

6.2 Media Access Control (MAC) Sublayer

6.2.1 MAC sublayer functions

- a. The MAC sublayer functions shall be implemented according to [IEEE 802.3] § 1 4.2.3.

6.2.2 MAC Addressing

- a. A MAC destination address of a Critical Traffic frame shall have a unique 32-bit configurable Critical Traffic (CT-Marker) field for critical traffic (TT and RC) in a Time-Triggered Network.

NOTE In order to be compliant with the Ethernet standard, MAC group addresses is used to send frames from End-System to End-System(s). The CT-Marker field should follow the formatting as illustrated in Figure 6-2.

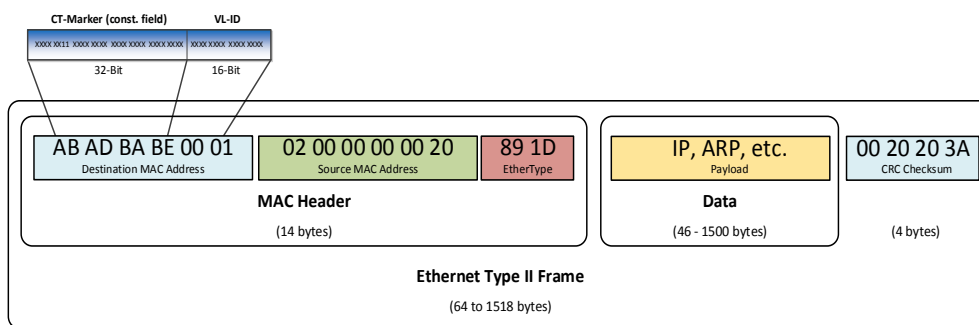


Figure 6-2: Destination MAC Address

- b. A Virtual Link shall be identified by the MAC destination address with a network unique CT-Marker and a Virtual Link Identifier (VL-ID).

NOTE Illustration is given in Figure 6-2.

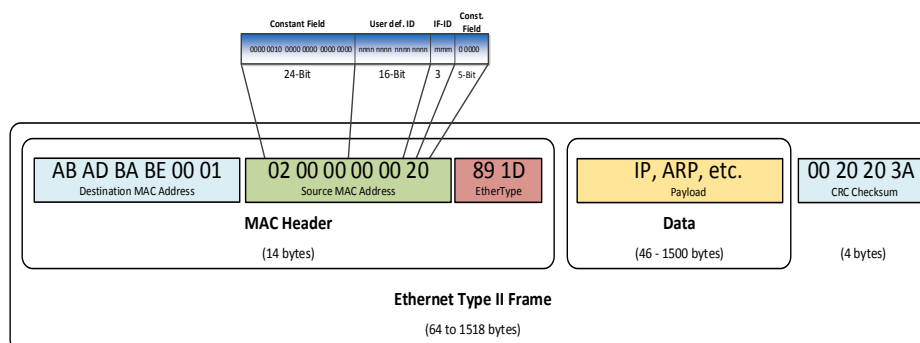


Figure 6-3: Source MAC Address

- c. The Constant field (24-Bit) of the source MAC address shall be set to "0000 0010 0000 0000 0000 0000".

- d. The MAC Source address shall be an Individual and Locally Administered address compliant with [IEEE 802.3] § 3.2.4.

NOTE As illustrated in Figure 6-3.

- e. The Const. Field (5-Bit) of the source MAC address shall be set to “0 0000”.

NOTE As illustrated in Figure 6-3.

- f. The User defined ID (User def. ID) is a single 16-bit field that shall be used to give each addressable host on the network a unique MAC address.

NOTE This is defined by the network integrator who creates the configurations for the network. It provides additional information on the source of the message.

- g. The redundant frames transmitted on all ports shall always be the same except the MAC source address where different interface ID fields are assigned at each port and the FCS.

- h. The network on which a frame is transmitted shall be identified according to the Interface ID (IF-ID) field of the Ethernet MAC source address as defined in Table 6-1.

