecture model for PROFINET IO

This chapter is for information only and will not be updated. For latest definition of PROFINET IO architecture, device model and diagnostic please refer to the PROFINET IO specification [14]

11.1.1 PROFINET IO – device model

The device model of a PROFINET IO device permits the implementation of both compact and modular devices.

11.1.1.1 Device structure

A PROFINET IO device is subdivided into slots and sub-slots. A module (= physical module) is mapped to each slot and a submodule (= physical submodule) is mapped to each sub-slot.

11.1.1.2 Address hierarchy

The device model of a PROFINET IO device has the following address hierarchy:

- **IO subsystem ID**
- **Station number (**IP address, InterfaceUUID, ObjectUUID)
- API (unique addressing of the application process)
- **Slot** (addresses the corresponding slot and thus the module)
- **Sub-slot** (addresses the corresponding sub-slot and thus the submodule)
- Index (addresses the individual data record)

11.1.1.2.1 Objects for modules

Modules cannot carry any objects in the device model of PROFINET IO.

11.1.1.2.2 Objects for submodules 1 .. 65536

Each submodule can be the carrier of the following objects:

- Cyclic data (useful data of the I/O interface to the process control)
- Alarms
- Data records
    - Parameters (transfer via data records)
    - Diagnosis (transfer via data records)

In the device model of PROFINET IO, it is permissible that submodules use only a subset of these objects.

11.1.1.2.2.1 Objects for submodule 0

The submodule 0 cannot carry any objects in the device model of PROFINET IO.

11.1.1.2.2.1.1 Objects for submodule “Device Access Point” (DAP)

The submodule “Device Access Point” (DAP) can be the carrier of the following objects:

- Alarms
- Data records
    - Parameters (transfer via data records)
    - Diagnosis (transfer via data records)

Cyclic useful data are not permissible in the device model of PROFINET IO.

However, it is permissible that the submodule “Device Access Point” (DAP) only uses a subset of these objects.

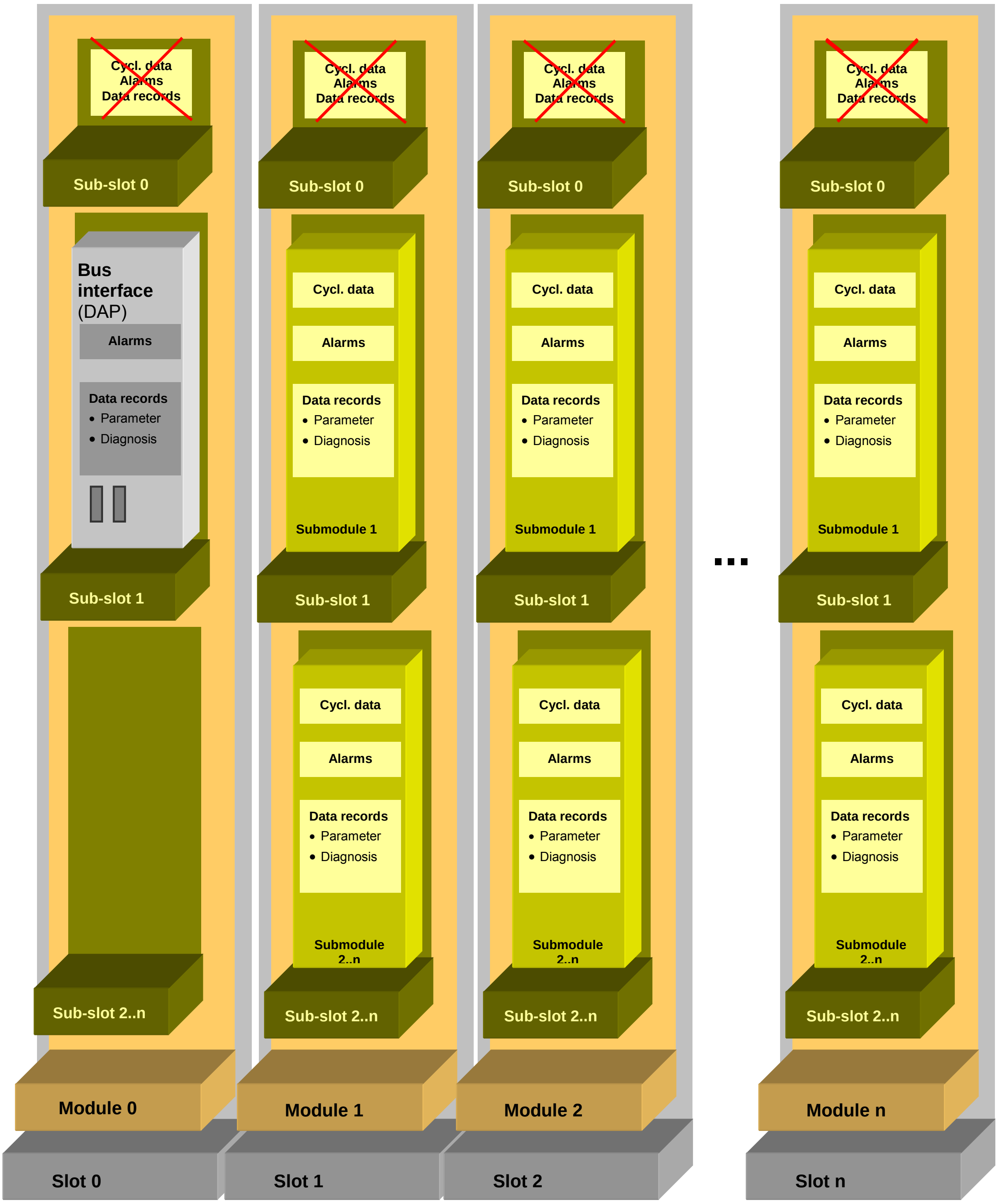


Figure 15 PROFINET IO – Device model

11.1.2 Diagnosis mechanisms in the PROFINET IO device model

11.1.2.1 Overall model

Principally, the diagnostic information for PROFINET IO devices is divided into two groups:

- **Event-driven** diagnostic information, which is transmitted as a diagnostic alarm or during the station's return to the PROFINET IO controller.
- **Acyclic** diagnostic information, which is transmitted to the PROFINET IO controller via read data record.

Both groups contain the following diagnostic information: group information on the submodule level, as well as the individual state of each channel of this submodule.

