ETHERNET POWERLINK

EPSG Draft Standard 302-B

Ethernet POWERLINK

Part B: Multiple-ASnd

Version 1.1.1

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Pre. 2 History

Vers.	Date	Author		short description
0.0.0	2006-09-22	S. Limal	Alstom	Creation Multiple-PRes part
0.0.1	2006-10-18	S. Limal	Alstom	Modifications after 6/10/06 and 13/10/06 conference calls and Addition Multiple-ASnd part
0.0.2	2006-10-30	S. Limal	Alstom	Modifications after WSP V0.0.1 feedbacks
0.0.3	2006-11-17	F. Matejka	B&R	Formal changes in header and cover page. Changed status to working draft proposal (not approved by TWG yet). File name changed to reflect document status.
0.0.4		S. Limal	Alstom	MultiMessage document split in MultiplePRes and Multiple-ASnd documents as recommended by the TWG.
0.0.5	2007-10-25	S. Potier	Alstom	- Timing information for sending of AInv added. - Indication that AInv is a unicast message which type is 0x0D (13) added. - Sub-Index 04h ASndMaxNumber changed to Sub-Index 03h and comments reworded. - Description for bit 15 of object 1F81h changed. - Chapter on Additional Device description entries removed - Consistency with communication profile specification reviewed.
0.0.6	2008-01-08	S. Potier	Alstom	Comments from Stephan Kirchmayer taken into account - Change EPSG address to new POWERLINK office - Default value of sub-index 3 of 1F8A was not changed from 4 to 3 - Some changes in chapter names and order - Some minor modifications in wording
0.0.7	2008-01-28	S. Kirchmayer	B&R	- Typos corrected - Obj. 1F81h bit 15 changed to a positive logic. - Fig.6 moved to new chapter ‘MN Cycle State Machine’
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1.1.0a	2021-08-21	S. Kirchmayer	B&R	Typos and other corrections
1.1.1	2023-05-23	S. Kirchmayer	B&R	© B&R due to dissolution of the EPSG

Pre. 3 Content

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Pre. 6 Definitions and Abbreviations

Pre. 6.1 Definitions

Communication Slot	Umbrella term for Asynchronous or isochronous communication slot. In the isochronous phase the communication slot consists of the PReq and PRes messages for a particular node or one PResMN message to all nodes In the asynchronous phase the communication slot consist of the SoA and ASnd (or any frame) messages, the AInv and ASnd (or any frame) messages or one ASnd (or any frame) from the MN message.

Pre. 6.2 Abbreviations

AInv	Asynchronous Invite
ASnd	Asynchronous Send
CN	Controlled Node
CS	Communication Slot
MN	Managing Node
PDO	Process Data Object
PReq	Poll Request
PRes	Poll Response
SDO	Service Data Object
SoA	Start of Asynchronous
SoC	Start of Cycle

Pre. 7 References

[1] EPSG Draft Standard 301 (EPSG DS 301), Ethernet POWERLINK, Communication Profile Specification

1 Introduction

With respect to the POWERLINK Communication Profile Specification [1], a current POWERLINK cycle timing is set the way illustrated by the following figure.