NOTE The Interface ID defined in Table 6-1 indicates to which redundant Time-Triggered Ethernet network the Ethernet MAC frame is transmitted.

Table 6-1: Interface ID

Interface ID	Description
0 0 1	The Ethernet MAC frame is transmitted to network A
0 1 0	The Ethernet MAC frame is transmitted to network B
0 1 1	Not used
1 0 0	The Ethernet MAC frame is transmitted to network C
1 0 1	Not used
1 1 0	Not used
1 1 1	Not used

6.2.3 Traffic Classes

- a. Each network element supporting this standard shall implement the three traffic classes: Time-Triggered, Rate-Constrained and Best-Effort.
- b. The priorities of traffic classes shall be as following:
1. Protocol control frame (PCF) has highest priority
 2. Time-triggered traffic (TT) has the second highest priority

3. Rate-Constrained traffic (RC) has priority(s) in between TT and BE
 4. Best-Effort (BE) has the lowest priority
- c. PCF, TT, RC and BE traffic shall be sent according to their priority.
 - d. In reception each network element should have at least two independent memory partitions one for Best-Effort and one for Critical Traffic.

NOTE This is an optional requirement to separate input memory partitions and allow in case of a babbling idiot behaviour to receive critical traffic on a faulty node.

- e. In transmission, each network element should have at least two independent memory partitions one for Best-Effort and one for Critical Traffic.

NOTE This is an optional requirement to separate output memory partitions allow in case of a babbling idiot behaviour to transmit critical traffic on a faulty node.

6.2.4 MAC Transmit

- a. Switch function without a compression master role shall not be able to generate PCF frames.

NOTE A Switch without a compression master role is only able to relay PCF frames.

- b. If a frame is discarded, a dedicated diagnostics counter shall be incremented to provide this information to the upper layers.

NOTE This counter allows to distinguish between sporadic or permanent errors

- c. A TT traffic shall be sent at defined scheduled points according to the synchronized time.
- d. If the End-System is not synchronized, only rate constrained frames and Best-Effort frames shall be transmitted.
- e. In case the MAC performs a clock correction, it shall adjust the time interval between the current schedule point and the next schedule point, by adding the clock correction value to this time interval.
- f. Frames shall be sent on the redundant ports simultaneously.

NOTE The delay between transmissions of the redundant frames is not specified but has an impact on the synchronization precision (refer to Clause 7.4).

- g. Redundant RC frames shall have the same sequence number.

6.2.5 MAC Receive

6.2.5.1 General

- a. At the successful receive of a MAC Frame, the MAC shall treat a valid MAC frame as specified in [IEEE 802.3].

6.2.5.2 Critical Traffic

- a. The MAC shall treat a valid MAC frame as Critical Traffic if the CT-Marker matches the CT-Marker entry of the Table 7-9.
- b. The MAC shall discard a valid MAC frame belonging to Critical Traffic if the VL-ID does not match any entry of the Table 7-6.
- c. The MAC shall discard a valid Critical Traffic frame if the MAC Frame Length is greater than the value configured for the maximum frame size.

NOTE If larger frames are sent, the bandwidth restrictions can be violated.

- d. Redundant TT frames shall be identified according to their destination MAC address (CT-Marker, VL-ID) and the respective receive window.
- e. The time-skew between the redundant instances of the TT frames shall be configurable.
- f. Redundant RC frames shall be identified according to their destination MAC address and the respective sequence number.
- g. The time-skew between the redundant instances of the RC frames shall be configurable.
- h. Depending on the configuration parameter, a configurable redundancy management unit shall forward the first valid frames to the host or forward all redundant frames to the host.

6.2.6 Switch Traffic Policing

- a. If the Switch is not synchronized, it shall discard all received Time-Triggered frames.
- b. The Switch shall discard a received frame which is policed to be Time-Triggered if the Switch holds a previous frame of the same VL-ID.
- c. In reception, if a TT frame is received outside its scheduled time window, the frame shall be discarded.

