GOVERNMENT OF INDIA, MINISTRY OF RAILWAYS

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FUNCTIONAL REQUIREMENT SPECIFICATION (FRS)
FOR

MASTER CLOCK SYSTEM
SPECIFICATION FOR
INDIAN RAILWAYS

Specification No. RDSO/SPN/Tele/….

I. DOCUMENT DATA SHEET

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Document Title:	Functional Requirement Specification (FRS) for Master Clock System Specification for Indian Railways
Prepared by, Designation:	Director/Telecom- I
Approved by, Designation:	PED/S&T
Abstract: This document specifies the functional requirement specification (FRS) for Master Clock System Specification for Indian Railways.	

II. DOCUMENT CONTROL SHEET

Designation	**Organisation**	**Function**	**Level**
SSE/Telecom	RDSO	Member	Prepare
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1.0 FOREWORD:

1.1 Indian Railways uses various applications and systems, such as speedometers in loco cabs, data loggers, EI, SCADA etc. which collect data from different sources and record various events in real time. They play a crucial role in day to day working of Indian Railways.

1.2 Currently, these different systems/equipments are synchronized by sourcing time from different sources. During failures and unusual incidents, any mismatch in timing distorts the investigation and the subsequent corrective actions. To eliminate such discrepancies, it is essential to synchronize all clocks with a common source.

1.3 This Functional Requirement Specification (FRS) is prepared for framing RDSO specification for Master Clock System Specification for Indian Railways. (Reference Railway Board Letter No. 2020/Tele/9(2)/1 dated 04.01.2025)

2.0 SCOPE:

This document outlines the functional requirements for the Master Clock System (MCS) to be implemented in the entire Indian Railways network. The MCS will synchronize the time across all railway stations, control rooms, and other critical infrastructure to ensure accurate and consistent timekeeping throughout the system.

3.0 OBJECTIVE:

3.1 Indian Railways are using various applications/systems which are taking time from different sources and there is a need to synchronize different systems in Indian Railways by adopting a common source for clock from NavIC (Navigation with Indian Constellation) or NPL (National physical Laboratories) or any Indian Cesium Atomic clock.

3.2 Different Railway equipment requires varying levels of time precision therefore both Precision Time Protocol (PTP) and Network Time Protocol (NTP) will be used to synchronize clocks across the distributed network.

3.3 A PTP master Clock will serve as the time source for IP-MPLS backbone network providing nanosecond accuracy, and the same PTP server will provide an NTP service to other parts of the distributed network, offering millisecond accuracy. This ensures time synchronization across the entire network with varying levels of precision where needed.

4.0 ARCHITECTURE OF MASTER CLOCK SYSTEM (MCS):

4.1 The Master Clock System (MCS) for Indian Railways will be designed to ensure precise and synchronized time across the entire railway network, which spans a vast and geographically dispersed area.

4.2 Master Clock System (MCS) system is to be implemented as a distributed architecture that incorporates multiple time sources, communication protocols, and time distribution mechanisms to maintain consistent and accurate time across the entire IPMPLS backbone, 4G/LTE-R network, Zonal and Divisional headquarters and railway stations.

4.3 The locations of the centralized Master Clock Server (Grandmaster Clock) and Sub-master Clocks will be strategically determined to ensure optimal coverage and efficiency across the entire Indian Railway network. The locations may include Zonal Headquarters, Divisional Headquarters, and key Railway stations.

4.4 Each station or critical device will have a local time synchronization client that periodically synchronizes with the Master Clock Server.

4.5 The system will support both wired and wireless communication protocols and will ensure redundancy through multiple master clocks and failover mechanisms.

5.0 COMPONENTS OF THE MASTER CLOCK SYSTEM: The Master Clock System for Indian Railways will consist of the following key components:

i. Grand Master Clock
ii. Sub-Master Clocks
iii. Time Synchronization Communication Network

5.1 **Grand Master Clock:**

5.1.1 The Grandmaster Clock, also known as the Master Clock, will be the central clock that synchronizes all other clocks within the network. It will receive time signals from the primary time source and distribute precise time to downstream devices.