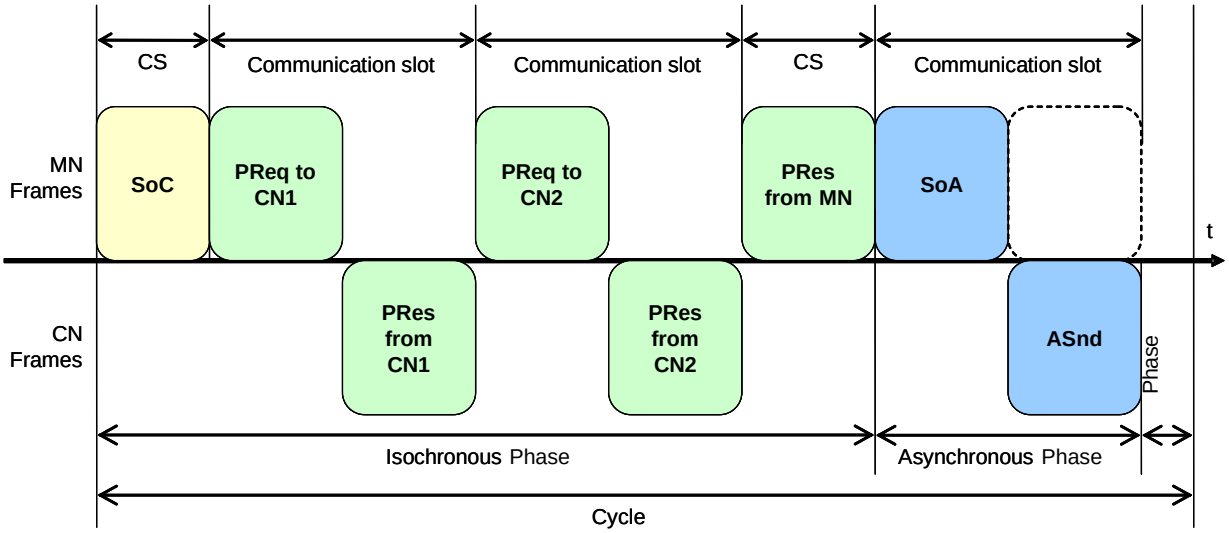

Fig. 1. Example of POWERLINK cycle

Only one ASnd can be sent each cycle in the asynchronous phase (sender is elected by MN).

We consider an application with a given POWERLINK cycle time in which the process does not require the lowest possibly reachable cycle time. This could result in a long idle phase. Depending on the number of nodes the isochronous phase is guaranteed but the ASnd frame rate sticks to one ASnd per cycle.

However the more nodes are on the network, the more number of ASnd messages are required to manage configuration, monitor status or do any other SDO communication.

The current POWERLINK Communication Profile Specification [1] allows improving the ASnd frame rate by means of multiplexed communication, like in Fig. 2.

The multiplexed cycle time equals the time required by the process. All POWERLINK cycles of this multiplexed cycle enable one asynchronous exchange each.

By this a better ASnd frame rate will be achieved than configuring one POWERLINK cycle with cycle time equal to the time required by the process.

This may result in over solicitation of nodes. More SoCs will have to be processed for the same process-given cycle. Moreover configuration may become more complicated. Finally, this might increase the message total error probability.

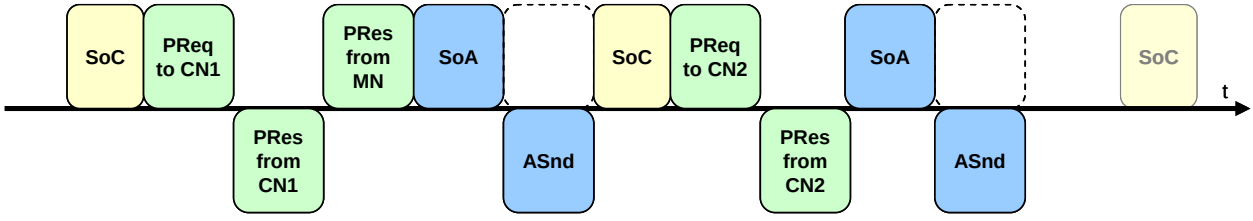

Fig. 2. Example of POWERLINK multiplexed cycle.

The purpose of this specification is to define Multiple-ASnd per POWERLINK cycle in order to achieve the following cycle timing (Fig. 3).

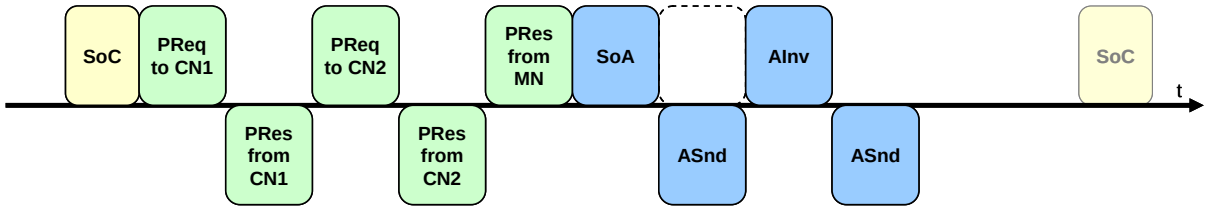

Fig. 3. Example of POWERLINK cycle with Multiple-ASnd

POWERLINK Multiple-ASnd improves the asynchronous performances of POWERLINK thanks to an optimized use of the asynchronous phase. It allows POWERLINK to offer best performance to applications which have no need for very short cycle time but have a need for large asynchronous bandwidth.

