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2					
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GUVERNUL ROMÂNIEI
ROMANIAN GOVERNMENT

PROJECT FINANTAT DE UNIUNEA EUROPEAN Â
EUROPIAN UNION FINANCED PROJECT

C.N.C.F. "C.F.R."- S.A.

CLIENT / CLIENT

ITALFERR
GRUPPO FERROVIE DELLO STATO

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Aprobat Approved	Responsabil GSM-R GSM-R Responsible	G. Clemenza	07-12-2011	
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Reabilitarea liniei de cale ferăta Braşov - Simeria, parte componentă a coridorului IV Pan European, pentru circulatia trenurilor cu viteza maxima de 160 km/h,

Sectiunea : Brasov-Sighisoara

Rehabilitation of the railway line Brasov – Simeria, component part of the IV Pan-European Corridor, for the trains circulation with maximum speed of 160 km/h.

Section : Brasov-Sighisoara

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Functional Specification for GSM-R

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1.1. GLOSSARY

AC	Alternative Current
ACK	Acknowledge Centre
ARFCN	Absolute Radio Frequency Channel Number
ASCI	Advanced Speech Call Items
BSC	Base Station Controller
BSS	Base Station Subsystem
BTS	Base Transmission Station
DC	Direct Current
EIRENE	European Integrated Railway Radio Enhanced Network
EN	European standard
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FRS	Functional Requirement Specification
GMSK	Gaussian Minimum Shift Keying
GSM-R	Global System for Mobile communication – Railway
HLR	Home Location Register
IEC	International Electro-technical Commission
IEE	Institution of Electrical Engineers
IN	Intelligent Network
IP	Internet Protocol
LAN	Local Area Network
LCT	Local Craft Terminal
LDA	Location Dependent Addressing
LSR	Label Switching Router
LER	Label Edge Router
KPI	Key Performance Indicators
MORANE	Mobile Radio for railway Networks in Europe
MPLS	Multi Protocol Label Switching
MSC	Mobile services Switching Centre
MTBF	Mean Time Between Failures
NMS	Network Management System
NOCC	Network Operation Control Centre
NSS	Network Switching Subsystem
OCC	Operation Control Centre
OMC	Operation and Maintenance Centre

PCM	Pulse Code Modulation
PAS	Public Address System
RAM	Reliability, Availability, Maintainability
RAMS	Reliability, Availability, Maintainability, Safety
SDH	Synchronous Data Hierarchy
SMS	Short Message Service
SRS	System Requirement Specification
TCU	Transcoding Unit
TDMA	Time Division Multiple Access
TSI	Tecnical Specifications for Interoperability
UIC	International Union of Railways
UPS	Uninterruptible Power Supply
VAS	Value Added Services
VLR	Visitor Location Register
WAN	Wide Area Network

1.2. ABSTRACT

In the contest of the European Union, Romania will play an important role in the context of the future trading and oil and gas pipelines from the Caspian Sea and Central Asia to South East Europe and Western Europe, therefore the Government of Romania is currently seeking to integrate the Pan European Corridor IV in Romania into the European Railway Network.

In this document there is a technical project for the subsection of Corridor IV: Brasov-Simeria- line.

The total length of the railway line, from Brasov-Simeria, is about 300 km, the Simeria station belong to the Timisoara Railway Junction area and Brasov station to Brasov Railway Junction area.

Line of Brasov-Simeria has been divided in three sections, the first section is Brasov-Sighisoara, the second section is Sighisoara-Coslariu and the third section is Coslariu-Simeria.

1.3. LINE SEGMENTATION

The following table shows the railway line design and its sections.

Railway line	Section Name	Location	Location
BRASOV-SIMERIA	Section 1	BRASOV	SIGHISOARA
	Section 2	SIGHISOARA	COSLARIU
	Section 3	COSLARIU	SIMERIA

Table 1 – Brasov-Simeria line segmentation

This document will deal the project of section 1 Sighisoara-Brasov; the following table shows the primaries stations:

Sighisoara-Brasov		
1	**Sighisoara**	Primary
2	**Albesti**	Primary
3	**Vanatori**	Primary
4	**Archita**	Primary
5	**Cata**	Primary
6	**Racos**	Primary
7	**Apata**	Primary
8	**Feldioara**	Primary
9	**Bod**	Primary
10	**Stupini**	Primary
11	**Brasov**	Primary

1.4. STANDARDS & REFERENCES

The following general standards shall be applied.

