सत्यमेवजयते

भारतसरकार
(रेल मंत्रालय)

Technical Specification of LTE Radio Access Network Design system

for

Mission Raftar Section (Delhi-Mumbai & Delhi-Howrah)

(TS No. ST-54/2023/RAN Ver 1.0p)

Feb 2024

द्वारा

सिग्नल एवं दूरसंचार निदेशालय
अनुसंधान अभिकल्प एवं मानक संगठन

DOCUMENT DATA SHEET

TS No. ST-54/2023/Abbreviation		Version 1.0p
Title of Document Technical Specification of LTE Radio Access Network Design Mission Raftar Section (Delhi-Mumbai & Delhi-Howrah).		
Authors See Document Control Sheet		

Abstract

This Technical specification of LTE Radio Access Network Design is prepared for incorporation in Bid Document for LTE system in Delhi-Mumbai & Delhi-Howrah routes by the committee members nominated by Railway Board vide 2023/S&T/Dev/4G.LTE.Implementation Dated 06.10.2023

Document Control Sheet

Name	Organization	Function	Signature
Sh. C K Prasad **Sr. Professor/IT**	**IRISET**	Member	
Sh. G. Pavan Kumar **ED/Tele-II**	**RDSO**	Convenor	
Sh. Saurabh Verma **ED/Tele Dev**	**CoE**	Member	

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Radio Access Network Design

1 Scope

1.1 The Radio Access Network shall be designed, installed and commissioned to ensure that failure of any one Cell Site or a Sector of a Cell site (Base Band, RRU, Power Supply, Antenna System and Cabling etc. does not result in any coverage unavailability).

1.2 The railway communications on LTE is aimed to provide linear coverage using directional base station antennas with main lobes along the rail track to transmit power focused on the narrow-strip-shaped regions and connected Loco-sheds, depots and sidings with the rail track with three or more sectors.It shall also provide indoor coverage for designated buildings in railway premises.

1.3 This document sets forth the requirements of Radio Access Network design to meet the Mission Critical Requirements of Indian Railways.

2 Description

2.1 General Capacity Requirements

2.1.1 In normal operational conditions, the “General Coverage area” area shall simultaneously support the following requirements taking into consideration the limits imposed on each application specified.

a) 100 attached UEs per sector and active UEs at Cell edge can be 14/24/40/80 at cell edge for rural/ sub urban/ urban/ dense urban sections
b) Minimum active Kavach sessions can be 7/12/20/40 at cell edge for rural/ sub urban/ urban/ dense urban sections per sector providing real-time information transmission of control information with less than 100ms delay.
c) The typical applications and their bandwidth requirement for uplink and down link requirement at cell edge for Indian Railways is enclosed as Annexure. The capacity requirements shall be assessed broadly as indicated in this annexure and shall be designed to meet the site requirements.

2.2 Coverage and Capacity Design Requirements

2.2.1 The network planner shall evaluate each clutter's link budget for dense urban/urban/suburban/rural to achieve proper coverage and capacity requirements. The LTE link budget analysis shall indicate a base station's coverage area, potential coverage gaps, and the achievable signal strength and signal to noise ratio at various locations within the coverage area by considering factors such as transmit power, antennae gain, path loss, and receiver sensitivity. Maximum RF radiated power (EIRP) shall be limited to 63 dBm as per the current regulatory requirement issued by DoT

2.2.2 Traffic analysis shall evaluate the data traffic patterns at call and frame level, characteristics, and behaviors to optimize network performance, resource allocation, and capacity planning.

2.2.3 The design report shall typically include comprehensive information and analysis of the radio access network (RAN) design and implementation.

2.2.4 It may also contain a summary of key findings, challenges, and opportunities identified during the radio network design process, along with a recap of recommendations for enhancing the LTE network's performance and reliability. The link budget, traffic analysis and design report for each Sector, explaining how the area requirements for coverage and capacity reliability is satisfied shall be submitted to purchaser railway.

2.2.5 There shall not be any gaps in the target area which fall below the minimum SINR($\geq 13\ dB$) or RSRP($\geq\ -100\ dB$) and submit graphs of signal strength measurement to the purchaser railway for acceptance.