5.1.2 The primary time source for the grand master clock will either be from NavIC (Navigation with Indian Constellation) or NPL (National physical Laboratories) or any Indian Caesium Atomic clock.

5.1.3 The Grandmaster Clock unit will receive timing information from the NavIC/IRNSS satellites using an outdoor antenna which will be mounted on rooftop for optimum reception.

5.1.4 The Primary Master Clock of the Master Clock System will act as main Grand Master clock and provides PTP services and distribute the time from the Grandmaster Clock to Sub-master Clocks ensuring time synchronization across the entire IP/MPLS backbone and 4G/LTE-R network as required.

5.1.5 The Primary Master Clock will also be able to provide NTP services to all the interfacing sub-systems through the DNS infrastructure and operates as a Network Time Protocol (NTP) server.

5.1.6 Accuracy in locked mode: The Grandmaster Clock shall provide required accuracy better than ± 100 ns (peak value) level in all time outputs and better than $1.0e^{-12}$ in all frequency outputs while operating with NavIC/IRNSS.

5.1.7 PTP client functionality: The unit shall provide a PTP input to enable synchronization from NPL clock.

5.1.8 Frequency input: Interconnection to any Indian Caesium Atomic clock will be accomplished through a 10 MHz, 5 MHz, 2048 kHz interface. To enable this application the Grand Master Clock will be equipped with a frequency input supporting all three frequencies mentioned in this point.

5.1.9 Input priority settings: It shall be possible to configure the precedence level of each clock reference input to determine the role of each of them as a primary or backup input.

5.1.10 Partial holdover (operation relying on a frequency input, with no time references): If the Caesium Atomic clock input is provisioned, it shall be possible to keep timing error in the system under 1 µs for at least 30 days when all other references are lost.

5.1.11 Holdover operation: The unit will keep the timing error in the system under 1 µs for a period of at least 18 hours when all clock reference inputs are lost.

5.1.12 The Grand Master Clock will support IEEE 1588v2 (PTP) and SyncE for highly accurate time synchronization. NTP (Network Time Protocol) will be used in less time-critical applications. It shall be possible to provide all three services (PTP, NTP, SyncE) in the same port at the same time to ensure interoperability with all kinds of timing client reachable from the port.

5.1.13 PTP profiles: The Grandmaster Clock shall be compatible with the following PTP profiles: ITU-T G.8265.1, ITU-T G.8275.1, ITU-T G8275.2, IEEE 1588-2008 Annex J "Delay Request-Response" Default PTP profile, IEEE 1588-2008 Annex J "Peer-to-Peer" Default PTP profile.

5.1.14 Client Capacity: The Grandmaster shall be able to provide PTP services to at least 256 unicast clients per port operating at the maximum transmission rate: 128 Sync messages/s, 128 Delay Request messages/s, 16 Announce messages per second.

5.1.15 PTP profile translation: It shall be possible to configure each Ethernet port with its own specific PTP profile. The PTP profile shall be translated seamlessly when timing information is propagated from the PTP input to any provisioned PTP output.

5.1.16 Protocol translation: It shall be possible for the Grandmaster Clock to seamlessly convert between packet input (PTP or NTP) and a packet output of a different protocol, including PTP-to-NTP and NTP-to-PTP translation function.

5.1.17 Master Clock will have provision of 16 x 2 LCD display for viewing of time parameters on the front panel. At-a-glance status and health information of NavIC/IRNSS receiver parameters shall be provided through discrete LEDs.

5.1.18 The internal clock shall be a Double Oven controlled crystal oscillator (DOCXO) with free running frequency accuracy on shipment will be better than $2.0e^{-9}$. Drift due to aging will be smaller than $1.0e^{-10}$ per day and $1.0e^{-8}$ per year.

5.1.19 A minimum of four Gigabit Ethernet ports for NTP, PTP and SyncE services shall be available. All the ports shall support both electrical (RJ45) and optical (SFP) interfaces.