The Multiple-ASnd specification is an add-on of the POWERLINK Communication Profile Specification [1]. It is designed in a way to ensure full compatibility with standard POWERLINK devices.

2 Overview

The introduction shows that some applications may have less requirements to the minimum cycle time than POWERLINK is offering. Such applications could result in a POWERLINK timing with a long idle phase This long idle phase is used to improve the performance of the asynchronous exchanges.

This specification describes how multiple asynchronous frames (Multiple-ASnd) are achieved by taking advantage of a possibly introduced long idle phase: The Multiple-ASnd feature avoids the use of the multiplex feature when having a lot of nodes, with the same required sending rate, only because the asynchronous frame rate needs to be increased.

This specification mainly relies on the definition of a new POWERLINK message type ID.

The new POWERLINK datagram “AsynchronousInvite” (AInv) shall be sent in a unicast manner to nodes handling Multiple-ASnd. This AInv message shall not occur if SoA has not yet been sent (Figure 4). Current nodes are supposed to discard it since they do not recognize this new message extension (cf. [1]).

The Multiple-ASnd extension is also based on planning the maximum number of asynchronous messages per cycle during configuration.

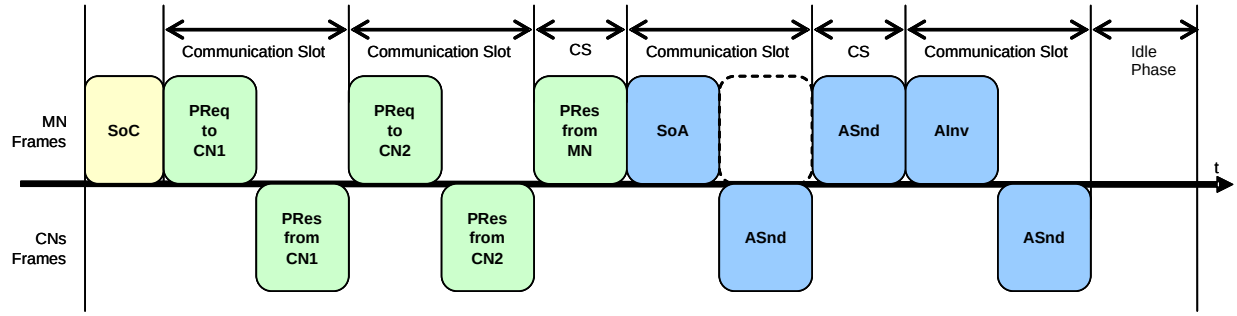

Fig. 4. Example of POWERLINK with Multiple-ASnd cycle and 3 asynchronous exchanges configured.

As an ASnd could be sent in a unicast manner from a CN to another CN, the MN does not receive such an ASnd. So the sending of AInv by the MN cannot be based on reception of a previous ASnd and shall be triggered by a timeout. This timeout shall be computed in the following manner:

AInvSendingTimeout = ((C_DLL_T_MIN_FRAME + C_DLL__T_PREAMBLE) + AsyncSlotTimeout_U32 + (AsyncMTU_U16*8*C_DLL_T_BITTIME + C_DLL_T_PREAMBLE))

In order to ensure a minimum idle phase, an AInv message shall not be sent in the following cases:

- Time remaining before next SoC is less or equal to the value of *AInvSendingTimeout*
- Number of ASnd sending has reached *ASndMaxNumber*.

3 AInv Frame Structure

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	Res	Message Type						
1	Destination							
2	source							
3	NMTStatus							
4	Res	Res	Res	Res	Res	EA	ER	Res
5	Res	Res	Reserved			Reserved		
6	RequestedServiceID							
7	RequestedServiceTarget							
8	EPLVersion							
9-45	Reserved							

Tab. 1 POWERLINK AInv Frame structure

The AInv is a new message type (value is 13 = 0x0D[1]) sent in a unicast manner. Only nodes supporting this new message type may be requested by AInv (support indicated by object 1F81h bit13, see chapter 4.3).