NOTE For the calculation of the acceptance window duration, refer to guidelines provided in Clause 7.5.8.

- d. The Switch shall discard all valid Time-Triggered frames stored inside the Switch and waiting for transmission in case of a Synchronization Loss.
- e. The Switch shall discard any valid Time-Triggered frames which frame length is greater than the MaxLength entry defined in Table 7-11.

NOTE The related diagnostics and status information counter are described in Clause 8.4.3.

- f. Traffic policing for RC traffic shall be in accordance with requirements specified in [ARINC 664 part 7] §4.1.1 and §4.2.2.
- g. In reception, if on a given port the Switch receives a frame with a VL-ID not consistent with the VL-IDs expected on this port, the frame shall be discarded.

NOTE The related diagnostics and status information counter are described in Clause 8.4.3

- h. If a PCF frame does not have a payload length of exactly 46 bytes, the frame shall be discarded as specified in [SAE AS6802] §4.6.
- i. A PCF frame shall include the actual integration cycle number as specified in [SAE AS6802] §4.6.
- j. A PCF frame shall include a membership vector of all synchronization master contributing to the synchronization protocol as specified in [SAE AS6802] §4.6.
- k. A PCF frame shall include the synchronization priority and synchronization domain as specified in [SAE AS6802] §4.6.
- l. A PCF frame shall include the transparent clock value as specified in [SAE AS6802] §4.6.
- m. In case the Switch is forwarding PCF's, a PCF frame shall be discarded if the time interval between two consecutive PCF of the same VL-ID is outside the limit specified by the entries BAG and Jitter in the Output VL Table associated to this VL-ID.

NOTE 1 The value for jitter depends on the precision.

NOTE 2 The Switch Output VL Table is defined in Table 7-11.

- n. In case the Switch is forwarding PCF's, the values for BAG shall be equal to the integration cycle.
- o. In reception, if a MAC frame is not correct, as specified in [IEEE 802.3], the frame shall be discarded.

6.2.7 Switch Transmit

- a. The Switch shall allow reserving the sending media for a defined CT-frame.

NOTE This is needed to ensure that TT frames are not delayed by other frames which are in the sending process when a TT frame is sent. The reservation of a window in front of a TT frame does not allow to process other frames within this window.

- b. If the following conditions are both true, the Switch shall start at a defined point in the Schedule Table:

1. The Switch adjusts its local clock to the network time received via an integration PCF frame,
 2. The Switch adjusts its local integration cycle number with the integration cycle number contained in the integration PCF frame.
- c. When the Switch finishes executing the last entry of the Schedule Table, the Switch shall restart with the first entry of the Schedule Table.

6.2.8 Switch Frame Routing

- a. The Switch shall support both of the following routing scheme:
1. Static Best-Effort routing according to a static Best-Effort routing table as part of the configuration
 2. Dynamic Best-Effort routing according to a dynamic Best-Effort routing table created via address learning according to RFC 826
- b. CT-Frames shall be routed according to their VL-ID
- c. In case preemption is not used, a Switch shall not cause sending of incomplete frames because of a priority conflict on a sending port.
- NOTE If a higher priority frame is sent at a dedicated port where a lower priority frame is in process, the low priority frame sending process cannot be interrupted.
- d. The Switch shall be able to perform independent frame routing on all ports at the same time with full line rate.
- e. The order of Rate-Constrained frames received on the same reception port and belonging to the same VL-ID shall be preserved on the transmission port.

Interoperability Specification

7.1 Overview

This Clause specifies the parameters of the implementation which are needed to achieve interoperability between the Switches and End-Systems developed according to this standard. This Clause specifies it for the implementation e.g. IP level and allows together with the Network Configuration Clause an integration of devices from different vendors into a complete network.

It further defines the network configuration parameters which are needed to create a configuration of the network and each device specifying e.g. senders, receivers, messages, time-constraints and redundancy constraints.