2.2.6 The coverage calculations and coverage plots (both up-link & down-link) to confirm that the required RF coverage stated above can be achieved with the proposed MIMO antenna location, height, tilt, beam width, azimuth etc. shall be submitted to the purchaser railwayfor acceptance.

2.3 Network Requirements

2.3.1 The LTE radio network shall have double radio coverage (100 % overlap) with interference control measures as per the 3GPP standards, so that ifone eNodeB fails, the requirements will be fulfilled by the adjacent eNodeBs.

2.3.2 The E-UTRAN shall provide coverage up to a distance of 30 meters from the nearest running rail in all the directions.

2.3.3 The level of coverage should be at least 95% of the time over 95% of the designated coverage area for a radio installed in a vehicle with an external antenna.

2.3.4 All of above to be measured considering User Equipment (UE) at height of 1.5 meter from the ground level

2.3.5 While planning Cell sites, towers should be planned invariably at station vicinity as far as possible.

2.3.6 Network planning shall be done using suitable licensed software tool for LTE and support for 5G along-with mapping on professional digital Maps. Digital map of minimum 5m resolution of the terrain data shall be employed by the bidder to achieve best accuracy in planning of the RF network.

2.3.7 Radio planning shall involve the following tasks, but not limited to:

2.3.8 The nominal cell planning and coverage predictions of the track/route shall be submitted with preliminary design and bidder shall be responsible for approval of the proposed prediction map by the Authority.

2.3.9 The bidder is required to carry out desktop/ Laptop based RF network cell planning and field survey to identify Antenna mounting arrangement locations i.eCell Towers.

2.3.10 Way Side eNodeB hardware shall be installed along with power supply unit at these foot of the tower in outdoor Cabinets. RRH unit shall be installed on the Tower near Antenna unit to minimize the RF cable loss. Aviation Light shall be supplied and installed at each tower location of each Cell Site.

2.3.11 The Design of antenna mounting structure such as Towers, Poles etc. shall meet all statutory requirements, Civil Constraints, Wind Speed etc. of that area. This design (height, weight, material etc.) shall be approved by the Authority.

2.3.12 All the documentation related to WPC, SACFA and any other regulatory authority approval/clearances shall be prepared and submitted by the bidder to the purchaser railway.

2.3.13 The network shall be designed for relative UE speed of 250 Kmph.

2.3.14 The LTE System provided by the bidders should comply the following:

2.3.14.1 The solution for LTE System shall be designed in order to reliably convey Safety Critical Railway's National Automatic Train Protection (Kavach) System data, MCX services (including MCPTT voice) over OTT, IOT/Sensor data, Limited onboard CCTV video data.

2.3.14.2 The system shall support 2x2 MIMO for dual-layer transmission (spatial multiplexing) and transmission diversity modes for dual antenna configurations.

3 eNodeB redundancy

3.1 The two adjacent eNodeBs are to be deployed in an alternate interleaving manner along the track to provide for geo-redundancy and nodal redundancy.

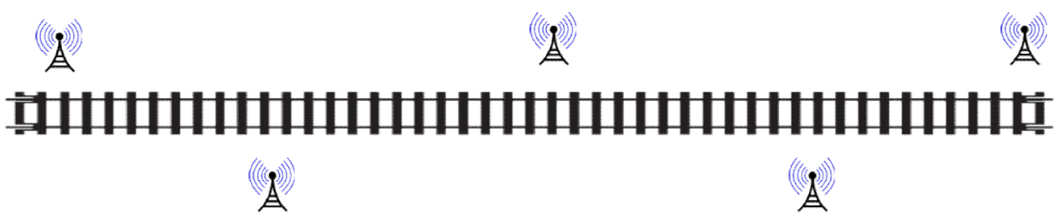


Figure 1 Interleaving eNodeB redundancy

3.2 Resilient IPMPLS backhaul

3.3 The backhaul network connecting all eNodeBswith the distributed LTE core network serves as the communication foundation of the railway infrastructure as it links all trackside and in-station equipment to equipment and servers in the CNOC and data centers.