The AInv message has nearly the same functionalities as the SoA, but does not start the asynchronous phase.

If there is no pending request for an asynchronous communication slot, no AInv message shall be sent.

If a pending asynchronous communication slot is assigned to the MN itself, no AInv message shall be sent, the MN skips it and sends its ASnd directly.

[1] AInv 13d=1101b, SoA 5d=0101b. So one filter may be used for both message types.

4 Additional Object Description

4.1 Object 1F8Ah: NMT_MNCycleTiming_REC

Sub-Index	1F8Ah	Object Code	RECORD
Name	NMT_MNCycleTiming_REC		
Data Type	NMT_MNCycleTiming_TYPE	Category	M

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	3 .. 4	Access	Ro
Default Value	-	PDO Mapping	No

- **Sub-Index 02h: AsyncSlotTimeout_U32**

Sub-Index	02h		
Name	AsyncSlotTimeout_U32		
Data Type	UNSIGNED32	Category	O
Value Range	>=250	Access	Rw, valid on reset
Default Value	100 000	PDO Mapping	No

The sub-index describes the worst case time interval in ns between the end of the SoA resp. AInv transmission and the beginning of the reception of an ASnd frame issued by a CN.

This sub-index is used in the computation of the timeout used to trigger sending of AInv messages. Please refer to the chapter “Overview” for details.

- **Sub-Index 03h: ASndMaxNumber**

Sub-Index	03h		
Name	ASndMaxNumber		
Data Type	Unsigned8	Category	M
Value Range	1.. D_NMT_MNMaxAsynchronousSlots_U8	Access	Rw, valid on reset
Default Value	1	PDO Mapping	No

ASndMaxNumber indicates the maximum number of ASnd which can be sent within one POWERLINK cycle.

During cycle time computation ASndMaxNumber shall be taken into consideration. The cycle time computation shall ensure that at least ASndMaxNumber ASnd frames can be sent in the asynchronous phase.

If ASndMaxNumber equals to 1, the asynchronous phase is as defined in the current POWERLINK specification [1]. No AInv message shall be sent.

An AInv message cannot be sent since the number of sent ASnd messages reaches ASndMaxNumber value.

4.2 Object 1F82h: NMT_FeatureFlags_U32

The Feature Flags indicate communication profile specific properties of the device given by its design. The object shall be setup by the device firmware during system initialisation.

Octet	Bit	Name	TRUE	FALSE
2	16	Multiple-ASnd Support	Device supports Multiple-ASnd	Device doesn't support Multiple-ASnd
	17…23	Res	--	--

Tab. 2 Multiple-ASnd NMT_FeatureFlags_U32 additional bit interpretation

4.3 Object 1F81h: NMT_NodeAssignment_AU32

The NMT_NodeAssignment_AU32 allows the MN to know if it is possible to send an AInv message to this CN. This bit may be set only if the corresponding feature flag on the CN is set.

Octet	Bit	value	Description	Property	Evaluate
1	13	0b	Multiple-ASnd disabled	CN	MN, CN
		1b	Multiple-ASnd enabled		

Tab. 3 Multiple-ASnd NMT_NodeAssignment_AU32 additional bit assignment

5 Cycle State Machines

The CN and MN cycle state machines for states NMT_MS_OPERATIONAL, NMT_MS_READY_TO_OPERATE and NMT_MS_PRE_OPERATIONAL_2 respective NMT_CS_OPERATIONAL, NMT_CS_READY_TO_OPERATE and NMT_CS_PRE_OPERATIONAL_2 are almost the same as in [1], only the management of the new AInv message type has to be added in transitions between the states.

5.1 Multiple-ASnd MN Cycle State Machine

5.1.1 New Event

DLL_ME_ASND_TIMEOUT: This event is produced when the ASnd frame was not (or not completely) received within a preconfigured time since SoA or AInv has been sent.