The **event-driven** diagnostic information is thus made up of

- the diagnostic alarm, which
  - contains the group information for a submodule in the AlarmSpecifier
  - contains the individual state of a submodule channel in the ChannelError

- the station's return, which
  - contains the group information for a submodule in the SubmodulState

    Note: The individual state of a submodule channel can be read acyclically from a station after its return.

The **acyclic diagnostic information** is made up of

- various diagnostic data records, which can be read as state information from the PROFINET IO devices whenever required.
  The data volume received corresponds to the event-driven diagnostic information.

The individual diagnostic information messages are described in detail below.

The figure below shows the classification of the channel, the diagnostic status and the group information with regard to the diagnostic alarm.

For detailed definition and coding refer to the PROFINET IO specification [14].

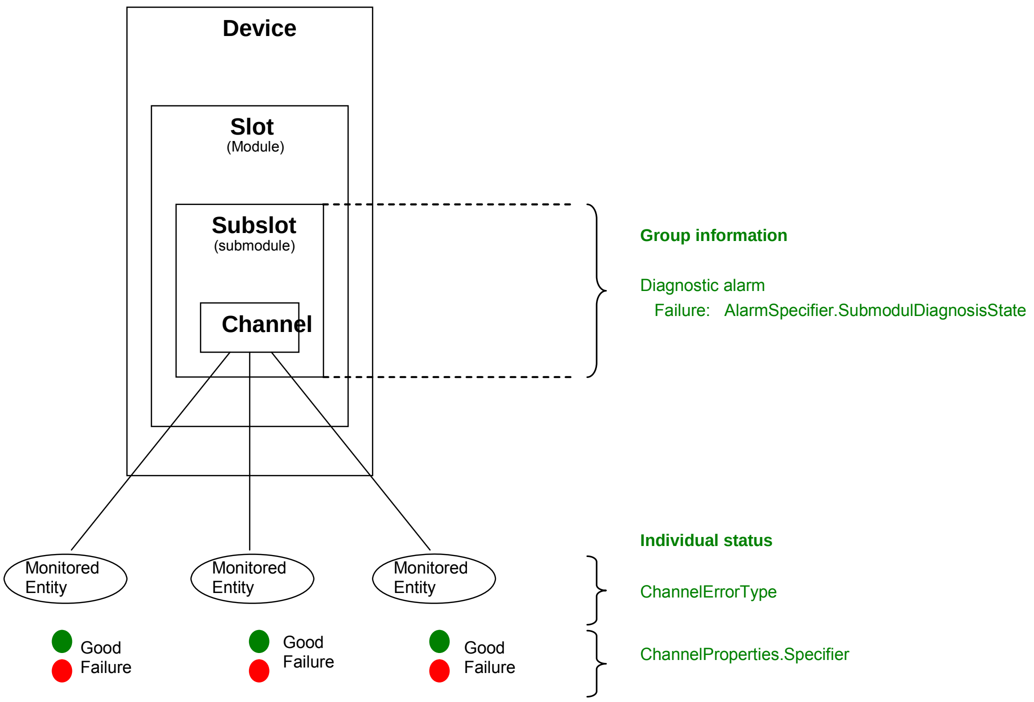


Figure 16 Classification of the channel, the diagnostic statuses and the group information with regard to the diagnostic alarm

11.1.2.2 Channel modeling with PROFINET IO

Within the diagnostics mechanisms (and only there), the channel is modeled in the device model of PROFINET IO.

The channel is a substructure of the submodule. A submodule can have up to 65536 channels.

11.1.2.3 Diagnostic function (Monitored Entities) of a channel

Diagnostic functions are monitored within a channel.

The monitoring of a channel's diagnostic function can be implemented as follows:

- Monitored by the submodule itself (e.g. short-circuit, wire break, overtemperature, ...)
- Monitored by the connected sensor/actuator, and by proxy the submodule provides the diagnostic information for the programmable controller (e.g. the status of a connected motor's slip ring, bearing or carbon brush is monitored).

  The information gained in this case is frequently utilized for maintenance purposes.

A channel can monitor several diagnostic functions simultaneously.

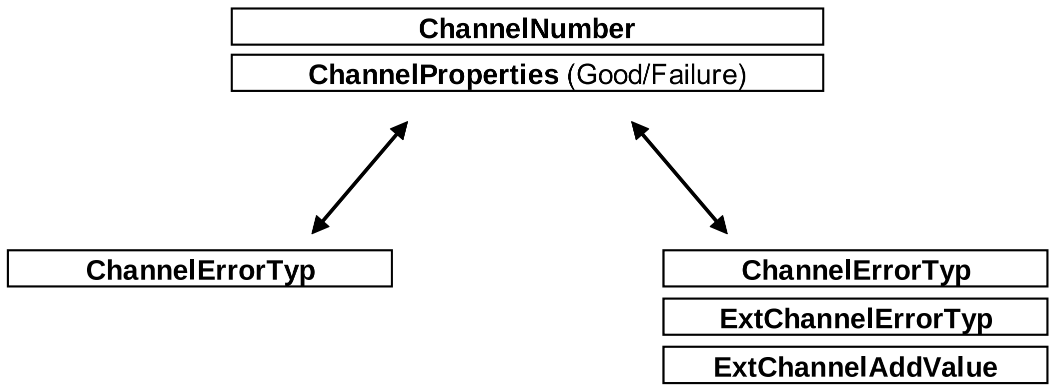
A **diagnostic function has two diagnostic statuses: Good/Failure**.

With PROFINET IO, the diagnostic function of a channel is represented by **ChannelErrorTypes/ ExtChannelErrorTypes**.

The diagnostic statuses Good/Failure of the diagnostic functions are derived from the **ChannelProperties.Specifier** (failure identifier) with PROFINET IO.

In the event of a fault, these faulty functions are coded as channel errors and provided via the diagnostic alarm and diagnostic data records.

For detailed definition and coding refer to the PROFINET IO specification [14].



ChannelDiagnosisData (USI 0x8000) ExtChannelDiagnosisData (USI 0x8002)

Figure 17 Overview of ChannelDiagnosisData in principle

Monitored Entities

The diagnostic functions to be monitored are called **Monitored Entities**.

This term is used for diagnostic functions monitored by the submodule itself as well as for diagnostic functions monitored by the connected sensor/actuator.