Ref	Reference	Document Name
[1]	A01T00041	MORANE ASCI Options for Interoperability
[2]	E10T6001 4	MORANE FFFS for Functional Addressing
[3]	F10T6001 4	MORANE FFFS for Location Dependent Addressing
[4]	F10T6002 4	MORANE FFFS for Confirmation of High Priority Calls
[5]	F10T6003 4	MORANE FFFS for Presentation of Functional Numbers to Called and Calling Parties
[6]	E12T6001 5	MORANE FIS for Functional Addressing
[7]	F12T6001 3	MORANE FIS for Location Dependent Addressing
[8]	F12T6002 4	FIS for Confirmation Of High Priority Calls
[9]	F12T6003 4	MORANE FIS for Presentation of Functional Numbers to Called and Calling Parties
[10]	H22T0012	MORANE Specification on Usage of the UUIE in the GSM-R Environment
[11]	ETSI EN 301 515	Global System for Mobile communication (GSM); Requirements for GSM operation on railways
[12]	PSA167D005-7	EIRENE Function Requirements Specification
[13]	PSA167D006-15	EIRENE System Requirements Specifications
[14]	A 11 T 60001 12	MORANE Radio Transmission FFFIS for Euroradio
[15]	UIC O-2475 3.0	ERTMS/GSM-R Quality of Service Test Specification
[16]	UNISIG Subset-093, Version 2.3.0	GSM-R Interfaces Class 1 Requirements,
[17]	P 38 T 9001 3	MORANE FFFIS for GSM-R SIM Cards specification
[18]	2002/95/EC	Directive RoHs 2002/95/EC (Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment)
[19]	1999/05/CE	Directive CE
[20]	EN 50121	Railway applications – Electromagnetic compatibility
[21]	EN 50125	Railway applications – Environmental conditions for equipment
[22]	EN 50126	Railway applications – The specification and demonstration of reliability, availability, maintainability and safety (RAMS)
[23]	EN 50128	Railway applications – Communication, signalling and processing systems – Software for railway control and protection systems
[24]	EN 50129	Railway applications – Communication, signalling and processing systems – Safety related electronic systems for signalling
[25]	EN 50155	Electronic Equipment used on Rolling Stock
[26]	EN 50159-1	Railway applications. Communication, signalling and processing systems. Safety related communication in closed transmission systems
[27]	EN 50159-2	Railway applications. Communication, signalling and processing systems. Safety related communication in open transmission systems
[28]	CNCF “CFR” SA	CFR GSM-R Beneficiary Requirements Version 3.4.4. – the 26th of October 2011
[29] [30]		EA5101C00TSSE00100020 Communication for Signalling technical specification EA5101C00TRSE0000002 Communication Signalling technical description
[31]	CNCF “CFR” SA	CFR Glosar GSM-R - Versiune 24t Ianuarie 2011
[32]	CNCF “CFR” SA	CFR Cerinţe Generale Beneficiar- Versiune 2.0.0 - 21 Decembrie 2011

Table 2 – General Standards

1.5. SUMMARY

Scope of this technical design is to supply a solution for the following systems for the section Sighisoara-Brasov:

- Railway Radio System (GSM-R);
- Backbone Transport Network.

The GSM-R and the Backbone Transport Network developed in this plan shall be fully integrated with other GSM-R network of Romanian Railway to guarantee a sure link for signalling system.

An Operational Control Centre (OCC) will need for supervision, monitoring, maintenance for all railway systems and in particular for GSM-R systems on the entire line Sighisoara - Brasov.

It will be provided an OCC for the entire line Sighisoara-Brasov and it will be located in BRASOV.

GSM-R installations in the OCC comprise mainly hardware and software of the core system for all applications.

2. RAILWAY RADIO SYSTEM GSM-R

2.1. INTRODUCTION

The railway radio system has to be in accordance with the GSM standard ETSI, which has been selected by the International Railway Organization (UIC) as part of the EIRENE program and which has been standardized by the group MORANE according to the EU directive UE 96/48/EC for the interoperability of European railways.

The GSM-R technology (Global System for Mobile Communications - Railway or GSM-Railway) is an international wireless communications standard for railway voice communications and data applications.