5.1.2 MN Cycle State Machine

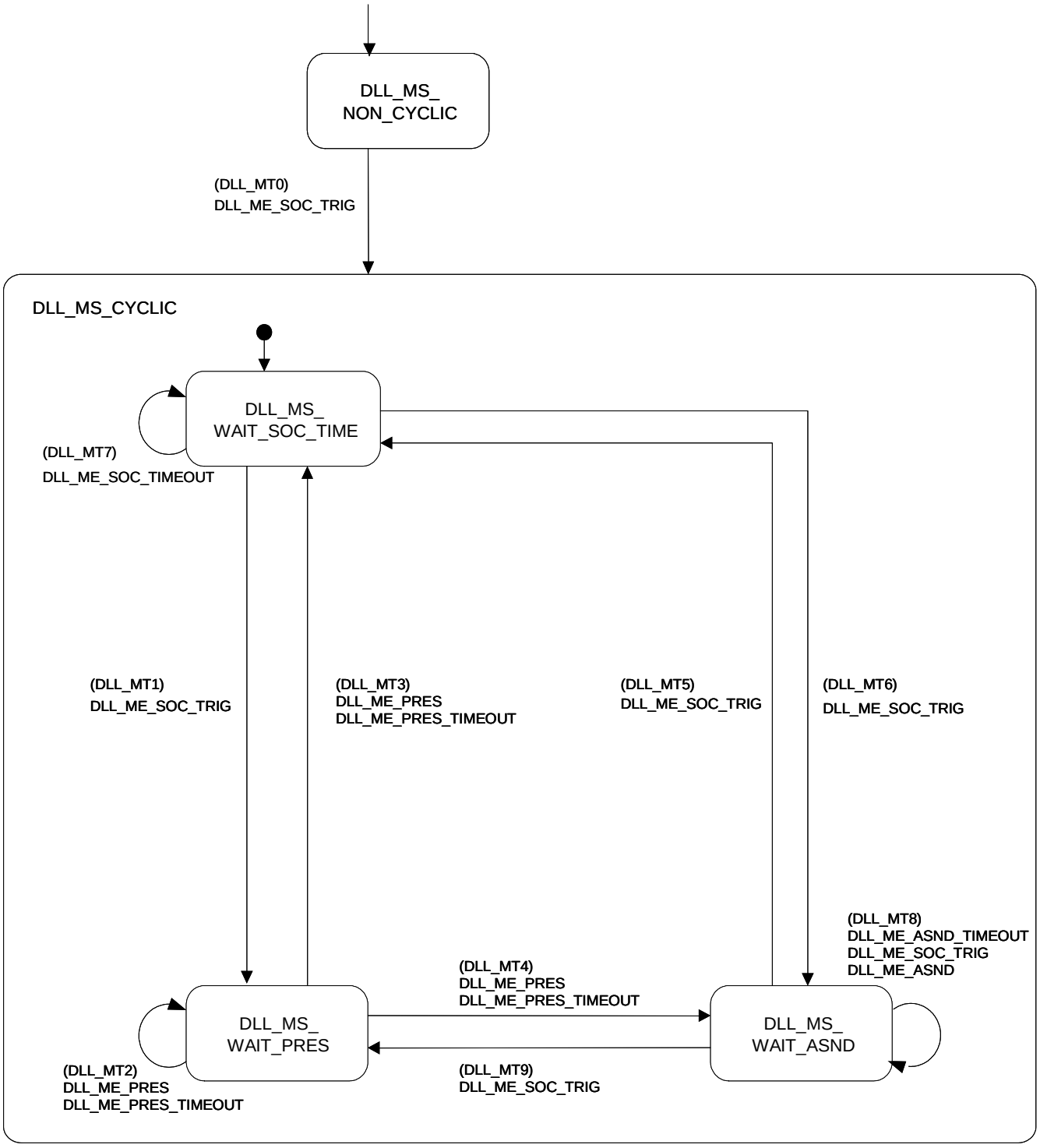

Fig. 5. MN Cycle State Machine valid for MN NMT states NMT_MS_OPERATIONAL, NMT_MS_READY_TO_OPERATE and NMT_MS_PRE_OPERATIONAL_2