11.1.2.4 Group information in the diagnostic alarm

The structures of the diagnostic alarm contain a group information on the submodule level.
This group information is derived from the disjunction (logical ORing) of all individual diagnostic statuses of the submodule.

The group information on the submodule level is represented by the **AlarmSpecifier.SubModuleDiagnosisState** in the device model of PROFINET IO.

For a channel, the entry ChannelProperties.Specifier can also be regarded as group information, since the identifier "error disappears but other error remain" represents a group information in this case.

Note:

Group information on the module and device level are not modeled in the diagnostic alarm of PROFINET IO (see also Diagnostic data records).

For detailed definition and coding refer to the PROFINET IO specification [14].

11.1.2.5 Diagnostic data records

The channel errors can be read out from the IO device via the **diagnostic data records** whenever required using acyclical services. The submodule is the smallest unit that can be scanned for diagnostic data records. This means that the service „Read ChannelDiagnosisData" supplies all present channel errors of a submodule. The channel errors of a specific channel cannot be scanned individually.

The diagnostic data records can be specifically filtered, e.g. on the module or device level, so that the application can generate the group information on the module and device level.

For example, all channel errors of a module can be read by a PROFINET IO device via the diagnostic data record with *Index 0xC00A ChannelDiagnosisData for one slot*.
If this data record does not contain any channel errors, this can be interpreted as group information indicating an undisturbed module.

For detailed definition and coding refer to the PROFINET IO specification [14].

11.1.2.6 Group information with return of the IO device

Within the framework of the return of an IO device, the diagnostic status for a submodule is exchanged between the IO device and the IO controller using the **SubmoduleState.DiagInfo** (= failure identifier for a submodule).

This group information is derived from the logical disjunction (logical ORing) of all diagnostic statuses of the submodule.

For detailed definition and coding refer to the PROFINET IO specification [14].

11.2 Integration of the maintenance function in the PROFINET IO device model

11.2.1 Maintenance information added to the overall model

The maintenance information is integrated into the diagnostic information (diagnostic alarm, diagnostic data records and return of a IO device).

- **Event-driven** diagnostic information, which is transmitted as a diagnostic alarm or during the station's return to the PROFINET IO controller.
- **Acyclic** diagnostic information, which is transmitted to the PROFINET IO controller via read data record.

To integrate the maintenance information in the diagnosis, the statuses **Maintenance required** and **Maintenance demanded** are added to the diagnostic statuses (Good, Failure) of a Monitored Entity.

Also up to thirty profile specific **Qualifier** are available.

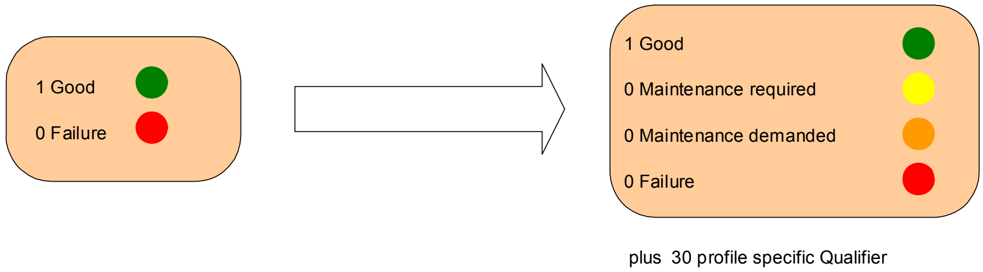


Figure 18 Extending the diagnostic status

11.2.2 Extending the group information in the diagnostic alarm

The group information on the submodule level in the AlarmSpecifier of the alarm header is supplemented with a **USI 0x8100** definition ("also called "header extension"), which contains the maintenance states Maintenance required, Maintenance demanded and thirty profile specific Qualifier..

Thus the group status of the submodule is directly entered in the diagnostic alarm.

With this extension, there is one group bit each for:

- Failure →in AlarmSpecifier.SubmoduleDiagnosisState
- Maintenance required →in USI 0x8100 definition ("header extension")
- Maintenance demanded →in USI 0x8100 definition ("header extension")
- Qualifier _2 … 31 →in USI 0x8100 definition ("header extension")

The group bits are derived in each case from the disjunction (logical ORing) of all corresponding channel-related diagnostic statuses of the submodule.

The group bits are managed on the submodule independently of each other. Thus they can be set in many different combinations. (For example, all four group bits can be set simultaneously.)

For detailed definition and coding refer to the PROFINET IO specification [14].

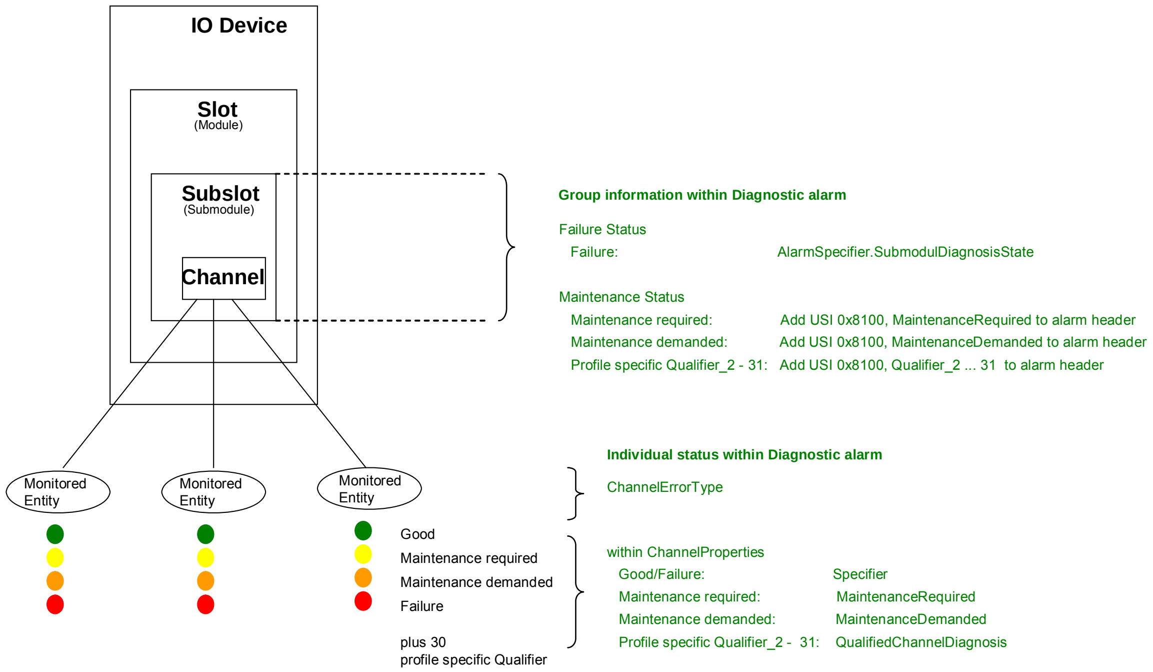


Figure 19 Classification of the channel, the diagnostic/maintenance states and the group information with regard to the diagnostic alarm

