OCORA

Open CCS On-board Reference Architecture

Addendum to SUBSET-147 (TTLS)

Train Time and Location Services

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1.00	Official version for OCORA Release R6	SSt	2025-01-31

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References

Reader's note: please be aware that the document ids in square brackets, e.g. [OCORA-BWS01-010], as per the list of referenced documents below, are used throughout this document to indicate the references to external documents. Wherever a reference to a TSI-CCS SUBSET is used, the SUBSET is referenced directly (e.g. SUBSET-026). OCORA always reference to the latest available official version of the SUBSET, unless indicated differently.

[OCORA-BWS01-010] – Release Notes

[OCORA-BWS01-020] – Glossary

[OCORA-BWS01-040] – Feedback Form

[OCORA-TWS02-010] – CCS Communication Network (CCN) – Evaluation

[SUBSET-026-7] - ERTMS/ETCS - System Requirements Specification - Chapter 7 - ERTMS/ETCS language

[SUBSET-147] - ERTMS Data Applications - FFFIS part: CCS Consist Network Communication Layers

[EN 50155:2021] - Railway applications - Rolling stock - Electronic equipment

[IEC 62625-1:2013] - Electronic railway equipment - On board driving data recording system - Part 1: System specification

[IETF RFC 5905:2010] - Network Time Protocol Version 4: Protocol and Algorithms Specification

[IETF RFC 8915:2020] - Network Time Security for the Network Time Protocol

1 Introduction

1.1 Purpose of the document

The purpose of this document is to specify of what is left open in the [SUBSET-147] to get a standardised and unambiguous implementation of the train time synchronisation and location services. The [SUBSET-147] is a mandatory specification of the TSI-CCS 2023 release which aims to define the standard network technology to be used for the on-board CCS system. Although not belonging to communication functionality also the central train time synchronisation service and location services are specified in this [SUBSET-147].

This OCORA Addendum is intended to be used in further specification activities in ERJU e.g. Innovation Pillar focus project R2DATO work package WP23/24 or System Pillar Train CS domain as well as the standardisation activities in EuroSpec. At a later point in time it is intended to be used in tenders for CCS on-board systems or one of its building blocks, either as part of a new rollingstock or as enhancement or replacement in existing legacy rollingstocks.

This document is addressed to experts in the CCS domain and to any other person, interested in the OCORA concepts for on-board CCS. The reader is invited to provide feedback to the OCORA collaboration and can, therefore, engage in shaping OCORA. Feedback to this document and to any other OCORA documentation can be given by using the feedback form [OCORA-BWS01-040] .

If you are a railway undertaking, you may find useful information to compile tenders for OCORA-inspired CCS building blocks, for tendering complete on-board CCS systems, or for on-board CCS replacements for functional upgrades or life-cycle considerations.

If you are an organization interested in developing CCS on-board building blocks according to the OCORA design principles, the information provided in this document can be used as input for your development.

1.2 Applicability of the document

In the current mandatory [SUBSET-147] v1.0.0, Train Time and Location Service (TTLS) is specified. The Train Time and Location Service (TTLS) should provide on one hand a common reference time and on the other hand 3D location information. The time service as well as the location service are both defined as a non-safe on-board service function. The specification of the TTLS in [SUBSET-147] v1.0.0 has some errors and gaps. This OCORA Addendum to SUBSET-147 specifies the Train Time and Location Services in sufficient level of detail in order to remove the errors and to close the gaps of the current [SUBSET-147] v1.0.0. The added requirements (e.g. Network Time Security) on the train time service are in line with the shared security services specified by System Pillar Security domain.

1.3 Context of the document

This document is published as part of an OCORA Release, together with the documents listed in the release notes [OCORA-BWS01-010] . All abbreviations and terms used are defined in the Glossary [OCORA-BWS01-020].

2 Train Time and Location Services

2.1 General

The Train Time and Location Services (TTLS) shall provide on one hand a common reference time and on the other hand the current location information for all applications on the vehicle. They are both defined as a non-safe service function. Both services are interconnected through a shared source of information, namely the GNSS module. The device, on which the services are running on, is out of scope of this specification.
Some applications need an additional safe but relative time. Therefore, they implement an independent time counter. An example of such an application is ETCS onboard implementing a time counter for safe communication with STMs or the RBC. The Train Time Service does not provide such a safe (relative) time information.

2.2 Architecture

Primary using an external GNSS module as time and location source, the TTLS will provide an NTP server for time distribution and a location service delivering location and velocity information.