5.1.3 Transitions

DLL_MT3	DLL_ME_PRES [isochr = 0 & async_in = 0] / send PRes [isochr_out != 0], SoA and ASnd [async_out!= 0] DLL_ME_PRES_TIMEOUT [isochr = 0 & async_in = 0] / send PRes [isochr_out != 0], SoA and ASnd [async_out != 0 &], report error DLL_MEV_LOSS_PRES
	The isochronous phase ends with either a DLL_ME_PRES or a DLL_ME_PRES_TIMEOUT (configurable via NMT_MNCNPResTimeout_AU32[Node ID]). If there is no more communication to be done (neither isochronous nor asynchronous), the MN sends a SoA frame and changes the state to DLL_MS_WAIT_SOC_TRIG. If there are outgoing asynchronous communications to be done in the current cycle, the MN sends these frames after the SoA since enough time is remaining.
DLL_MT7	DLL_ME_SOC_TRIG [isochr = 0 & async_in = 0] / send SoC, PRes [isochr_out != 0], SoA and ASnd [async_out != 0]
	Immediately after the DLL_ME_SOC_TRIG event a SoC frame will be sent, the communication with the NMT State Machine will be done. If there is no communication to be done, then a SoA frame is additionally sent. The state doesn't change. If there is outgoing asynchronous communication to be done in the current cycle, the MN sends these frames after the SoA since enough time is remaining.
DLL_MT8	DLL_ME_SOC_TRIG [isochr = 0 & async_in != 0] / send SoC and SoA with Invite DLL_ME_ASND [ ] / process the frame, send AInv [async_in != 0 & AsyncSlot_OK !=0] or send ASnd [async_out!= 0 & AsyncSlot_OK !=0] DLL_ME_ASnd_TIMEOUT/ send AInv [async_in != 0 & AsyncSlot_OK !=0] or send ASnd [async_out!= 0 & AsyncSlot_OK !=0]
	Immediately after the DLL_ME_SOC_TRIG a SoC frame will be sent. Then, the communication with the NMT State Machine will be done. If there are only asynchronous frames to send, the SoA frame will be send. If the asynchronous communication is directed to a CN, an ASnd frame will be sent additionally. Since enough time is remaining, depending on its queuing policy, MN can send ASnd or AInv to enable other asynchronous communication slot dynamically.

Tab. 4 MN Cycle State Machine transitions modified to allow Multiple-ASnd

- „async_in != 0" means that some invite shall be sent in this cycle and some ASnd or some non POWERLINK frame could be received.
- "async_out != 0" means that some ASnd shall be sent (only, no invite is needed) in this cycle after a SoA was sent.
- AsyncSlot_OK !=0 means that there is enough time before SoC to insert an asynchronous communication slot

5.2 Multiple-ASnd CN Cycle State Machine

5.2.1 New Event

DLL_CE_AINV: This event signals that a POWERLINK AInv frame was received from the MN.