Rules for using the USI 0x8100

- A newly defined USI (0x8100) comes right after the AlarmHeader
- Basically it is an extension of the AlarmHeader. Therefore, if there is an USI 0x8100, it must always be at the first position of the AlarmItem.
- The maintenance state of the submodule is included in the USI 0x8100.
- Since the USI 0x8100 is always in the first position, the AlarmItem must not be structured as "multiple".
  (however, this is possible when ChannelDiagnosis and ExtChannelDiagnosis are present in the AlarmItem).
- If a device supports the Maintenance functions, the USI 0x8100 must be used in the diagnostic alarm, even when the diagnostic alarm only transmits failures (that is, no maintenance information).
  In this case the maintenance bits are set to “0”.

For detailed definition and coding refer to the PROFINET IO specification [14].

11.2.3 Extending the individual diagnostic status of a Monitored Entity

To display the two maintenance states (required, demanded) and the 30 profile specific qualifier, the following information is added to the ChannelProperties within the channel errors.

- **ChannelProperties.MaintenanceRequired**
- **ChannelProperties.MaintenanceDemanded**
- **One Qualifier for 30 profile specific maintenance statuses**

Also a new user structure identifier USI 0x8003 is defined to handle 30 QualifiedChannelQualifier.

Thus the states Failure, Maintenance demanded, Maintenance required and 30 QualifiedChannelQualifier, can be transferred in a diagnostic alarm for a Monitored Entity.

For detailed definition and coding refer to the PROFINET IO specification [14].

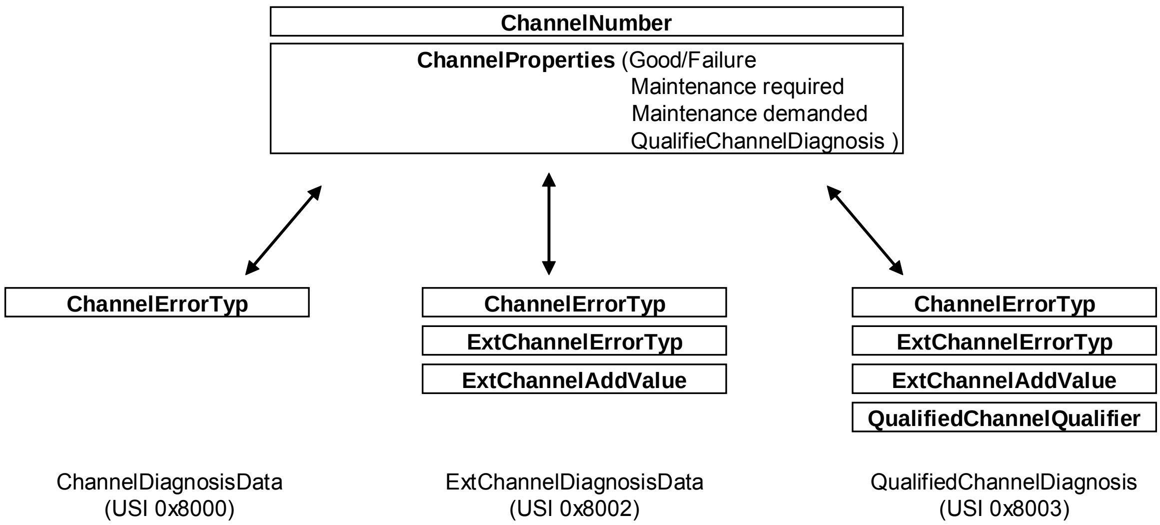


Figure 20 Overview of ChannelDiagnosisData with Maintenance in principle

ChannelProperties

Within the ChannelProperties there isn’t a exclusive Bit for each status.
The dependencies with elements of the field ChannelProperties are specified in following Table.

ChannelProperties			Result
.Maintenance-Required	**.Maintenance-Demanded**	**.Specifier**	
0	0	Appears	Failure
0	1	Appears	Maintenance Demanded
1	0	Appears	Maintenance Required
1	1	Appears	Qualified Channel Diagnosis
0	0	Disappears	Good

Table 11-1 Valid combinations within ChannelProperties

For detailed definition and coding refer to the PROFINET IO specification [14].

By adding the two maintenance state bits and the QualifiedChannelDiagnosis to the ChannelProperties, these statuses can be transferred in the diagnostic alarm utilizing the mechanisms for ChannelDiagnosis as well as utilizing the mechanisms for ExtendedChannelDiagnosis and QualifiedChannelDiagnosis.

By adding maintenance state bits to the ChannelProperties, it is even possible to subsequently assign the “pre-stages” for Maintenance requested, Maintenance for channel errors already specified today.

11.2.4 Diagnostic data records

Since channel errors can be read out from the IO device using acyclical services via the **diagnostic data records** whenever required, the maintenance information is included in the diagnostic data records due to the extension of the channel errors.

The submodule is the smallest unit that can be scanned for diagnostic data records. This means that the service “Read ChannelDiagnosisData” supplies all existing channel errors of a submodule. The channel errors of a specific channel cannot be scanned individually.

For detailed definition and coding refer to the PROFINET IO specification [14].

11.2.5 Examples for Use

The definitions permit that Device Development can implement many diagnostic and maintenance functions.

The figure below demonstrates this based on an example which shows the utilization of the diagnostic alarm.

The example shows a motor interface which is mapped to a submodule. The motor example was selected since both simple faults as well as maintenance information can occur.