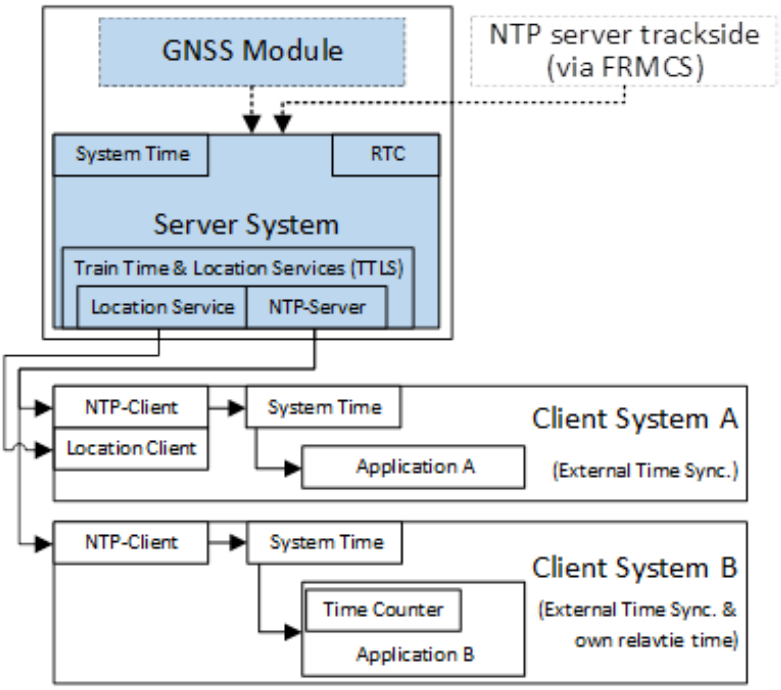

Figure 1 Time and Location Services Architecture

The time service implements an onboard NTP server. Over the NTP protocol every system (NTP client) can synchronise its system time to the system time of the NTP server. By default, the system time of a client system (NTP client) is not continuous. Time jumps can be caused by leap seconds or transient effects for NTP synchronisation. For client systems needing a continuous system time the NTP client can be configured accordingly.

2.3 Requirements

2.3.1 General Requirements

OCORA-10668 - Services definition

There shall be two services active building the two interfaces to the applications:

- Time Service providing Clock Synchronisation to UTC.
- Location Service providing location information (including also velocity, acceleration, attitude) marked with a timestamp. The time information of the timestamp contains the time when the location and the speed information was valid.

Status	✓ Approved
Rationale	TTLS implements two services
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10912 - Central Time Service

There shall be only one active time service on a train used for absolute time synchronisation for all applications.

Status	✓ Approved
Rationale	All application shall get the same accurate absolute time (UTC).
Remark	
Acceptance Criteria	
Acceptance Method	Inspection

OCORA-10675 - Watchdog function for the TTLS

A watchdog function shall check if the Train Time and Location Services (TTLS) are running as expected and restarted automatically if detected as not running.

Status	✓ Approved

Rationale	Stuck time or location service shall be resetted without manual intervention.
Remark	
Acceptance Criteria	
Acceptance Method	Test

2.3.2 Requirements on Time and Location Sources

OCORA-10673 - NTP Stratum

The onboard NTP server shall work as Stratum 1 or 2.

Status	✓ Approved
Rationale	Only onboard GNSS module (stratum 0) or trackside stratum 1 server shall be used to get an accurate time.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10672 - Time Sources

The onboard NTP server shall be able to use the following sources:

- Primary time source:
  - Energy-buffered local real-time clock (RTC). Note: to be used after startup as long as there is no time with higher precision available.
  - GNSS module
- Secondary time source:
  - NTP server (with or without support of NTS according to [IETF RFC 8915:2020]) Stratum 1 from trackside e.g. over FRMCS

Status	✓ Approved
Rationale	Different time sources for different purposes needed.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10914 - Simultaneous time sources

If available, several time sources shall be used simultaneously in a redundant manner to minimise the time service loss.

Status	✔ Approved
Rationale	This requirement minimises the loss of time sources and improves the accuracy.
Remark	
Acceptance Criteria	
Acceptance Method	Demonstration

OCORA-10915 - Resynchronisation after time source loss

The time service shall resynchronise after a loss of time sources when time sources are available again.

Status	✔ Approved
Rationale	Best time sources shall always be used automatically.
Remark	
Acceptance Criteria	
Acceptance Method	Test

OCORA-10721 - RTC buffer time

The energy-buffered local real-time clock (RTC) shall be maintenance free for 15 years (e.g. no battery change). It shall run at least 14 days (336 h) without power supply. If energy has to be re-charged, the energy needed for the period of 14 days shall be re-charged within 1 hour.