5.1.20 It will generate wide range of time code and pulse signals via different output ports including at least the following interfaces: 1PPS in BNC 50 Ohm; NMEA ZDA, GGA and RMC in RS422, E1 in RJ48 120 Ohm, 2048/5000/10000 kHz in BNC 50 Ohm interface, IRIG-B in BNC 50 Ohm.

5.1.21 Redundancy: The Secondary Master Clock will act as standby and provides the redundancy and become the PTP/NTP server in case of failure of Primary Master Clock.

5.1.22 Cooling mechanism: To minimize the probability and the effects of a fault, the Grandmaster clock shall not contain any moving part or component. Heat dissipation will be achieved through a passive mechanism without fans.

5.1.23 Rack installation: The Grandmaster Clock will include all the necessary options and accessories for installation in a standard 19" rack. Required rack space shall be of 1 RU.

5.1.24 **Power Supply:** The system shall operate on redundant power supply consisting of 1 AC (100V-240V) and 1 DC (18V to 75V). The power consumption of the system shall be maximum 20W.

5.2 Sub Master Clocks:

5.2.1 Sub-master clocks will serve as intermediaries between the master clock and the railway network devices. They receive time synchronization from the Grandmaster and act as time sources for downstream devices.

5.2.2 Redundancy: Multiple Sub-master clocks shall be deployed at key points within the network for high availability, ensuring time synchronization is not disrupted if one Sub-master clock fails.

5.2.3 Time Signal Distribution: Sub-master clocks are responsible for passing on the time signal to downstream devices and synchronizing time across long-distance or remote network segments.

5.2.4 PTP client functionality: The unit shall provide a PTP input to enable synchronization from a Grand Master clock.

5.2.5 The Sub Master Clock units will receive timing information from the NavIC/IRNSS satellites from an outdoor antenna which will be mounted on rooftop for optimum reception.

5.2.6 Accuracy in locked mode: The Grandmaster Clock shall provide the required accuracy better than ± 100 ns (peak value) level in all time outputs and better than $1.0e^{-12}$ in all frequency outputs while operating with NavIC/IRNSS.

5.2.7 SyncE input: It shall be possible for the unit to use a SyncE signal received from the Time Synchronization Communication Network as a clock reference input.

5.2.8 Input priority settings: It shall be possible to configure the precedence level of each clock reference input to determine the role of each of them as a primary or backup input.

5.2.9 Partial holdover (operation relying on the SyncE input, with no time references): It shall be possible to keep timing error in the system under 1 µs for at least 30 days from the SyncE when all other references are lost.

5.2.10 Holdover operation. The unit will keep the timing error in the system under 1 µs for a period of at least 4 hours when all clock reference inputs are lost.

5.2.11 The Grand Master Clock will support IEEE 1588v2 (PTP) and SyncE for highly accurate time synchronization: NTP (Network Time Protocol) will be used in less time-critical applications. It shall be possible to provide all three services (PTP, NTP, SyncE) in the same port at the same time to ensure interoperability with all kinds of timing client reachable from the port.

5.2.12 PTP profiles: The Grandmaster Clock shall be compatible with the following PTP profiles: ITU-T G.8265.1, ITU-T G.8275.1, ITU-T G8275.2, IEEE 1588-2008 Annex J “Delay Request-Response” Default PTP profile, IEEE 1588-2008 Annex J “Peer-to-Peer” Default PTP profile.

5.2.13 Client capacity: The Grandmaster shall be able to provide PTP services to at least 256 unicast clients per port operating at the maximum transmission rate: 128 Sync messages/s, 128 Delay Request messages/s, 16 Announce messages per second.

5.2.14 PTP profile translation: It shall be possible to configure each Ethernet port with its own specific PTP profile. The PTP profile shall be translated seamlessly when timing information is propagated from the PTP input to any provisioned PTP output.