3.4 IP/MPLS shall provide for resiliency capabilities such as nonstop routing, fast reroute and secondary label-switched path protection.

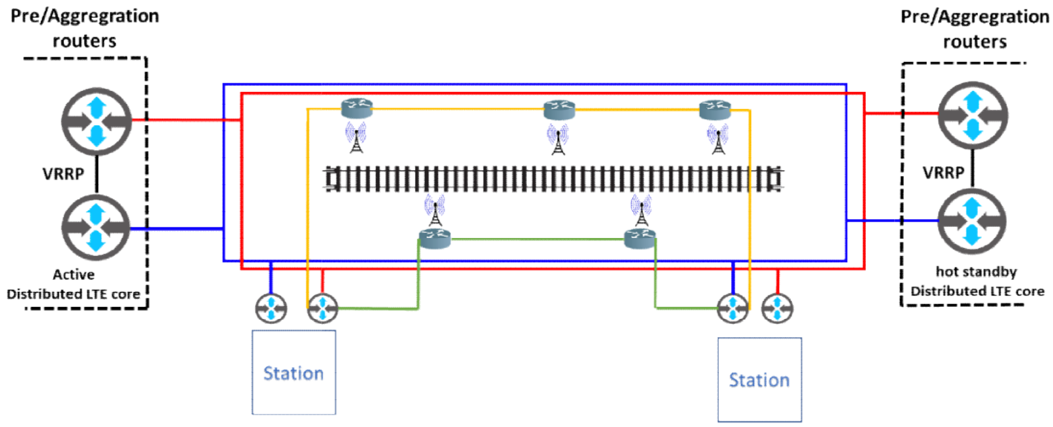
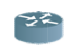


Figure 2 IPMPLS Backhaul

3.5 The backhaul network shall have rich and diverse connectivity so that IP/MPLS can reroute data around multiple failure points to meet the requirements of the safety-critical and mission critical applications.

3.6 Inside a station, there shall be two **IPMPLS service**  **routers** connected to either the blue or red fibreloop.

3.7 The eNodeBs shall be connected to the **cell site routers**  which shall be in turn connected to station IPMPLS service routers through green and blue fibers.

3.8 The IPMPLS service routers shall have scalable IP VPNs over L2/L3 for supporting multiple applications.

3.9 Based on a rich set of classification attributes at layers 1, 2 and 3, the QoS policy shall classify all traffic and prioritize traffic transmission accordingly, with queuing and scheduling, in a hierarchical manner. The IPMPLS service router shall enable multiple levels and instances of shaping, queuing and priority scheduling, so that the performance parameters (such as bandwidth, delay and jitter) for different applications can be met continuously across the network.

4 Core and Serverredundancy

4.1 The distributed LTE core and the server act as the gateway terminating all LTE paths and the corresponding unique, multi-path traffic flow from the Onboard LTE Router (OLR).

4.2 The distributed LTE core and the server shall work in fault-tolerant mode, with an active and hot standby for each.

4.3 The distributed LTE core and the server shall work in geo-redundant pairs connected through IP MPLS and DWDM optical fiber network.

4.4 The distributed LTE core shall impose the QoS requirements which the IPMPLS backhaul and Radio access network shall map for targeted end-to-end service performance.

5 Design Factors

5.1 LTE Radio interface parameters

Parameter	Down Link	Up Link
Frequency	768-773 MHz	713-718 MHz
Bandwidth	5MHz	5 MHz
Multiple Access	OFDMA	Single carrier FDMA
Modulation	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM
Channel encoding	Turbo	Turbo
HARQ	Should be supported	Should be supported
Cell edge throughput	2 Mbps	1Mbps
Handover	Hard, network triggered	Hard, network triggered
Number of Tx/Rx Antenna	2 x 2	1 x 2

5.2 Cyclic Prefix (CP)

5.2.1 LTE supports both short (4.76 ms) and long (16.67 ms) CP schemes.

5.2.2 The short CP scheme is sufficient for LTE-R when trains run in (semi)rural/suburban environments.

5.2.3 In special environments with rich multiple reflections, such as cuttings, in the presence of mountains along the rail track, before and after the train enters and leaves tunnels a large delay spread is expected and after a measurement-based validation the long CP scheme should be used.