Status	✔ Approved
Rationale	Low maintenance in onbaord equipment is a prerequisite.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10671 - Update of Real-Time Clock (RTC)

During time with GNSS reception or connected trackside NTP server the system time of the NTP server shall be written at least once per hour to the local real-time clock (RTC).

Status	✔ Approved
Rationale	RTCs are quite inaccurate. A periodic overwriting of the RTC with accurate time information improves its accuracy.

Remark	
Acceptance Criteria	
Acceptance Method	Inspection

OCORA-10670 - Time Sync Accuracy with GNSS fix

The deviation of the system time of the NTP server to UTC shall be less than 30 µs with a steady 3-dimensional GNSS fix.

Info: To meet the requirement, the GNSS receiver can output a pulse-per-second (PPS) signal. This PPS signal can be directly connected to NTP server and can be used as a time source signal.

Status	✓ Approved
Rationale	As long as there is no IP connection to the trackside available as FRMCS is not in place, GNSS is the only time source on the vehicle. In order to have 10ms time accuracy to UTC even in areas without GNSS reception within 1 hour, an accurate GNSS time sync is needed.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10669 - Clock drift

The clock drift of the NTP servers' system time shall not exceed ±2.5ppm within the operating temperature range class OT3 according to [EN 50155:2021] in a cabinet.

Justification: The deviation of the system time of the NTP server to UTC shall not exceed 10 ms within 1 hour GNSS reception loss. The accuracy of the system time shall be below the cycle time of client applications (e.g. ATO 50 ms, JRU logs 50 ms). Additionally, the defined accuracy value of 10 ms corresponds to the resolution of the current onboard train time (T_TRAIN) defined in [SUBSET-026-7] chapter 7.5.1.154.

Info: Using a high-quality temperature compensated crystal oscillator (TCXO) or using the NTP implementation "chrony" with its clock frequency calibration to PPS signal, the accuracy requirement can be met.

Status	✓ Approved

Rationale	As long as there is no IP connection to the trackside available as FRMCS is not in place, GNSS is the only time source on the vehicle. In order to have 10ms time accuracy to UTC even in areas without GNSS reception within 1 hour, an accurate GNSS time sync and stable local clock is needed.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10663 - Dead reckoning function

After startup, once having steady GNSS reception, the location (including also velocity, acceleration, attitude) information shall be available even in areas without GNSS reception (e.g. tunnels, stations etc.). For this function of “dead reckoning”, additional sensors (e.g. accelerometer, gyroscope, counting of external wheel tick pulses) to the GNSS receiver are needed.

Justification: The “dead reckoning” function is state of the art and is already in scope of ITxPT localisation standard.

Status	✓ Approved
Rationale	Dead reckoning helps e.g. for diagnostic purposes in stations and tunnels.
Remark	
Acceptance Criteria	
Acceptance Method	Inspection

OCORA-10916 - Position error GNSS

The 2D position error of the GNSS positioning shall be less or equal to 2m CEP50 (circular error probable) in open sky environment with a roof mounted antenna.

Status	✓ Approved
Rationale	GNSS modules with this value are available on the market with reasonable costs.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10724 - Position error of dead reckoning function

The position error during GNSS reception loss shall be max. 3% (68% error incurred without GNSS as

a percentage of travelled distance of 3000m).

Status	✔ Approved
Rationale	GNSS modules with this value are available on the market with reasonable costs.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10928 - Minimum navigation update rate

The navigation update rate in normal conditions shall be min. 1Hz.

Status	✔ Approved
Rationale	GNSS modules with this value are available on the market with reasonable costs.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

2.3.3 Requirements on Interface to Applications

2.3.3.1 Time Service (Clock Synchronisation to UTC)

OCORA-10667 - NTP protocol

The local (onboard) distribution of the synchronisation to UTC time shall take place via NTP protocol according to [IETF RFC 5905:2010].

Info: The derivation of the local time is in the responsibility of the client system (e.g. DMI).

Status	✔ Approved
Rationale	Client systems need to synchronise their system time
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10913 - Time distribution after startup

Time distribution shall be started earlier than 50s after power on.

Status	✔ Approved

Rationale	The start-up of the NTP server shall be lower (with some margin) than the JRU start-up time of 60s defined in chapter 4.3.1.1 of [IEC 62625-1:2013].
Remark	
Acceptance Criteria	
Acceptance Method	Test

OCORA-10722 - Leap second behaviour

The system time of the time service (NTP server) shall step at the moment a leap second occurs.

Info: To get a continuous system time on the client system with no or only small time jumps, the NTP client in the client system can be configured accordingly.

