CTAO Array Clock System (CLK) to Telescope ICD

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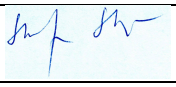
Approved by (7)	S. Stanghellini, Telescope Task Coordinator	 Digitally signed by Stefano Stanghellini Date: 2023.07.07 11:59:01 +02'00'
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Revision History				
Issue	**Rev.**	**Created**	**Reasons / Remarks / Section**	**Author**
1	a			
Draft	01	2022-12-15	First Draft Proposal	C. Montanari
Draft	02	2023-01-23	Added system descriptions, general interface description, requirement specifications, and responsibilities	H. Prokoph
Draft	03	2023-02-20	Added signature matrix (CM), added verification matrix, implemented comments from Computing	H. Prokoph, C. Montanari
1	a	2023-05-30	Implemented comments from the different telescope teams: - added some clarifications - removed WR calibration responsibilities - remove CLK requirements specification from list of ADs - fixed sign matrix	H. Prokoph C. Montanari

Abbreviations	
ACRV	Acceptance Review
CDR	Critical Design Review
CLK	Array Clock System
CTAO	Cherenkov Telescope Array Observatory
ICD	Interface Control Document
ICT	Information Communication Technologies
MST	Medium Sized Telescope
NTP	Network Time Protocol
LC	Lucent Connector
LST	Large Sized Telescope
RX and TX	Receive and Transmit
SFP	Small Form-factor Pluggable
SST	Small Sized Telescope
TEL	Telescopes
TPP	Telescope Patch Panel
WR	White Rabbit

Definitions	
Term	**Definition**
Telescope Patch Panel	The telescope patch panel is a passive patch panel (i.e. standard ICT device) which is located in the close vicinity of the telescope (e.g. in the interface cabinet or within the telescope structure).
WR Device	A WR Device is a physical device capable of providing one or multiple WR capable optical fibre links, e.g. a WR Switch or WR Node. A WR Device can run as “WR Master” or/and as “WR Slave”.
WR Link	A WR Link is defined by two WR Devices connected via a WR Fibre, i.e. it consists of a “WR Master” and “WR Slave” and the corresponding optical fibre connecting the two where time and frequency are transferred downstream from the “WR Master” to the “WR slave”.

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1 Introduction

1.1 Scope

This Interface Control Document (ICD) defines and describes the interface between the CTAO Array Clock System (henceforward called CLK) and the Large-sized Telescope (LST), Medium-sized Telescope (MST) and Small-sized telescope (SST) (henceforward called Telescopes, TEL).

Conventions:

This document contains two types of items: requirements and information.

- Requirements have to be verified by the supplier while information items do not.
- Requirements are identified with a requirement tag following the provisional format CLK-TEL-NNNN where NNNN is a unique number. The NNNN identifier does not need to be sequential or continuous. In that way additional requirements can be introduced when revisions of the ICD will be needed.
- Each requirement carries a verification tag that should be taken as a guide for selecting the minimum verification method(s) applicable for that requirement verification (A: Analysis, C: Certification, D: Demonstration, R: Review of Design, I: Inspection, T: Test).
- Information which is not identified with a tag: this information which is fully binding to this document, refers usually to context, conditions or definitions that have to be taken into consideration for all or for specific requirements.

1.2 Applicable and reference documents

1.2.1 Applicable documents

AD-1	Interface General Definition Document (IGDD), CTA-STD-SEI-000000-0002
AD-2	White Rabbit Specification, version 2.0 (2011). https://ohwr.org/project/wr-std/wikis/Documents/White-Rabbit-Specification-(latest-version)
AD-3	Characteristics of a single-mode optical fibre and cable, Recommendation ITU-T G.652.D (11/2016). https://www.itu.int/rec/T-REC-G.652/en
AD-4	IEEE Standard for Ethernet, IEEE 802.3-2022

1.2.2 Reference Documents

RD-1	Level B Requirements Specification for the Array Clock System, CTA-SPE-COM-302000-0002, 1b (2023)
RD-2	Network Time Protocol Version 4: Protocol and Algorithms Specification, RFC 5905 (2010). https://datatracker.ietf.org/doc/html/rfc5905

2 Interface Context and Definition

2.1 General

The Array Clock System (CLK) provides a common time reference to the CTA Observatory, i.e. to all its on-site array elements, its on-site ICT sub-systems and all other (sub-)systems which need a time or synchronized clock. As such, the following functionalities of the CLK **(RD-1)** are relevant for this ICD:

- The CLK will provide a common, synchronized time reference based on the **Network Time Protocol** (NTP, RD-2) to all the CTAO systems and subsystems such as array elements, on-site ICT equipment, etc.
- The CLK will provide high-precision reference timing signals based on **White Rabbit** (WR, **AD-2**) technology to each Cherenkov telescope camera to support the absolute timestamping of events.