5.2.2 CN Cycle State Machine

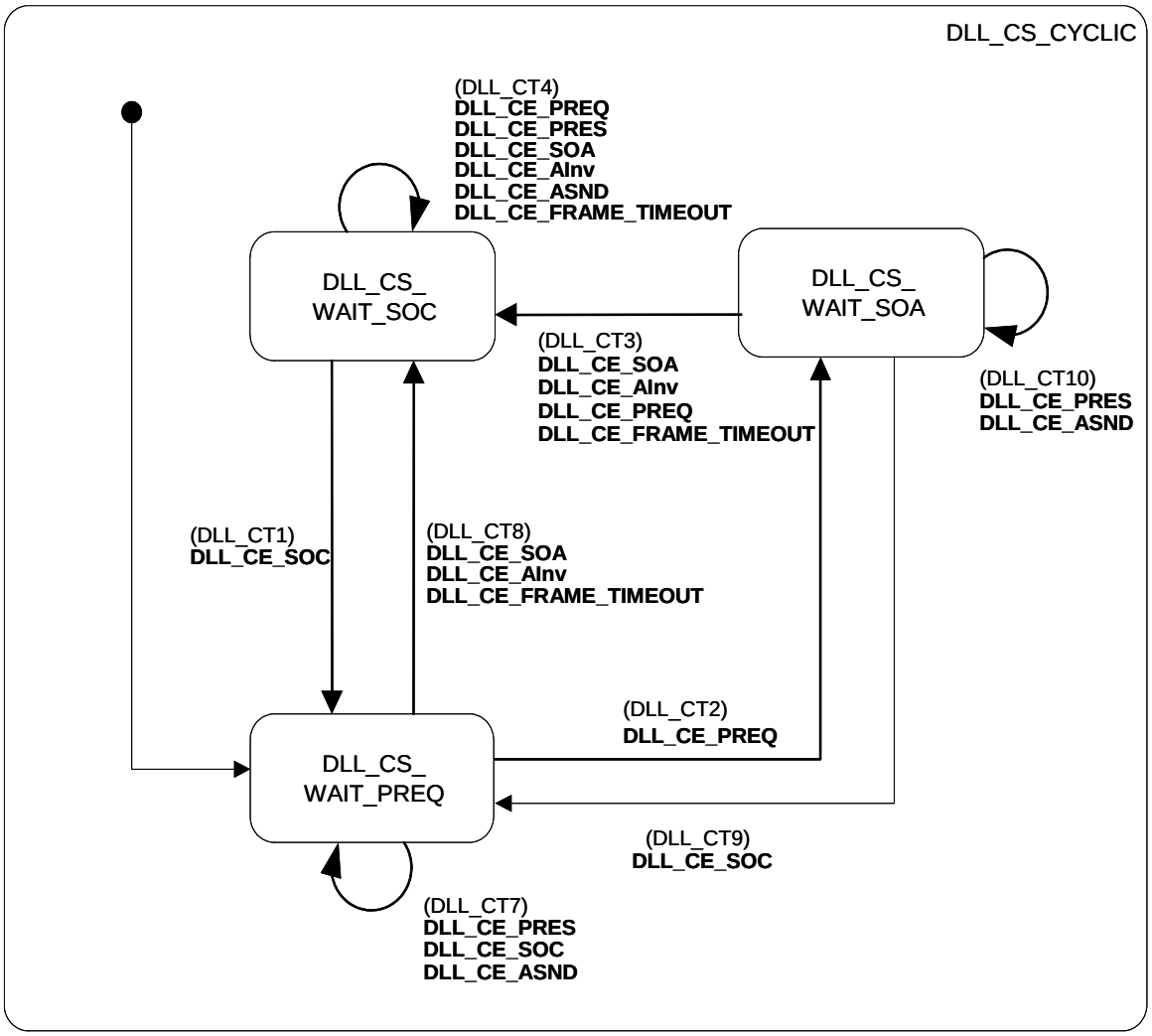

Fig. 6. CN Cycle State Machine, valid for CN NMT states NMT_MS_OPERATIONAL, NMT_MS_READY_TO_OPERATE and NMT_MS_PRE_OPERATIONAL_2

5.2.3 Transitions

DLL_CT3	DLL_CE_SOA [ ] / process SoA, if allowed send an ASnd frame or a non POWERLINK frame DLL_CE_AINV [ ] / process AINV; if invited, transmit a legal Ethernet frame, additionally report error DLL_CEV_LOSS_SOA DLL_CE_FRAME_TIMEOUT [ ] / Synchronize to the next SoC, report error DLL_CEV_LOSS_SOC and DLL_CEV_LOSS_SOA DLL_CE_PREQ[ ] / accept the PReq frame and send a PRes frame, report error DLL_CEV_LOSS_SOC and DLL_CEV_LOSS_SOA
	The DLL_CE_SOA event denotes the end of the isochronous phase and the beginning of the asynchronous phase of the current cycle. If the SoA frame includes an invitation to the CN, the CN may respond with one valid frame. The occurrence of a DLL_CE_PREQ signifies that an expected SoA and SoC frame were lost. The DLL_CS will attend to synchronize the new cycle. The DLL Error Handling shall be notified. The occurrence of a DLL_CE_AINV signifies that an expected SoA frame was lost. The DLL_CS will attend to synchronize the new cycle. The DLL Error Handling shall be notified. In case of a DLL_CE_FRAME_TIMEOUT event happened, SoA and SoC frames may have been lost. The DLL Error Handling shall be notified.
DLL_CT4	DLL_CE_ASND [ ] / process frame DLL_CE_ AINV [ ] / process AINV, if allowed send an ASnd frame or a non POWERLINK frame DLL_CE_PREQ [ ] / respond with PRes frame, report error DLL_CEV_LOSS_SOC DLL_CE_PRES [ ] / report error DLL_CEV_LOSS_SOC DLL_CE_SOA [ ] / report error DLL_CEV_LOSS_SOC DLL_CE_FRAME_TIMEOUT [ ] / report error DLL_CEV_LOSS_SOC
	If an ASnd frame has been received it shall be processed. If the AInv frame includes an invitation to the CN, the CN may respond with one valid frame. The state shall not be changed. The state machine of the CN does not limit the amount of sent or received frames within the asynchronous phase of the cycle. If a SoA, PReq or PRes frame is received, there may be a loss of a SoC frame in between. The DLL Error Handling shall be notified with the error DLL_CEV_LOSS_SOC. If a PReq frame was received, the incoming data may be ignored and a PRes frame shall be sent.
…	