5.2.15 Protocol translation: It shall be possible for the Grandmaster Clock to seamlessly convert between packet input (PTP or NTP) and a packet output of a different protocol, including PTP-to-NTP and NTP-to-PTP translation function.

5.2.16 Master Clock will have provision of 16 x 2 LCD display for viewing of time parameters on the front panel. At-a-glance status and health information of NavIC/IRNSS receiver parameters shall be provided through discrete LEDs.

5.2.17 The internal clock will be an Oven controlled crystal oscillator (OCXO) with free running frequency accuracy better than $5.0e^{-8}$. Drift due to aging will be smaller than $5.0e^{-10}$ per day and $5.0e^{-8}$ per year.

5.2.18 A minimum of four Gigabit Ethernet ports for NTP, PTP and SyncE services shall be available. All the ports shall support both electrical (RJ45) and optical (SFP) interfaces.

5.2.19 It will generate wide range of time code and pulse signals via different output ports including at least the following interfaces: 1PPS in BNC 50 Ohm; NMEA ZDA, GGA and RMC in RS422, E1 in RJ48 120 Ohm, 2048/5000/10000 kHz in BNC 50 Ohm interface, IRIG-B in BNC 50 Ohm.

5.2.20 Cooling mechanism: To minimize the probability and the effects of a fault, the Grandmaster clock shall not contain any moving part or component. Heat dissipation will be achieved through a passive mechanism without fans.

5.2.21 Rack installation: The Grandmaster Clock will include all the necessary options and accessories for installation in a standard 19” rack. Required rack space shall be of 1 RU.

5.2.22 **Power Supply:** The system shall operate on redundant power supply consisting of 1 AC (100V-240V) and 1 DC (18V to 75V). The power consumption of the system shall be maximum 20W.

5.1 **Time Synchronization Communication Network**:

The communication network carries time synchronization signals between different network elements. The network must support protocols IEEE 1588v2 (PTP) and SyncE or latest for sub-microsecond accuracy, and NTP for broader synchronization.

6.0 TIME DISTRIBUTION MECHANISMS:

6.1 The master clock system will provide a high-precision reference clock using the Precision Time Protocol (PTP) IEEE 1588v2 and SyncE for synchronization of Railway IP/MPLS network and other railway equipments requiring accuracy in sub-microsecond or nanosecond viz. 4G/LTE equipments etc.

6.2 For other Railway equipments which require precision in the range of 1-100 milliseconds, Network Time Protocol (NTP) shall be used to synchronize clocks in a distributed network.

6.3 Time synchronization in the Railways legacy system such as PD-MUX, SDH equipment etc. which might not support modern protocols like NTP/PTP will be implemented through gateways or adapters to integrate legacy systems with the new time synchronization infrastructure.

7.0 MANAGEMENT AND MONITORING SYSTEM:

7.1 Centralized Monitoring: A centralized monitoring system should be implemented to monitor the health of the Master Clock, Sub-master clocks, and local clocks.

7.2 Logging and Alarm Systems: Real-time monitoring, logging, and alerting of clock synchronization status, performance, and errors.

7.3 Status Monitoring: Provides estimates of time synchronization accuracy in terms of time error and other performance metrics.

7.4 Performance Testing: It shall be possible test and monitor the network conditions affecting synchronization (e.g., packet loss, network latency) and the timing accuracy provided by the network (time error, frequency offset and drift) by a neutral standalone solution not depending on the Time Synchronization Communication Network. The neutral standalone solution will be equipped with a high-performance Rubidium oscillator and GNSS/NavIC receiver.

7.5 Reports and Analytics: Generate reports to analyse system performance over time, identifying potential issues with time synchronization or network connectivity.

7.6 System agnostic management: It shall also be possible to integrate devices from multiple vendors, including routers, switches and other network elements in the NMS. In such cases all third party equipment shall be integrated using SNMP Protocol or any other industry accepted standard protocol.

8.0 FUNCTIONAL REQUIREMENTS:

8.1 Operation of MCS

8.1.1 Master Clock Unit (Grand Master clock) will act as the primary reference time source and further distributes the time synchronization signal to the Sub Master Clocks/ Railway Network.