All these parameters are taken by the configuration tools as an input to derive the device specific configurations. Since not every device needs to be aware of the whole network configuration, these configurations only need to define the device related parameters to ensure the interoperability with the network. However, the network related device parameters need to be consistent to ensure a correct behaviour of the TT and RC traffic flows.

This Clause aims at specifying the parameters needed on the different layers (network and device) to ensure the interoperability within a network.

Figure 7-1 shows the interface between the tool creating the device specific configuration out of the network level specification which are used by the IP to perform the operation.

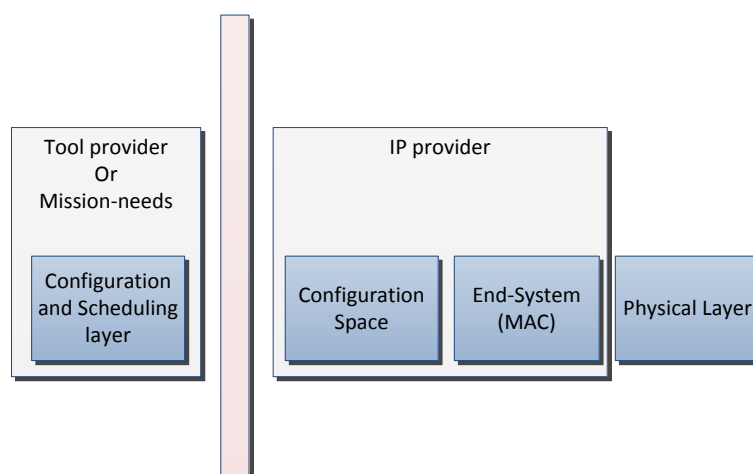


Figure 7-1: Configuration Interface Tool – IP

7.2 Device Specification

7.2.1 Device Parameters Description

- a. The parameters which are used to ensure the interoperability between the nodes in the network for the Switch and the function shall be defined as per Table 7-1, Table 7-2 and Table 7-3.

NOTE These parameters are essential inputs for the creation of the configuration for the devices since it defines the performances of each of them within the network.

Table 7-1: General Interoperability Parameter Table

Parameter	Description
CLOCK_SYNC_PRECISION	Clock synchronization precision

Table 7-2: Switch Interoperability Parameter Table

Parameter	Description
SW_TT_TX_LENGTH	Frame length of the Time-Triggered frame to be sent
SW_TT_TX_PERIOD	Period of the Time-Triggered frame to be sent
SW_TT_TX_PHASE	Phase of the Time-Triggered frame to be sent
SW_SCHEDULE_GRANULARITY	Raster granularity in which the Time-Triggered frames can be placed for sending
SW_MIN_TT_TX_GAP	The minimum gap between two consecutive Time-Triggered frames to be transmitted
SW_TT_TX_MAX_JITTER	Maximum duration from synchronized state to the first bit placed onto the transmit line
SW_TT_TX_FRAMES	Number of Time-Triggered frames the Switch is able to transmit
SW_NUM_TT_TX_PERIOD	Maximum number of different Time-Triggered periods a Switch supports for transmit
SW_LIST_TT_TX_PERIOD	List of Time-Triggered frame periods the Switch supports
SW_TT_RX_WINDOW_CHECK	Input policing for Time-Triggered frames supported by the Switch
SW_TT_RX_EXPECT_ARR_TIME	Expected arrival time of a certain Time-Triggered frame
SW_TT_RX_ACT_ARR_TIME_EARLY	Earliest point in time for a Time-Triggered frame to be accepted at the input port of the Switch
SW_TT_RX_ACT_ARR_TIME_LATE	Latest point in time for a Time-Triggered frame to be accepted at the input port of the Switch
SW_MAX_NUM_TT_FRAMES	Maximum number of Time-Triggered frames a Switch can buffer at any time
SW_MAX_TT_BUFFER_SIZE	Maximum buffer size for Time-Triggered frames

Parameter	Description
SW_MAX_FORWARD_DELAY	Maximum forward delay of the Switch for Time-Triggered frames