The international groups and entities involved in the GSM-R standardization are the following:

- **UIC** stands for Union Internationale des Chemins de Fer, or International Union of Railways. The UIC is the worldwide international organization of the railway sector.

- **EIRENE** stands for European Integrated Railway Radio Enhanced Network: EIRENE is a UIC-led project to develop the specifications for, and to facilitate the standardization of, the GSM-R railway radio communication system. These specifications are subject to changes that are tracked, managed and agreed by the UIC members. Today the latest versions of these specifications are the Functional Requirements Specification v7 (FRS v7) and the System Requirements Specification v15 (SRS v15).

- **MORANE** stands for Mobile Radio for railway Networks in Europe: the main purpose of the MORANE project, which ended in 2000, was to develop the GSM-R system in accordance with the EIRENE specifications and perform validation on three trial sites in France, Italy and Germany. The project's objectives have been attained, and implementation of GSM-R is currently underway in a number of European countries.

2.2. GENERAL REQUIREMENTS

Additionally to the GSM call scenarios, because of the high security requirements in railway operations, the GSM-R needs commercial proven solution as it requires high quality of service, faster call set-up and other features that are needs to fulfill all the operation sensitive requirements.

GSM-R system to be provided in Romania project requires tested and validated solution compliant with MORANE and EIRENE specifications defined by UIC.

GSM-R plan to be provided in Romania shall be compliant with Technical Specifications for interoperability TSI to allow free international railway traffic.

This plan must be complied with all requirements requested by document/annex *:"CFR GSM-R Beneficiary Requirements" Version 3.4.4. – the 26th of October 2011 [28];*
The Contractor must assure that all requirements of *:"CFR GSM-R Beneficiary Requirements" Version 3.4.4. – the 26th of October 2011 [28]* will be respected in its plan.
In case of mismatch between the present specification and the requirements provided by CFR, the CFR requirements will prevail.

In addition all requirements described below must be assured.
The following aspects shall be considered for the plan:

- Cost efficiency (i.e. power and traffic reduction)
- Operational efficiency (i.e. equipment size reduction)
- System Availability (i.e. level of system internally redundancy)
- Maintainability (i.e. spare part dimensioning)

The railway radio system shall be compliant to the EIRENE specification (SRS Version 15) and to functional requirements related to EIRENE (FRS Version 7).
The GSM-R project shall guarantee radio signalling services for ERTMS System Level 2 with redundancy of radio coverage and connection links.
The GSM-R system shall be scalable and easily extensible in order to address further improvement of the railway line.
The GSM-R system shall be based on the "state of art" of the GSM-R technology.
The supplier shall guarantee the operative and support during the operative of the system for at least 20 years after the commissioning.
The supplier shall guarantee the availability of spare parts for the GSM-R system for at least 20 years after the commissioning.
Contractor must preview sufficient spare parts to manage roll out of network and guarantee 10% of spare parts available for the Customer.

The GSM-R system shall be able to support the future evolution of the EIRENE standards (FRS v7 and SRS v15) trough a software upgrade without any hardware changing or swap.
The system shall be able to support integration with public and private external telephone network wired and wireless.

The proposed systems will have executed the interoperability tests (on the basis of EIRENE standards) with a GSM-R system manufactured by a different supplier, system which must fulfill "Commercial operation with ETCS level 2" and "Voice commercial operation" conditions. Entrepreneur will present the results of these tests inside bid.

The proposed system must be in commercial operation (at the date of bid submission) for an ETCS system of level 2 executed according to SRS 222 or further specifications, on a length (single, non-cumulated) of minimum 60 km in a railway system from European Union or Switzerland

The proposed system must be in commercial operation (at the date of bid submission) for voice transmissions on a cumulative length of minimum 1000 km in a railway system from European Union or Switzerland

The IOT tests will be realized with systems already in service in EU and/or in Switzerland;

The Contractor will provide the radio plan for CFR according to the License for the utilization of the radio frequencies and requirements of ANCOM.

Environmental conditions

- **Climatic conditions**

Outdoor emplacements

The outdoor equipments must be capable to operate in the following limit climatic conditions**:**

- Heavy rain, snow;
- Wind with speed up to 40 m/s;
- Temperatures: -35 ÷ +70°C.