5.3 Shadow fading

5.3.1 The fluctuations of signal strength associated with shadow fading cause a call sometimes to be repeatedly handed over back and forth between neighboring base stations (BSs), which is mostly called the “ping-ponging” effect. The design parameter of the RAN shall take care of such effects are mitigated.

5.4 Others

5.4.1 Number of processes enabled in HARQ, Channel Quality Indicator, target block error rate etc shall be considered in design of LTE network.

6 LTE System design for Handover without Call Drops

6.1 The clauses below are suggestive to guide for designing an LTE system with smooth and seamless handovers. The bidder shall customize the parameters and techniques based on the network requirements and performance goals.

6.2 Handover Techniques:

6.2.1 **Inter-LTE Handover**: Utilize X2 interface for fast handovers between eNodeBs served by the same MME.

6.2.2 **Intra-LTE Handover**: Employ A3 and A5 handovers based on signal measurements by the User Equipment (UE).

6.3 Handover Criteria:

6.3.1 **Signal Strength**: Primarily based on Received Signal Strength (RSRP) and Received Signal Received Power (RSRQ).

6.3.2 **Mobility**: Consider cell reselection criteria with measurements of neighbor cells to predict future signal degradation.

6.3.3 **QoS Parameters**: Monitor Packet Delay, Jitter, and Packet Loss for maintaining service quality.

6.3.4 **Load Balancing**: Distribute UEs across cells to avoid congestion and improve overall network performance.

6.4 Pre-Handover Detections:

6.4.1 UE measures neighboring cell RSRP, RSRQ, and interference levels.

6.4.2 eNodeB monitors UE signal strength, mobility, and resource utilization.

6.4.3 MME (Mobility Management Entity) tracks UE location and service requirements.

6.5 Important Handover Parameters:*

6.5.1 Hysteresis: Margin between serving and target cell signal before triggering handover.

6.5.2 A2 Threshold: Minimum acceptable RSRP value for the serving cell.

6.5.3 Time-to-Trigger (TTT): Duration for which a threshold violation persists before triggering handover.

6.5.4 Cell reselection parameters Including frequency reuse offset and selection probability.

6.5.5 Event Triggered for Handover: RSRP of serving cell falls below A2 threshold and remains below for TTT duration.

THRESHOLD CALCULATION FOR EVENT
ASSUMING: HYSTERESIS (HYS) = 3 dB A2 THRESHOLD = -105 dBm DESIRED RSRP IN TARGET CELL = -95 dBm $Threshold\ for\ Event = A2\ threshold + Hysteresis - Desired\ RSRP$ = -105 + 3 - (-95) = -13 dBm THIS MEANS IF THE SERVING CELL RSRP FALLS BELOW $-13\ dBm$ AND REMAINS THERE FOR TTT, A HANDOVER WILL BE TRIGGERED TO THE TARGET CELL WITH $-95\ dBm$ RSRP.

6.6 Additional Considerations:

6.6.1 Optimize handover parameters based on network load, mobility patterns, and service requirements.

6.6.2 Implement advanced handover algorithms like cell load balancing and soft handovers for smoother transitions.

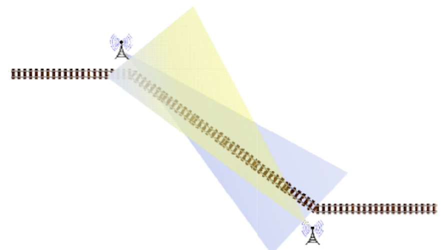
6.6.3 Preferably utilize machine learning or AI to dynamically adjust handover thresholds based on real-time network conditions.

7 Geographical conditions

7.1.1 The following geographical conditions are predominantly available on Indian Railways and shall be taken care of while evaluating path loss.