The Telescopes (TEL) will use the provided time and clock signals to synchronize their (sub-)system clocks and will use this reference time for all timestamps associated with data products by their corresponding subsystems. Depending on the needed timestamp accuracy, the reference time used will be either NTP- or WR-based.

2.2 Interface Description

The interface between the CLK and TEL can be split into two parts:

1. **The WR Link:** The interface for the exchange of high-precision timing signals between the Precision Clock Distribution System (i.e. the WR Switch) of the CLK and the Cherenkov Camera Field Unit (i.e. the WR node inside the camera) of the TEL.
2. **NTP packets:** The interface for the exchange of NTP messages between the NTP Server (as part of CLK) and the NTP Clients (as part of TEL and its corresponding subsystems).

The first part of the interface, i.e. the WR Link, is shown in *Figure 1*. It consists of the WR Switch on the CLK side and the WR Node on the TEL side which are connected via a dedicated optical fibre over which time and frequency are transferred downstream, i.e. from the CLK to the WR Node inside the Camera Field Unit.

The interface along the WR Link is physically located inside the Telescope Patch Panel (TPP).

In addition to the WR packets exchanged over the WR Link for clock synchronization, additional data packets can be transferred over the same physical link. These data packets are e.g. camera configuration data or trigger timestamps and are internal to the Cherenkov camera of the TEL (hence it effectively constitutes an internal interface to the Cherenkov camera system). The WR Switch of the CLK acts in this case as ethernet switch and provides a data connection between the Cherenkov Camera Field Unit and its respective Camera Server in the On-Site Data Centre through the On-site ICT Central Switch Stack.

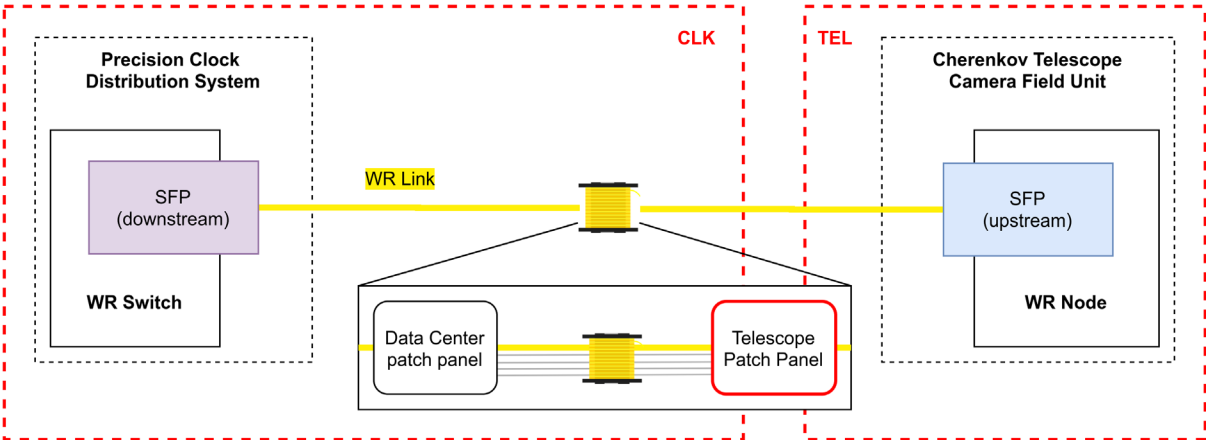

Figure 1 – Schematic view of the physical interface between Precision Clock Distribution System of the CLK and the Camera Field Unit of the TEL for the exchange of high-precision timing signals over a dedicated WR Link which is physically located at the Telescope Patch Panel (highlighted in red).

The second part of the interface between CLK and TEL, i.e. the NTP part, is detailed in an one-sided ICD of the Array Clock System as listed in the Requirements Specification of the CLK and will be applicable to all CTAO subsystems (including TEL) which require a date, time and/or a synchronized clock.