The figure below shows the classification of the channel, the diagnostic status and the group information with regard to the diagnostic alarm after adding maintenance data.

For detailed definition and coding refer to the PROFINET IO specification [14].

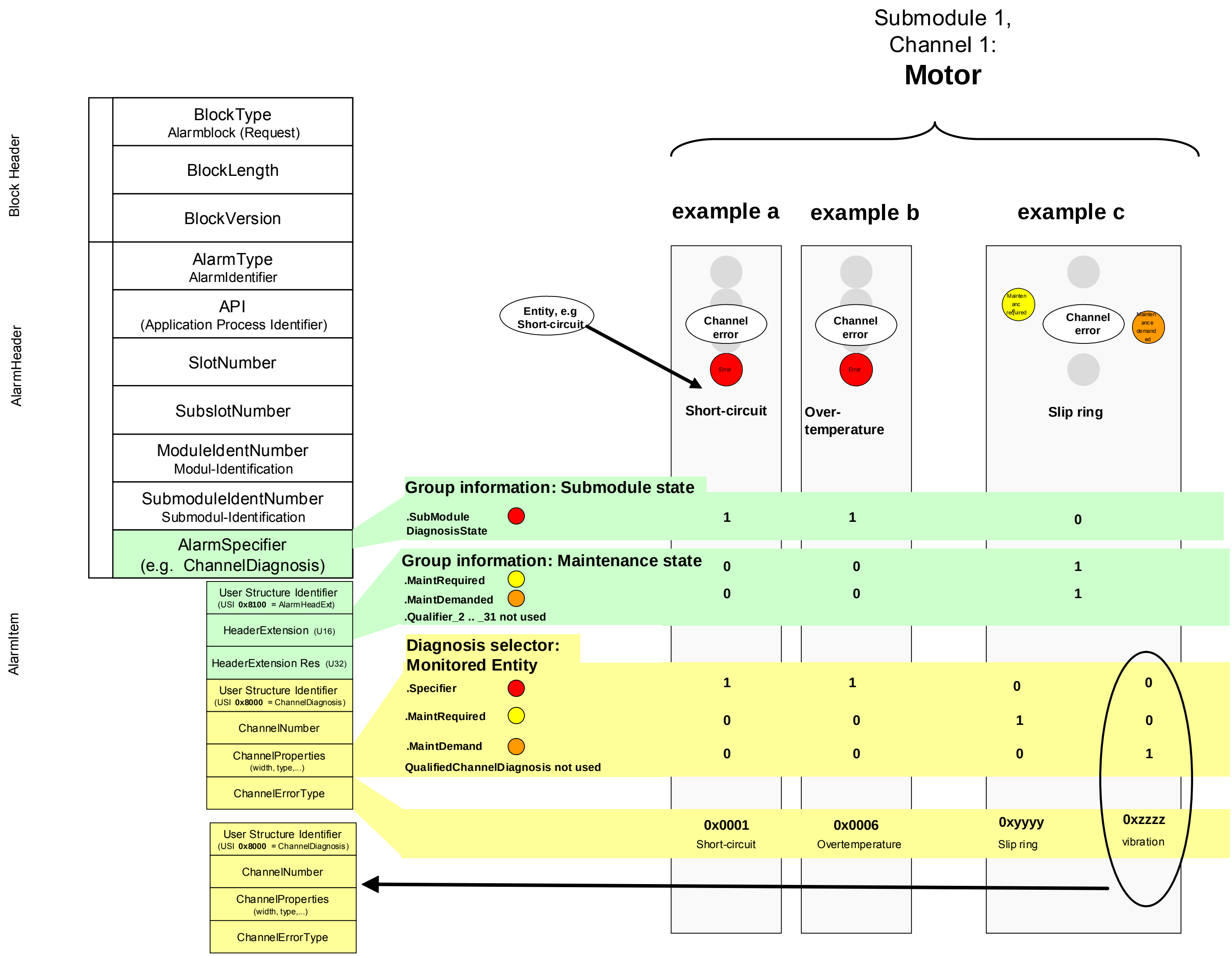


Figure 21 Example with USI 0x8000: Utilization options of the diagnosis/maintenance with regard to the diagnostic alarm