Emplacements in external boards / containers

The following equipments will be placed in external boards or containers**:**

- BTS base stations;
- IP/MPLS network elements.

Locations for beneficiary operating personnel

The conditions for these locations must be identical with those for IDM control chambers, as it is described in the documentation for electronic centralization installations**.**

Earthquake conditions

All equipments must be designed and installed taking account of the area earthquake risks**.**

- **MECHANICAL DISTURBANCES**

GSM-R equipments (including those afferent to transport network) must be able to operate in vibratory conditions of 1,5 g**.**

- **ELECTRICAL CONDITIONS**

Electromagnetic disturbances

Environmental specific characteristics:

- approach to the railway with high voltage supply;
- radio transmissions;
- access limited to cable ducts and small relative distances between cables belonging to different systems.

Excepting cases in which there is provided in a different way, the environment must be considered “industrial” as it is defined in EN 50082-2.

From the electromagnetic influences point of view, the equipment must observe the following:

- Radiated emission – the equipment must fall between ETS 300386-1 and EN 55022 limits; this requirement applies to all equipment, including for supply and interconnection cables**.**
- Beam emission – the equipment must be approved according to ETS 300386-1 regarding beam emissions through all physical connections towards equipment**.**
- Sensitivity to electromagnetic radiations – the equipment must have the immunity level according to EN 50082-1 and IEC 801-3 level 2**.**
- The radiated flow density must not be greater than 10 mW/cm2, at 10 cm distance from equipment, when all doors are closed and all shielding are active**.**

Electrostatic discharges (ESD) sensitivity

From the electrostatic discharges (ESD) sensitivity point of view, the equipment must fulfil the specifications of EN 55101-2 and IEC 801-2 standards (level 2 or greater):

- The equipment must withstand without functionality deterioration at level 2 tests, not only for direct contract, but also for air discharge**.**
- The equipment must withstand without permanent damage at level 3 tests, not only for direct contract, but also for air discharge**.**
- These tests must be executed in accordance with IEC 801-2 and ITU-T K.32 recommendation.

Transient overvoltages protection

The equipment must withstand without permanent damage at transient overvoltages, as specified in IEC 801-4, 801-5 and 801-6 standards for level 2**.**

These overvoltages and overcurrents are considered to be applied at all inputs and outputs, excepting the internal connection via motherboard**.**

Personnel protection

Equipments must be protected according to specifications of EN 60950 and EN 41003 standards**.** The supplied equipments must not present any danger for personnel life or health. In this respect, the equipment must include efficient mechanisms/devices against dangerous voltages and lightning/lightning discharges**.**

Dangerous voltages must not appear on/in exterior parts of equipment that could be accidentally touched not only during normal operation, but also during disturbances**.**

The equipment must provide protection against indirect contacts**.**

All metal parts of CSG must be grounded**.**

The breakdown field strength of internal wirings towards mass, with printed plates taken out, must of minimum 500 Vef./50 Hz, during 1 minute**.**

The breakdown field strength of connection/line circuits terminals towards mass must be of minimum 1500 Vef./50 Hz**.**

The insulativity of wired terminals must be of minimum 100 MΩ in normal conditions.

Overvoltages and overcurrents protection

Equipments will operate in an “exposed environment”, as defined by ITU-T Recommendations from K series**.**

Protection to overvoltages due to lightning

The supplied equipments must be designed in such a way as to provide the protection at mass potential growth in case of lightning (lightning discharge), in accordance with ITU-T K.26 Recommendations**.**

The new installed poles will have own protection system against lightning (lightning discharge), including own ground outlet**.**

Induced voltages protection

Bided equipments must be designed in such a way as to provide protection against dangerous voltages that could appear inside the lines connected to it, by magnetic induction and/or resistive coupling, in accordance with ITU-T K.20**.**

Protection to direct contact with voltage sources

Equipments must withstand the tests defined by ITU-T Recommendation K.20, Table 1a (without any additional protection), Criterion B**.**

Telecommunication and electric energy supply cables must be easy to distinguish**.**

Earthing requirements

The Contractor will submit the mass and earth connection diagrams for equipments**.**

These diagrams must be executed in accordance with ITU-T Recommendations K.27 and K.31, as well as ETS 300253**.**

2.3. FUNCTIONAL & SYSTEM REQUIREMENTS

2.3.1. GSM-R SYSTEM AVAILABILITY

The availability of the GSM-R system must be clearly indicated due to its future possible use for Train Control Systems. The availability of every GSM-R subsystem shall be given.