8.1.2 Master Clock units will also supply timing signals through PTP or NTP as required to other telecom subsystems including various NMS equipment.

8.1.3 Sub-master clocks will also support NTP in addition to PTP and will distribute the time synchronization signal NTP or PTP to the Railway Network as per requirement.

8.1.4 In case of invalid or unavailability of input signal, Master Clock unit will operate in holdover mode with internal clock supplying the time signal. Once the signal is restored and validated, Master Clock unit will correct itself. Similarly Sub-master Clocks will operate in holdover mode in case of invalid input.

8.1.5 The appropriate location for the antenna (NavIC receiver) will be identified such that there is minimal obstruction to the sky and therefore visibility to the maximum number of satellites.

8.1.6 A surge Protector will be provided between Antenna and Central Master Clock / Sub Master Clock Units which will protect the equipment from lightning.

8.2 Redundancy and Failover

8.2.1 Redundant Master Clocks shall be deployed to ensure high availability and fault tolerance.

8.2.2 In case of failure of the primary Master Clock, the secondary Master Clock should take over automatically without affecting the synchronization of other devices.

8.2.3 The failover process should be seamless and require no manual intervention.

8.3 Monitoring and Alerts

8.3.1 An SNMP based Clock Management System will be deployed at central location to facilitate status monitoring of Master Clock System.

8.3.2 The MCS NMS also provides full configuration support of Master Clock units and Sub Master clock.

8.3.3 The NMS PC will be equipped with virus checking and anti-virus protection facilities to prevent virus infection.

8.3.4 The Master Clock supports SNMP protocol for management and alarm monitoring in real time.

8.3.5 Alerts should be triggered in the event of time synchronization errors, hardware failures, or network issues.

8.3.6 Alerts should be logged and communicated to a centralized monitoring dashboard for easy tracking and resolution.

8.4 **Time Accuracy and Drift Compensation**

8.4.1 The system should be capable of detecting and compensating for any drift in time over long periods, ensuring that time remains accurate and consistent.

8.4.2 The system must account for leap seconds and leap years without requiring any specific intervention from the system administrators.

8.5 **Security and Access Control**

8.5.1 Access to the Master Clock System for configuration and maintenance should be restricted to authorized personnel.

8.5.2 The system should support user authentication, role-based access control (RBAC), and logging of administrative actions.

8.5.3 Communication with external time sources and network protocols should be encrypted to protect against tampering or unauthorized access.

8.5.4 RADIUS / TACACS+. Grand Master and Sub Master clocks should accept distributed authentication through RADIUS and TACACS+ protocols to enable the system administrators to deploy and maintain a centralized user database.

8.5.5 Session timeout. Any open session, including web, SSH and console sessions, shall be automatically terminated after a custom period of inactivity.

8.5.6 Password structure. The system can detect and reject weak passwords assigned to user accounts to preserve the system security. For the same reason users will not have any default password assigned when they are created.

8.5.7 Host / network-based access restrictions. It shall be possible to restrict remote access to the unit to certain hosts or networks. This feature helps preserving the system security ensuring that only users in authorized locations are allowed to log in the system.

8.6 **System Interface, User Interface and Reporting**

8.6.1 The Interfaces of Master Clock System will be with various subsystem of Indian Railway (Telecom and Non-Telecom).

8.6.2 The Interfaces of Master clock system and Sub-Master clock system shall be utilized to synchronize all system and network elements of Indian Railways that requires time and frequency information. Below is an example table of showcasing different systems and interfaces within Indian railway system.