7.2 Curves

7.2.1 At large curves, it is preferable to install the towers on the start of the curve for proper coverage.



7.3 Water bodies

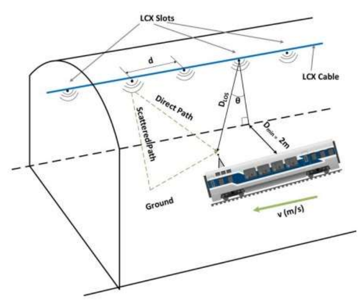
7.3.1 COST 231-Hata propagation model or equivalent which is optimized for evaluating path loss prediction near water bodies shall be used.

7.4 Long bridges

7.4.1 The path loss predication model shall consider the attenuation due to metallic structures of the bridge and river in such cases.

7.5 Tunnels

7.5.1 Leaky Coaxial Cables (LCXs) shall be used to provide a uniform signal coverage inside the main and rescue tunnels.



7.5.2 Inside Tunnel, RF communication shall be as per RDSO specification No. RDSO/SPN/TC/109/2023 dated 29.3.2023 or latest. Scheme & Layout of Tunnel coverage shall be submitted for Purchaser's railway approval before implementation.

7.6 Stations,Platforms, Marshalling yards and shed

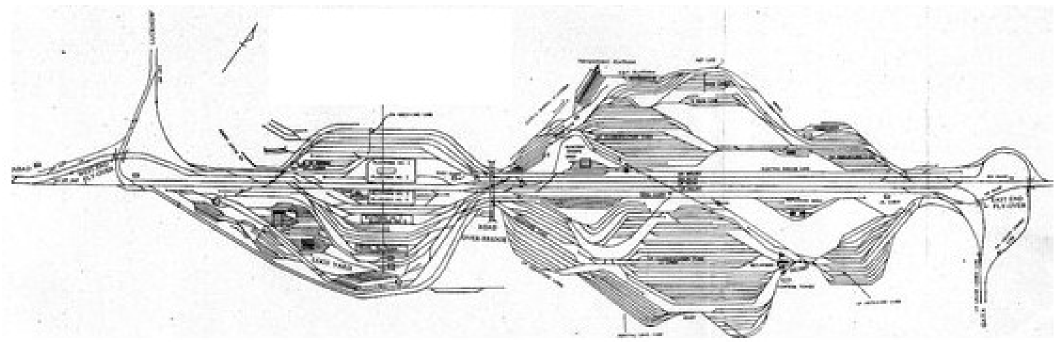
7.6.1 A railway station usually has awnings with 0.4-0.8 km long, 0.1-0.5 km wide, and 10-80 m high.

7.6.2 Diverse take offs, broad marshalling yards and

train depots/sheds are important characteristics need to be taken care in design.

7.6.3 The path loss propagation model shall be thoroughly evaluated at every portion of the yard and multiple tower locations shall be planned.

7.6.4 In building solution can be catered for station buildings and on platforms for better coverage.



7.7 Dense Urban/ Urban/Suburban/Rural

7.7.1 Type of urbanization shall be considered while evaluating the path loss to determine the location of towers.

7.8 Vegetation

7.8.1 When placing the base station in the dense vegetation territory it is recommended to use a Generic model, One Woodland Terminal, Ray Tracing and Knife-edge models or equivalent to evaluate path loss.

7.9 Hilly terrain

7.9.1 When the railway track passes through vast area of hilly terrain, the fading characteristics and loss of line of sight shall be studied before finalizing the location of towers and their heights.

7.10 Valley or cutting terrain

7.10.1 The cuttings have steep walls on both sides of the track.

7.10.2 The path loss predication model shall consider the fact that the rail roof top antenna is located at much lower height than the banks.

8 Performance Requirements:

8.1 The following are the suggestive performance requirements for LTE system design

8.1.1 RSRP: $\geq -100\, dB$. RSRP based results and comparison (for the range -100 to -90 dBm) shall be submitted.

8.1.2 SINR:$\geq 13\; dB$

8.1.3 RSRQ: $\geq -15\; dB$

8.1.4 Channel Quality Indicator (CQI): $QPSK\colon 1 \leq CQI \leq 6,\;\; 7 \leq CQI \leq 9,\;\; 10 \leq CQI \leq 15$. It shall be ensured that block error rate shall be less than 10%. CQI vs. MAC downlink throughput results and CQI vs. RS SNR results shall be submitted.