Status	✓ Approved
Rationale	Leap second behaviour shall be up to the client systems and its needs. Together with the leap second indicator, every synchronised client can always derive the exact UTC time information even if the system time of the client is not continuous.
Remark	The system time of the time service (NTP server) is possibly not continuous. Time jumps can be caused by leap seconds or transient effects for NTP synchronisation.
Acceptance Criteria	
Acceptance Method	Inspection

OCORA-10723 - Leap second indicator

Leap seconds shall be indicated by the NTP server with the leap indicator according to [IETF RFC 5905:2010].

Status	✓ Approved
Rationale	Leap second behaviour shall be up to the client systems and its needs. Together with the leap second indicator, every synchronised client can always derive the exact UTC time information even if the system time of the client is not continuous.
Remark	The system time of the time service (NTP server) is possibly not continuous. Time jumps can be caused by leap seconds or transient effects for NTP synchronisation.
Acceptance Criteria	

Acceptance Method	Inspection

OCORA-10665 - Network Time Security (NTS)

Network Time Security (NTS) according to [IETF RFC 8915:2020] shall be supported by the onboard NTP server.

Info: The usage of a correctly configured service “chrony” on a Linux based system would normally fulfil the requirement.

Status	✓ Approved
Rationale	IEEE 802.1X:2004 as defined in [SUBSET-147] on layer 2 is not sufficient to secure the time synchronisation.
Remark	
Acceptance Criteria	
Acceptance Method	Inspection

OCORA-10666 - PCP value of NTP packets

In accordance with [SUBSET-147] chapter 8.4.4.1.2 the NTP packets for time synchronisation shall be sent with PCP value 6 in order to get high priority in the network and therefore high synchronisation accuracy. This requirement is not only valid for the NTP server (train time service) but also for the NTP clients (clients of the train time service).

Status	✓ Approved
Rationale	PCP value definition for NTP missing in [SUBSET-147]
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

2.3.3.2 Location Service

OCORA-10664 - Location service definition

The location (including also velocity, acceleration, attitude) shall be derived from GNSS. The time information contains the time when the location and the speed information was valid.

Status	✓ Approved
Rationale	Basic service requirement
Remark	
Acceptance Criteria	
Acceptance Method	Demonstration

OCORA-10662 - Location information distribution

The information shall be distributed locally (onboard) over the traffic mechanisms “process data”.

Status	✓ Approved
Rationale	Process data communication allows location information to be distributed rapidly (real-time). Also low-end devices are able to get the information over process data.
Remark	
Acceptance Criteria	
Acceptance Method	Design Review

OCORA-10661 - Definition Process Data Location Packet

For process data the following packet shall be distributed (R):

PVAAT Packet (Position, Velocity, Altitude, Acceleration, Time):

Properties:

- ComId: configurable
- Data class: Time-critical process data (VLAN Prio 6)
- Cycle Time: ≤1000 ms

Byte Offset	Type	Name	Unit	Description	classification in case of 2D/3D fix
0	UINT8	VERSION		Version of the packet, current version (this definition): 1	mandatory

1	UINT16	VALIDITY		Flags: Bit 0: valid date (UTC_YEAR, UTC_MONTH, UTC_DAY) Bit 1: valid time (UTC_HOUR, UTC_MINUTE, UTC_SECOND, UTC_NANO) Bit 2: valid sensor configuration (GNSS_TO_EXTREMITY_1/2) Bit 3: valid position (POSITION_LAT, POSITION_LONG) Bit 4: valid altitude (ALT_HAE) Bit 5: valid track angle (TRACK) Bit 6: valid speed (SPEED) Bit 7: valid acceleration (ACCELERATION_X/Y/Z) Bit 8: valid climb (CLIMB) Bit 9: valid heading angle (HEADING) Bit 10: valid pitch angle (PITCH) Bit 11: valid roll angle (ROLL)	mandatory
3	UINT8	STATUS		Status: 0: no fix 1: Dead Reckoning (DR) 2: 2D GNSS fix 3: 3D GNSS fix 4: 3D GNSS fix + Dead Reckoning (DR)	mandatory
4	UINT16	UTC_YEAR	y	Year of UTC date and time associated to the data collection.	mandatory
6	UINT8	UTC_MONTH	month	Month of UTC date and time associated to the data collection. Range 1…12	mandatory
7	UINT8	UTC_DAY	d	Day of UTC date and time associated to the data collection. Range 1…31	mandatory
8	UINT8	UTC_HOUR	h	Hour of UTC date and time associated to the data collection. Range 0…23	mandatory
9	UINT8	UTC_MINUTE	min	Minute of UTC date and time associated to the data collection. Range 0…59	mandatory
10	UINT8	UTC_SECOND	s	Second of UTC date and time associated to the data collection. Range 0…60	mandatory