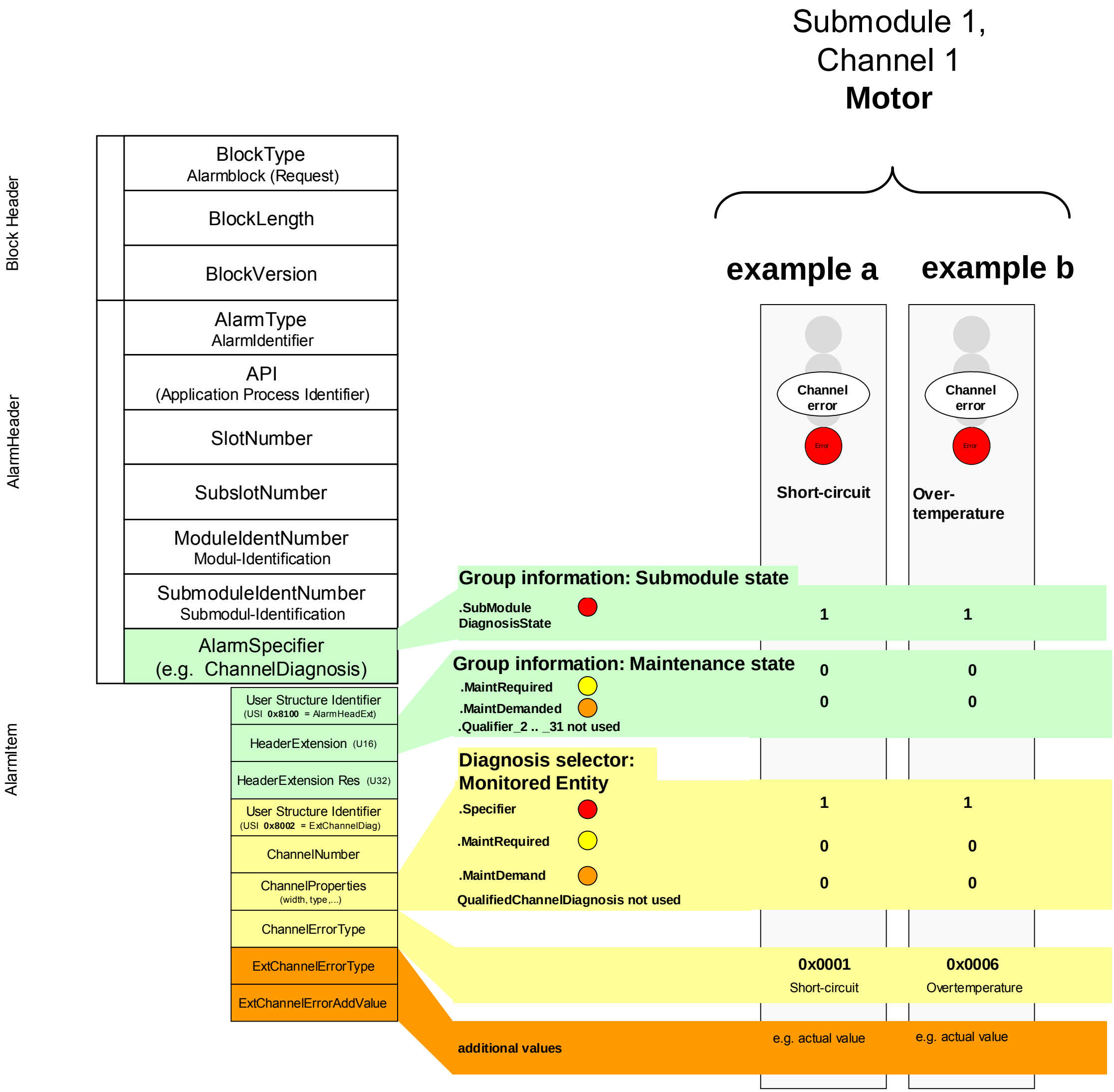


Figure 22 Example with USI 0x8002: Utilization options of the diagnosis/maintenance with regard to the diagnostic alarm

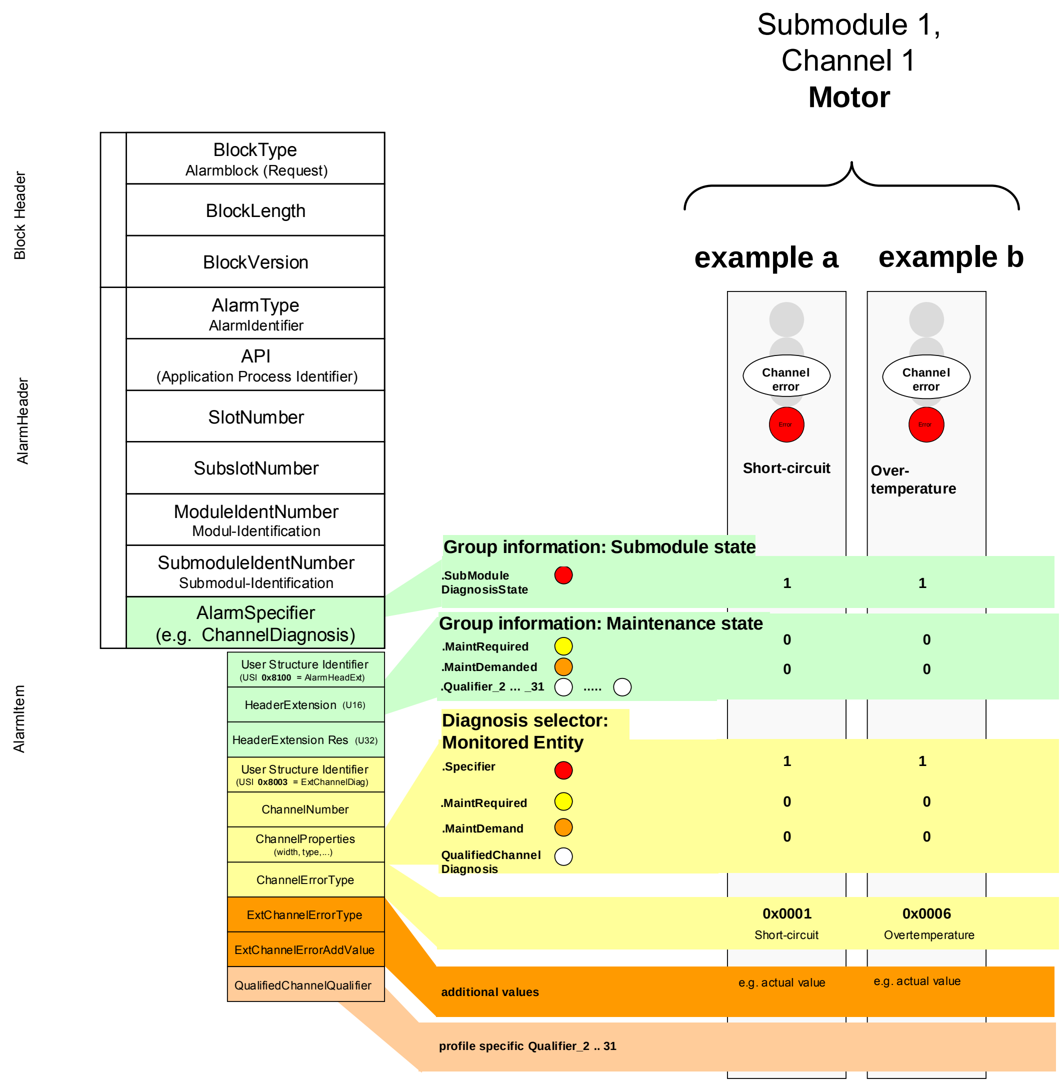


Figure 23 Example with USI 0x8003: Utilization options of the diagnosis/maintenance with regard to the diagnostic alarm

11.2.6 Extending the group information on return of the IO device within the SubmoduleState

The submodule status which is exchanged between the IO device and the IO controller on return of the IO device is also supplemented with one group information for each maintenance status (Maintenance required and Maintenance demanded) and one group information for all profile specific QualifiedChannelQualifier.

This group information are derived by a logical disjunction (logical ORing) of all diagnostic statuses of the submodule.

To display the group information of the two maintenance statuses and of the QualifiedChannelQualifier, the following entries are defined for the SubmoduleState:

- **SubmoduleState.MaintenanceRequired**
- **SubmoduleState.MaintenanceDemanded**
- **SubmoduleState.QualifiedInfo**

Thus the group status of the submodule is directly entered in the submodule state.