Master Clock System Internal Interface with Telecom System

SN	Systems	Location	Protocol	Interface	Connector
1.	DNS	Central location, Station and Depots	NTP over TCP/IP	10/100/1000 ETH	RJ45
2.	SDH	Central location	Sync/E1	Sync/E1	RJ48 bal.
3.	SDH NMS	Central location	NTP over TCP/IP	10/100/1000 ETH	RJ45
4.	Telephone System	Central location	NTP over TCP/IP	10/100/1000 ETH	RJ45

5.	GSM-R	Central location	NTP over TCP/IP	10/100/1000 ETH	RJ45
6.	48V DC NMS	Central location	NTP over TCP/IP	10/100/1000 ETH	RJ45

Master Clock System External Interface with Non-Telecom System

SN	Systems	Location	Protocol	Interface	Connector
1.	Signaling	Central location	NTP over TCP/IP	10/100/1000 ETH	RJ45
2.	Traction /Non Traction SCADA	Central location	NTP over TCP/IP	10/100/1000 ETH	RJ45
3.	Any Other Systems as required	Central location	NTP over TCP/IP	10/100/1000 ETH	RJ45

8.6.3 A user-friendly interface should be available for operators and administrators to monitor the status of the Master Clock System.

8.6.4 The UI should allow for easy configuration, time source management, and historical data reporting (e.g., time synchronization logs, system health checks).

8.6.5 Reports should include information on system performance, time synchronization accuracy, and incident logs.

7.8 Scalability

7.8.1 The Master Clock System must be scalable to accommodate the growth of the Indian Railways network.

7.8.2 New railway stations, facilities, and devices should be easily integrated into the system without requiring major modifications.

7.8.3 The system should be able to handle an increasing number of connected devices and users as the railway infrastructure expands.

9.0 NON-FUNCTIONAL REQUIREMENTS:

9.1 **Performance Requirements**

9.1.1 The Master Clock System should be able to synchronize with thousands of connected devices across the Indian Railways network with minimal latency (ideally within milliseconds).

9.1.2 Time synchronization should occur in real time, with minimal disruption to operations.

9.2 **Reliability and Availability**

9.2.1 The system must ensure 99.99% uptime for time synchronization across critical infrastructure.

9.2.2 The Master Clock should be capable of operating continuously without the need for frequent maintenance or downtime.

10.0 MAINTENANCE AND SUPPORT:

10.1 The Master Clock System will require regular maintenance to ensure optimal performance.

10.2 A dedicated support team should be in place to handle system issues, updates, and upgrades.

10.3 The system should be able to self-diagnose problems and offer troubleshooting guidance to operators.

11.0 INFORMATION TO BE FURNISHED BY THE PURCHASER:

SN	Description of the Item	Quantity
1.	Grandmaster Clock	To be specified by purchaser as per requirement
2.	Sub-Master Clock	To be specified by purchaser as per requirement
3.	Co-axial cable (up to 50 mtrs.)	1 No. for each Grandmaster clock and/or Sub-Master Clock
4.	GPS inline amplifier (for cable length more than 50+10=60 mtr.)	1 No. for each Grandmaster clock and/or Sub-Master Clock
5.	GNSS Antenna (with NavIC) with mounting kit	1 No. for each Grandmaster clock and/or Sub-Master Clock
6.	Surge Arrester with interfacing cable (10M as per site requirement)	1 No. for each Grandmaster clock and/or Sub-Master Clock
7.	Network Management System	To be specified by purchase as per requirement
8.	License for Integrating Grandmaster Clock	One License require per Grandmaster Clock.
9.	License for Integrating Sub-master Clock	One License require per sub-master Clock.
10.	Stand-alone Device for Sync Performance Monitoring for PTP/NTP/SyncE/E1/ 2048KHz /5MHz/10MHz/1PPS (With built-in GNSS/NavIC receiver and Rubidium Oscillator) complete with Antenna/cables/ accessories/licenses.	One unit per Division or as specified by purchase as per requirement

12.0 All the provisions contained in RDSO's ISO procedures laid down in Document No. QO-D-8.1-11 Version 3.1 date effective 20.11.2024 or latest (Document Title: Vendor Changes in approved status) and "subsequent versions/amendments thereof, shall be binding and applicable on the successful vendors in the contracts floated by Railways to maintain quality of products supplied to Railways".