11	UINT32	UTC_NANO	ns	Fraction of second in nanoseconds of UTC date and time associated to the data collection. Range 0…999'999'999.	mandatory
15	UINT32	UTC_ERROR_EST	ns	Estimated time error in nanoseconds associated to the data collection. Value 0 if no error estimate is available.	optional
19	FLOAT32	GNSS_TO_EXTREMITY_1	m	Distance from the centre of the GNSS antenna to the consist end on extremity 1 in meters. GNSS_TO_EXTREMITY_1 + GNSS_TO_ EXTREMITY _2 = overall consist length.2	mandatory
23	FLOAT32	GNSS_TO_EXTREMITY_2	m	Distance from the centre of the GNSS antenna to the consist end on extremity 2 in meters. GNSS_TO_ EXTREMITY _1 + GNSS_TO_ EXTREMITY _2 = overall consist length.2	mandatory
27	FLOAT32	POSITION_LAT	deg	Latitude in degrees in the WGS84 reference system Range: -90.000000° to +90.000000° +/- signifies North/South	mandatory
31	FLOAT32	POSITION_LONG	deg	Longitude in degrees in the WGS84 reference system Range: -180.000000° to +180.000000° +/- signifies East/West	mandatory
35	FLOAT32	POSITION_ ERROR_EST	deg	Estimated horizontal position error in meters. Value 0 if no error estimate is available.	mandatory
39	FLOAT32	ALT_HAE	m	Altitude / height above WGS84 ellipsoid in meters	mandatory (only 3D fix)
43	FLOAT32	ALT_ERROR_EST	m	Estimated vertical position (altitude) error in meters	optional
47	FLOAT32	TRACK	deg	Course of motion over ground in degrees clockwise from true north	mandatory
51	FLOAT32	TRACK_ERROR_EST	deg	Estimated track direction (direction of ground speed) error in degrees. Value 0 if no error estimate is available.	optional
55	FLOAT32	SPEED	m/s	Speed over ground (2D) in meters per second	mandatory
59	FLOAT32	SPEED_ERROR_EST	m/s	Estimated speed error in meters per second. Value 0 if no error estimate is available.	optional

63	FLOAT32	ACCELERATION_X	m/s^2	Compensated x-axis acceleration (gravity free) in meters per second square $(m/s^2)2$	mandatory
67	FLOAT32	ACCELERATION_Y	m/s^2	Compensated y-axis acceleration (gravity free) in meters per second square $(m/s^2)2$	mandatory
71	FLOAT32	ACCELERATION_Z	m/s^2	Compensated z-axis acceleration (gravity free) in meters per second square $(m/s^2)2$	mandatory
75	FLOAT32	ACCELERATION_ERROR_EST	m/s^2	Estimated acceleration error over the ground in meters per second square (m/s^2). Value 0 if no error estimate is available.	optional
79	FLOAT32	CLIMB	m/s	Climb (positive) or sink (negative) rate in meters per second	mandatory
83	FLOAT32	CLIMB_ERROR_EST	m/s	Estimated climb error in meters per second. Value 0 if no error estimate is available.	optional
87	FLOAT32	HEADING	deg	Heading of vehicle towards extremity 1 over ground in degrees clockwise from true north	mandatory
91	FLOAT32	HEADING_ERROR_EST	deg	Estimated heading direction error in degrees[1]. Value 0 if no error estimate is available.	optional
95	FLOAT32	PITCH	deg	Pitch angle in degrees between -90 and + 90	mandatory
99	FLOAT32	PITCH_ERROR_EST	deg	Estimated pitch error in degrees. Value 0 if no error estimate is available.	optional
103	FLOAT32	ROLL	deg	Roll angle in degrees between -180 and + 180	mandatory
107	FLOAT32	ROLL_ERROR_EST	deg	Estimated roll error in degree. Value 0 if no error estimate is available.	optional

Table 1 Process Data Specification PVAAT Packet

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[1] The consist and vehicle directions and axis are defined according to [IEC 61375-1:2012] chapter 5.5. The x-axis is the vehicle longitudinal axis oriented toward the extremity 1. The y-axis is the orthogonal to the vehicle longitudinal axis oriented to the left (side A). The z-axis is the orthogonal to the vehicle x-axis and y-axis oriented up.

Status	✔ Approved

Rationale	Process data communication allows location information to be distributed rapidly (real-time). Also low-end devices are able to get the information over process data.
Remark	
Acceptance Criteria	
Acceptance Method	Inspection