3 Interface Requirements

Table 1 Interface Requirements for the WR Link for time and frequency exchange.

Req. ID	Name of the requirement	Description	Verification requirememt (A,C,D,I,R,T)	
			CDR	ACRV
CLK-TEL-1000	WR Fiber Type	The optical fiber used for the WR Link shall follow the ITU-T.G652.D standard (**AD-3**) at both sides of the interface located at the telescope patch panel (or shall at least be compatible with this standard).	R	T
CLK-TEL-1010	Number of WR Fibers	A total of two single-mode optical fibers shall be reserved for the exchange of WR packets: one for use in production, one as a (cold) spare[1].	R	I
CLK-TEL-1020	Passivity of the WR Link	There shall be no active components (e.g. amplifiers, converters, etc.) anywhere along the WR Link between the CLK (i.e. the port of the WR switch) and the TEL (i.e. the WR node inside the Cherenkov camera field unit).	R	I
CLK-TEL-1030	WR Link Connection	At the telescope patch panel, one LC simplex port shall be used for establishing the WR Link between CLK and TEL by connecting the dedicated WR Fiber to the same port of the	R	I

[1] The term "(cold) spare" indicates that switching from the production fiber in use to the spare fiber requires a physical interaction by the operator and does not happen automatically in case of an identified failure.

Req. ID	Name of the requirement	Description	Verification requirememt (A,C,D,I,R,T)	
		patch panel. The exact port is TBD (in consolidation with on-site ICT). The connector type of the optical fiber shall be LC male to match the physical configuration of the telescope patch panel. The other LC simplex port shall be reserved as a WR Fiber spare.		
CLK-TEL-1100	WR Specification	The exchange of high-precision time and frequency signals shall follow the WR Specification (detailed in Section 6 of **AD-2**).	R	R
CLK-TEL-1110	CLK WR Port Configuration	The WR port of the CLK shall be configured as "`wr_master`".	R	I
CLK-TEL-1120	TEL WR Port Configuration	The WR port of the TEL shall be configured as "`wr_slave`".	R	I
CLK-TEL-1200	WR Link ethernet standard	The WR Link shall follow 1000BASE-BX10 ethernet standard specified in IEEE 802.3 (detailed in chapter 59 of **AD-4**), i.e. it shall use bi-directional data transfer over a single optical fiber.	R	R
CLK-TEL-1210	CLK SFP specifications for the WR Link	The SFPs of the CLK shall follow IEEE 802.3 (detailed in chapter 59 of **AD-4**) 1000BASE-BX10-D, i.e. they shall have the following wavelengths: TX = 1490nm and RX = 1310nm	R	I
CLK-TEL-1220	TEL SFP specifications for the WR Link	The SFPs of the TEL shall follow IEEE 802.3 (detailed in chapter 59 of **AD-45**) 1000BASE-BX10-U, i.e. they shall have the following wavelengths: TX = 1310 nm and RX = 1490 nm	R	I
CLK-TEL-1500	WR Link Data Rate	The maximum data rate per telescope exchanged over the WR Link shall be 50 Mbit/s.	R	A
			CDR	ACRV

Legend: A: Analysis, C: Certification, D: Demonstration, R: Review of Design, I: Inspection, T: Test, CDR: Critical Design Review, ACRV: Acceptance Review

4 Interface Responsibilities

In the following the responsibilities of the ICD stakeholders are given. Please note, that the calibration of the WR Link will be subject of a different document which shall detail the WR calibration method, its application in CTAO and the (shared) responsibilities of the stakeholders.

4.1 Array Clock System responsibilities

The CLK shall provide matching SFPs for the WR Link to the telescope teams:

- The SFP transceivers for the WR Link (CLK-TEL-1200) shall be interchangeable with products listed by the Open Hardware Repository: https://ohwr.org/projects/white-rabbit/wiki/SFP (those with digital diagnostics monitoring shall be preferred).
- CLK will purchase all SFPs needed for the WR Links, i.e. those for the CLK (CLK-TEL-1210) and those for the TEL (CLK-TEL-1220).
- CLK will provide the upstream SFPs to the TEL teams prior installation including spares. The exact number is TBD.

4.2 Telescope responsibilities

The telescopes shall implement the WR protocol inside their Cherenkov camera to obtain time and frequency from the CLK.