With this extension, there is one group bit each for:

- Maintenance required → SubmoduleState.MaintenanceRequired
- Maintenance demanded → SubmoduleState.MaintenanceDemanded
- Failure → SubmoduleState.DiagInfo
- Profile specific Qualifier (one for all Qualifier_2 .. 31) → SubmoduleState.QualifiedInfo

The group bits are derived in each case from the disjunction (logical ORing) of all corresponding channel-related diagnostic statuses of the submodule.

The group bits are managed on the submodule independently of each other. Thus they can be set in many different combinations. (For example, all three group bits can be set simultaneously.)

For detailed definition and coding refer to the PROFINET IO specification [14].

The SubmoduleState can additionally be read out as **data record** from the IO device utilizing acyclical services.

11.2.7 Local LED signaling

The maintenance states MaintenanceRequired and MaintenanceDemanded can be optionally signaled on site. We recommend the use of a yellow LED for this purpose.

The two maintenance states MaintenanceRequired and MaintenanceDemanded can be mapped to this LED.

Local signaling can be implemented either on the device, on the module and/or submodule.

11.2.8 Integration of maintenance in the GSD

11.2.8.1 Assigning an error message to a channel error

When evaluating a diagnostic alarm or a diagnostic data record with the help of the GSD, the assignment of a message to a channel error is not solely determined by the ChannelErrorType, but the ChannelProperties (MaintenanceRequired, MaintenanceDemanded or Specifier) must also be evaluated. Only in this way can it be determined whether the respective channel error represents a failure or a maintenance state.

The error message text is to be selected accordingly.

The text components “Maintenance required”, “Maintenance demanded” and “Failure”, which for differentiation purposes precede the actual error message text, are not included in the GSD. They are specified manufacturer-specifically via the GSD Interpreter.

Example: Maintenance required: slip ring
GSD Interpr. from GSD

Example: Text for indicating contact erosion in an intelligent switching device

Maintenance required:	Contact erosion 80%
Maintenance demanded:	Contact erosion 95%
Failure:	Contact erosion 100%

11.2.8.2 Identifier for ChannelErrorType with Maintenance

For every state of a Monitored Entity, a message must be created, since the states are assigned to different message classes (separate message numbers).

Therefore, using an identifier it must be described in the GSD whether a ChannelErrorType is a Maintenance state and therefore has to be created several times.

Note:

The GSD has to be extended for this.

11.2.9 Description of Monitored Entities with PROFINET IO

With PROFINET IO, Monitored Entities always refer to a sub-slot.
With PN IO, the references of the Monitored Entities to the underlying data can be implemented in the GSD within the framework of the extended channel diagnosis.

Example:

```
<MonitoredEntityList>
        <MonitoredEntityItem Identification="PowerUnit" Unit="Volt">
                <ChannelError ErrorType="35" ExtendedErrorType="1"/>
                <!-- ExtChannelAddValue is the supplemental value of the extended channel
                diagnosis-->
                <ExtChannelAddValue Index="22" ByteOffset="2"/>
                <LimitValues>
                        <MaintenanceRequest Index="1" ByteOffset="2" BitOffset="0"
                         DataType="Unsigned16"/>
                        <MaintenanceDemand Index="1" ByteOffset="4" BitOffset="0"
                         DataType="Unsigned16"/>
                        <Failure Index="1" ByteOffset="6" BitOffset="0"
DataType="Unsigned16"/>
                </LimitValues>
                <References>
                <!- any number of entries->
                        <Ref Index="12" ByteOffset="2" DataType="Unsigned16"
                         TextId="Beschreibender Text"/>
                        <Ref Index="1" ByteOffset="2"  DataType="Unsigned16"
                         TextId="Beschreibender Text"/>
                        <Ref Index="1" ByteOffset="2"  DataType="Unsigned16"
                         TextId="Beschreibender Text"/>
                </References>
        </MonitoredEntityItem>
</MonitoredEntityList>


<ChannelDiagList>
        <ChannelDiagItem ErrorType="35">
                <Name TextId="IDT_DIAG_NAME_PowerSupplyFailure"/>
                <ExtChannelDiagList>
                        <ExtChannelDiagItem ErrorType="1">
                                <Name TextId="IDT_DIAG_NAME_BatteryLow"/>
                        </ExtChannelDiagItem>
                        <ExtChannelDiagItem ErrorType="2">
                                <Name TextId="IDT_DIAG_NAME_Overload"/>
                        </ExtChannelDiagItem>
                </ExtChannelDiagList>
        </ChannelDiagItem>
</ChannelDiagList>
```


12 Maintenance state of CBA components

The maintenance state as described in chapter 9.1 is also valid for relevant CBA components. Since CBA does not support alarms the interface of the CBA component shall be extended to include the defined states “maintenance required” and “maintenance demanded”. A CBA component can include one or several monitored entities. Beside the maintenance state of the whole component the maintenance state information of each monitored entity should be made available in the component interface in a uniform manner. The name of the monitored entity is defined as the name of the corresponding connector in the component interface. The provision of the necessary monitored entities and their connection to the component interface is within the responsibility of the component manufacturer.

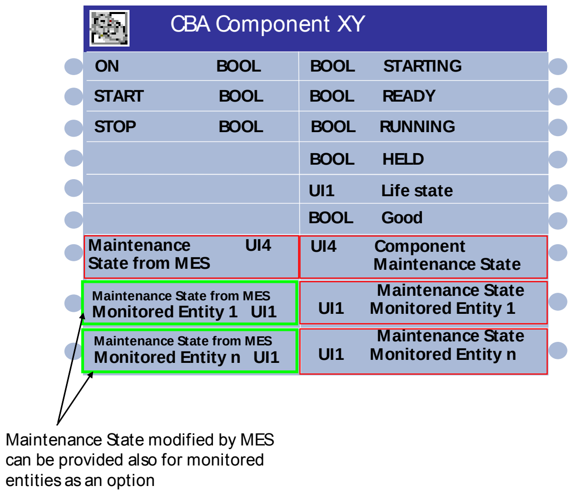


Figure 24 Example of a CBA component with n monitored entities

The component maintenance state shall consider CBA components with integrated redundancy. In this case the maintenance state shall be indicated for each of the redundant components. Thus the determination of the resulting component maintenance state can be made in the superior system. The redundancy information shall only be provided on component level, not on monitored entity level.