…	
DLL_CT8	DLL_CE_SOA [CN = multiplexed] / process SoA; if invited, transmit a legal Ethernet frame DLL_CE_SOA [CN != multiplexed] / process SoA; if invited, transmit a legal Ethernet frame, additionally report error DLL_CEV_LOSS_PREQ DLL_CE_FRAME_TIMEOUT [ ] / Synchronize on the next SoC, report error DLL_CEV_LOSS_SOC and DLL_CEV_LOSS_SOA DLL_CE_AINV [CN = multiplexed] / process AINV; if invited, transmit a legal Ethernet frame DLL_CE_AINV [CN != multiplexed] / process AINV; if invited, transmit a legal Ethernet frame, additionally report error DLL_CEV_LOSS_PREQ and DLL_CEV_LOSS_SOA
	If the CN is in the NMT_CS_OPERATIONAL or NMT_CS_READY_TO_OPERATE the CN will assume a LOSS_OF_PREQ if the number of cycles since the last PReq is greater than that expected. (1 for non multiplexed CN, n for multiplexed CN where n is NMT_CycleTiming_REC.MultipleCycleCnt_U8) In case of a DLL_CE_FRAME_TIMEOUT event happened, SoA and SoC frames may have been lost. On non-multiplexed nodes or if a multiplexed node should have been requested this cycle, the PRes frame was additionally lost. The DLL Error Handling shall be notified. If an AInv frame has been received, it shall be processed; there may be a loss of a SoA in addition to loss of PReq. The DLL Error Handling shall be notified with the error DLL_CEV_LOSS_SOA (and DLL_CEV_LOSS_PREQ eventually)

Tab. 5 CN Cycle State Machine transitions modified to allow Multiple-ASnd

5.3 Non Multiple-ASnd CN Cycle State Machine

[1] tells that: “The unexpected frame types and unexpected sender shall be accepted. The state does not change. The PRes frames shall be passed to the NMT State Machine, which may analyse this frames (and e.g. remove the corresponding CN from the communication). The state machine does not react in any other way to this event.”

Since current POWERLINK CNs are not invited to send an ASnd or another Ethernet frame with AInv, it will not detect any error due to Multiple-ASnd.

Thus implementation of the extension shall plan priority of SoA invitation to current CNs, as it will be the only asynchronous communication slot they could use.

6 Additional Device Description Entry

Name	Description	Type	Category		Default	
			MN	CN	MN	CN
D_NMT_CNMaxAInv_U32	Maximum number of AInv the CN is able to process per cycle	UNSIGNED32	-	M	-	0
D_NMT_MNMaxAsynchronousSlots_U8	Maximum number of asynchronous slots per cycle	UNSIGNED8	M	-	1	-

7 Conclusion

Thanks to this extension, POWERLINK asynchronous phase is more efficient. As the POWERLINK cycle time is fixed, the asynchronous phase could dynamically take advantage of time remaining after the isochronous phase.

In applications where the data update rate (i.e. POWERLINK cycle time inverse) is fixed and not optimized to be the highest possible, asynchronous frame and data rate would be well improved.

The only point to take care, with respect to existing POWERLINK CNs (not handling Multiple-ASnd), is to invite them in priority when the MN sends a SoA.

Finally, fair distribution of Multiple-ASnd to nodes shall be manufacturer-specific.

A future version of this specification may precise the handling of asynchronous transmit priorities.