Table 7-3: End-System Interoperability Parameter Table

Parameter	Description
ES_TT_TX_LENGTH	Frame length of the Time-Triggered frame to be sent
ES_TT_TX_PERIOD	Period of the Time-Triggered frame to be sent
ES_TT_TX_PHASE	Phase of the Time-Triggered frame to be sent
ES_SCHEDULE_GRANULARITY	Raster granularity in which the Time-Triggered frames can be placed for sending
ES_MIN_TT_TX_GAP	The minimum gap between two consecutive Time-Triggered frames to be transmitted
ES_TT_TX_MAX_JITTER	Maximum duration from synchronized state to the first bit placed onto the transmit line
ES_NUM_TT_TX_PERIOD	Maximum number of different Time-Triggered periods an End-System supports for transmit
ES_LIST_TT_TX_PERIOD	List of Time-Triggered frame periods the End-System supports
ES_TT_RX_WINDOW_CHECK	Input policing for Time-Triggered frames supported by the End-System
ES_TT_RX_EXPECT_ARR_TIME	Expected arrival time of a certain Time-Triggered frame
ES_TT_RX_ACT_ARR_TIME_EARLY	Earliest point in time for a Time-Triggered frame to be accepted at the input port of the End-System
ES_TT_RX_ACT_ARR_TIME_LATE	Latest point in time for a Time-Triggered frame to be accepted at the input port of the End-System

7.2.2 General Requirements

- a. All End-System and Switches that transmit, forward or receive a given Time-Triggered frame shall have access to a synchronized timebase with precision CLOCK_SYNC_PRECISION.

7.2.3 Switch Level Specification

7.2.3.1 General

- a. The Switch forwarding and Switch reception requirements shall be equivalent to the End-System transmission and End-System reception requirements.

7.2.3.2 Switch Forwarding

- a. A Switch shall associate each Time-Triggered frame it forwards with a SW_TT_TX_LENGTH, a SW_TT_TX_PERIOD, and a SW_TT_TX_PHASE.

NOTE A scheduler for Time-Triggered frames typically takes the SW_TT_TX_LENGTH and SW_TT_TX_PERIOD values of all frames as an input and returns a value for SW_TT_TX_PHASE for each Time-Triggered frame as an output.

SW_TT_TX_LENGTH is the allowed length of an Ethernet frame including IFG and preamble:

- Minimum(SW_TT_TX_LENGTH) = IFG (12 bytes) + preamble (7 bytes) + start of frame delimiter (1 bytes) + frame (64 bytes)
- Maximum(SW_TT_TX_LENGTH) = IFG (12 bytes) + preamble (7 bytes) + start of frame delimiter (1 bytes) + frame (1518 bytes)

SW_TT_TX_PERIOD is the transmission period with which the Switch dispatches the respective Time-Triggered frame.

SW_TT_TX_PHASE is a value given by:

$$\text{SW_TT_TX_PHASE} = K * \text{SW_SCHEDULE_GRANULARITY}$$

where:

SW_SCHEDULE_GRANULARITY is the granularity of the schedule

K is a natural number such that SW_TT_TX_PHASE \leq SW_TT_TX_PERIOD holds.

- b. A Switch shall specify SW_SCHEDULE_GRANULARITY the granularity of SW_TT_TX_PERIOD at which the Switch accepts values of SW_TT_TX_PHASE from the scheduler.

NOTE An example is SW_TT_TX_PERIOD = 20ms, SW_SCHEDULE_GRANULARITY 20us; which means that SW_TT_TX_PHASE takes any value between 0 and 20ms in 20us increments.

- c. A Switch shall specify the maximum duration SW_TT_TX_MAX_JITTER that it takes starting from the synchronized timebase reaching the phase SW_TT_TX_PHASE in the period SW_TT_TX_PERIOD of a Time-Triggered frame until the first bit of the frame is placed on the transmit communication line.

NOTE There can be two jitter values, one in case media reservation is set and another one if media reservation is not set.

- d. A Switch shall specify the number of SW_TT_TX_FRAMES Time-Triggered frames it is capable to transmit.