Based on the maintenance state reported by the CBA components the maintenance personnel or the maintenance system may make their own assessment of the maintenance state. This assessment may result in a change of the maintenance state. Additionally the maintenance state will change during the further workflow (refer to Figure 2 Simplified maintenance workflow). CBA components are functional units which often include beside a PLC also local HMI devices. Therefore it is useful to provide beside the maintenance state reported by the component also the actual maintenance state assessed by the maintenance personnel using the MES maintenance system. Thus the full information is available in the MES maintenance system and locally within the component. This information can be used as a trigger for a predefined reaction of the component and for local visualization purpose.

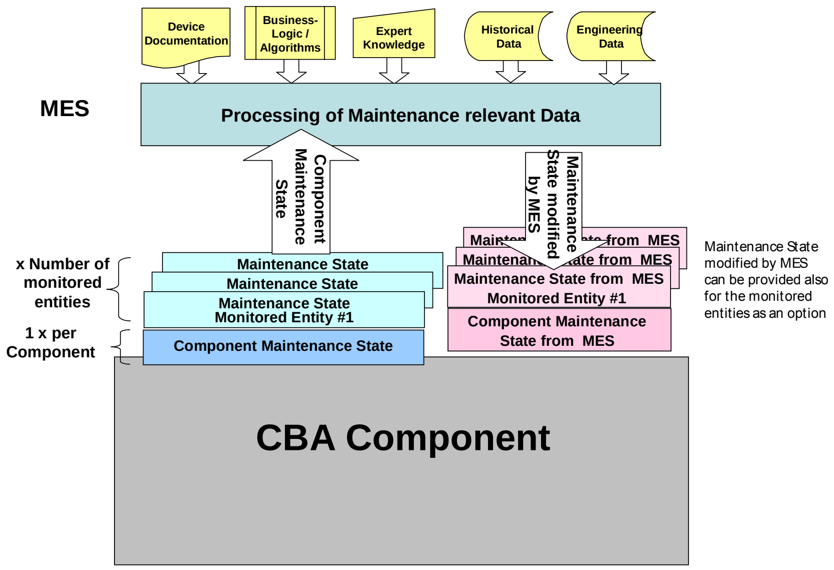


Figure 25 Maintenance state for CBA components

12.1 CBA Maintenance State

12.1.1 Component interface (output)

The component maintenance state is used as accumulated information of <u>one CBA component</u>.

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8">Maintenance State modified by MES Table 12-6</td><td colspan="6">Reserved</td><td>M</td><td>R[1]</td><td colspan="8">Reserved for redundancy</td><td colspan="8">Maintenance State Ref.Table 12-5</td></tr>
</table>

Table 12-1 Output component maintenance state (format = unsigned 32)

In addition to the component maintenance state it may be useful to provide the detailed maintenance state of the monitored entities additionally. For <u>each monitored entity</u> one octet should be used for the description of the maintenance state. The maintenance state of the monitored entities shall have the following format.

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8">Maintenance State Ref. to Table 12-5</td></tr>
</table>

Table 12-2 State of a monitored entity (format = octet)

12.1.2 Component interface (input)

The maintenance state set within the MES maintenance system shall be communicated back to the component. The following format shall be used.

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8">Maintenance State modified by MES Ref. to Table 12-6</td><td colspan="24">Reserved</td></tr>
</table>

Table 12-3 Input maintenance state of a component (format = unsigned 32)

Optionally one octet which includes the maintenance state set within the MES maintenance system should be used for <u>each monitored entity</u>.

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8">Maintenance State modified by MES Ref to Table 12-6</td></tr>
</table>

Table 12-4 Input maintenance state of a monitored entity *(format = octet)*

[1] Redundancy state is described in chapter 12.3

12.2 Coding of the CBA maintenance state

The same coding shall be used for the maintenance state of components and monitored entities

State ***7………0*** ***(15…….8)***[2]	**Meaning**
00000000	Good
00000001	Reserved
00000010	Reserved
00000011	Reserved
00000100	Reserved
00000101	Maintenance required
00000110	Maintenance demanded
00000111	Failure
00001000 …. 11111111	Reserved

Table 12-5 Coding of the maintenance state of the output

Remarks:

- ***Priority: 00000000 ... lowest, 11111111 ... highest***

[2] Maintenance state of redundant CBA component refer to chapter 12.3

The same coding is used for the maintenance state modified by MES which is used for:

- The input section of the maintenance state of a component
- The output section of the maintenance state of a component
- The maintenance state of one monitored entity (input)

Modified State *31…….24* *31…….24* *7………0*	**Meaning** *Modified component state (input)* Table 12-3 *Modified component state (output)* Table 12-1 *Modified state of monitored entity (input)* Table 12-4
00000000	Done
00000001	Request changed to maintenance required
00000010	Request changed to maintenance demanded
00000011	Request changed to maintenance state „failure“
00000100	Reserved
00000101	Maintenance was required and is now in progress
00000110	Maintenance was demanded and is now in progress
00000111	Maintenance state was “failure” and maintenance is now in progress
00001000	Canceled
00001001 …. 11111111	Reserved

Table 12-6 Coding of maintenance state set by MES maintenance system

The setting of the values by the MES is done according to the principle workflow ref. to Figure 2 Simplified maintenance workflow

12.3 Maintenance state for redundant CBA components

The maintenance state can also be extended to include additional information needed for redundant CBA components.

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8">Maintenance State modified by MES Ref. to Table 12-6</td><td colspan="6">Reserved</td><td>M</td><td>R</td><td colspan="8">Maint.State of redundant component Ref. to Table 12-5</td><td colspan="8">Maint. State Ref. to Table 12-5</td></tr>
</table>

Table 12-7 Coding of the output Component Maintenance State (format = unsigned 32)

Remarks:

R = 0 ... no redundant device available i.e. state of device 2 is not relevant

R = 1 and M = 0 means device 1 is “Master”; device 2 is “Stand-by”; or “Fault” (if device state = 00000111)

R = 1 and M = 1 means device 2 is “Master”; device 1 is “Stand-by”; or “Fault” (if device state = 00000111)

R = 1 and device state 1 = device state 2 = 00000111 → double failure! ; M is ignored.

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