8.1.5 Impact of high speed on LTE downlink and uplink data rates in steps of 10 kmph for speeds above 80 kmph to the section speed shall be submitted. These tests shall be conducted near the cell and far the cell.

8.1.6 Practical throughputs and theoretical limits shall be compared.

8.1.7 Results and comparison for the timing advance range 0 to 20.

8.1.8 Results and comparison for RSRP versus RS SNR shall be performed for all category of environments listed in clause 7.

8.1.9 Results and comparison when Air Plane Mode on or off tests at near the cell and far the cell.

8.1.10 Results and comparison for Speed test at near the cell and far the cell.

8.1.11 Results and comparison for Ping 32 bytes 100 iterations per ping near the cell and far the cell.

8.1.12 Results and comparison for *Out of Service* to *In Service* at near the cell and far the cell.

8.1.13 Single Cell Functional test reports shall be carried out for each cell.

Annexure

#	Bandwidth requirement (kbps)	Limit	Rural	Sub Urban	Urban	Dense Urban
	UPLINK	**Application limit (kbps)**	**(2 lines + 1 line for future expansion)**	**(3 lines + 1 line for future expansion)**	**(4 lines + 1 Line for future expansion)**	**(>6 lines + 20 Line for Marshalling yard), Trains at Cell Edge**
		Trains at Cell Edge	**7**	**12**	**20**	**40**
1	Kavach Signalling	20	140	240	400	800
2	MCX – Voice Call (Assumption : 2 MCX Voice Call per Train i.e. Cab Radio of Loco Pilot and MC PTT Handset of Guard)	20	280	160	800	1600
(A)	**Cell Edge Throughput for Emergency operational Requirement : (1 - 2) (kbps)**		**420**	**400**	**1200**	**2400**
3	MCX-Video Call @25%	140	245	735	3675	1400
4	EoTT (in all Trains)	25	175	300	500	1000
5	DPWCS (mimimum 1/3 Train)	25	59	100	167	334
(B)	**Operational Requirement : (1 - 5) (kbps)**		**899**	**1535**	**5542**	**5134**
	Desired Services (Uplink)					
6	Passenger information display system (Kbps)	20	140	240	400	800
7	IoT services (Kbps) (for Trains only) and faults at the rate of 2%	1000	140	240	400	800
8	*On Board Video Surveillance (minimum eight Camera per coach and 24 coaches for each passenger Train at 66% and probability of emergency at 2%) (Kbps)	359	2513	4308	7180	14360
(C)	**Desired Services (6-8) (kbps)**		**2793**	**4788**	**7980**	**15960**
(D)	**All Services (B+C) (kbps)**		**3692**	**6323**	**13522**	**21094**
	Bandwidth requirement (kbps)		**Rural**	**Sub Urban**	**Urban**	**Dense Urban**

Annexure

	DOWNLINK	**Application limit (kbps)**	**(2 lines + 1 line for future expansion)**	**(3 lines + 1 line for future expansion)**	**(4 lines + 1 Line for future expansion)**	**(>6 lines + 20 Line for Marshalling yard), Trains at Cell Edge**
		Trains at Cell Edge	**7**	**12**	**20**	**40**
1	Kavach Signalling	20	140	240	400	800
2	MCX – Voice Call (Assumption : 2 MCX Voice Call per Train i.e. Cab Radio of Loco Pilot and MC PTT Handset of Guard)	20	280	480	800	1600
3	Level Crossing Gate Monitoring CCTV Camera (Assumption 2 Cameras per LC Gate and 140 kbps per Camera) and one cell in each sector	280	1960	1960	1960	1960
(E)	**Down link Cell Edge Throughput for Emergency Operational Requirement : (1 - 3) (kbps)**		**2380**	**2680**	**3160**	**4360**
4	MCX-Video Call (calls at 25%)	140	245	420	700	1400
5	EoTT (in all Trains)	25	175	300	500	1000
6	DPWCS (mimimum 1/3 Train)	25	59	100	167	334
(F)	**Down link Operational Requirement including all services (kbps) (1 - 6)**		**2859**	**3500**	**4527**	**7094**