The “mean time between failures” (MTBF) for all network elements and equipment shall be provided in answer at this project. A RAMS document is required to elaborate performance of system.

A detailed calculation of availability and its conformity with the requirements regarding availability must be included. These calculations will be based on a reference communication way for ETCS L2 which would include NSS, BSS and the transport network but it must be excluded the radio cab equipment. All used parameters, including the rates for hardware and software components failure, the coverage rates and other working hypotheses will be clearly specified and justified.

Concerning each service crucial for railway operations, the GSM-R system architecture shall assure a condition of No Single Point of Failure.

The main GSM-R system components (i.e. BSC, BTS) including associated equipment shall be redundant interconnected by the optical fiber backbone transmission network.

In case of a failure in one communication link, an automatic switch-over to a redundant link shall be performed, thus preventing a complete loss of communication.

For each equipment, the Contractor shall describe the automatic recovery procedure in case of faults of primary board and interface. The recovery times for each sub-system shall be given.

Wrong side failures shall not occur and irregular inputs shall not affect the failsafe operation of the system.

2.4. RADIO SPECTRUM

The available channels spectrum for the GSM-R system in railway radio system is below defined:

- 876MHz — 880MHz: uplink transmission from mobile radio to Base Transceiver Station (BTS).
- 921MHz — 925MHz: downlink transmission from Base Transceiver Station (BTS) to mobile radio.

As specified in the GSM standard, the frequency spacing between 2 consecutive radio frequency channels shall be 200kHz. Therefore 19 frequency channels are available to perform the GSM-R frequency planning.
Each frequency shall be uniquely identified by its Absolute Radio Frequency Channel Number (ARFCN) as illustrated below.

ARFCN number	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973
$F_{lower}(n)$, MHz	876,2	876,4	876,6	876,8	877,0	877,2	877,4	877,6	877,8	878,0	878,2	878,4	878,6	878,8	879,0	879,2	879,4	879,6	879,8
$F_{upper}(n)$, MHz	921,2	921,4	921,6	921,8	922,0	922,2	922,4	922,6	922,8	923,0	923,2	923,4	923,6	923,8	924,0	924,2	924,4	924,6	924,8

Table 3 – GSM-R frequency-carriers

The GSM-R radio physical layer shall be identical to the GSM physical layer and it shall address the following characteristics:

- Channel access: based on Time Division Multiple Access (TDMA) principle.

- Timeslot per frame: 8 consecutive timeslots sharing a same frequency and is sent over 4,615 milliseconds.
- Radio Modulation type: GMSK modulation (Gaussian Minimum Shift Keying).

2.5. GSM-R ARCHITECTURE

2.5.1. OVERALL SYSTEM ARCHITECTURE

The GSM-R network architecture is composed by the following main layers:

- **The Network Switching Sub System (NSS)**: it comprises the GSM-R switch, the Mobile Switching Centre (MSC) together with the Home Location Register (HLR) and Visitor Location Register (VLR). The Acknowledge Centre (ACK) and Intelligent Network (IN) are considered as part of NSS.
  The NSS is in charge of setting up the calls to and from mobile terminals, setting up the EIRENE services (dedicated to railway environments) to mobile terminals, providing adequate traffic channels in the core network for these calls and services, and managing the mobility and authentication of subscribers.

- **The Base Station Sub-System (BSS)**: is composed by Base Transceiver Station (BTS), Base Station Controller (BSC) and Transcoding Unit (TCU). The BSS is in charge of allocating and managing radio resources of the GSM-R terminals ensuring seamless handovers between cells.

- **The Operation and Maintenance Centre (OMC)**: allows for the configuration management, fault management and performance management and administration of the NSS and BSS subsystems;

- **The Value Added Services (VAS)**: will manage all the value added for the GSM-R network (like as SMS-C, Dispatcher server)

- **Mobiles stations**: handheld and cab radio terminals equipped with a SIM Card;

- **Controller Terminal**: this terminal offers calls initiation and reception functionality for IDM and traffic dispatcher at GSM-R mobile users, at the existing analogical radio systems users (for IDM) and from network external users.

The following figure shows a typical GSM-R network architecture:

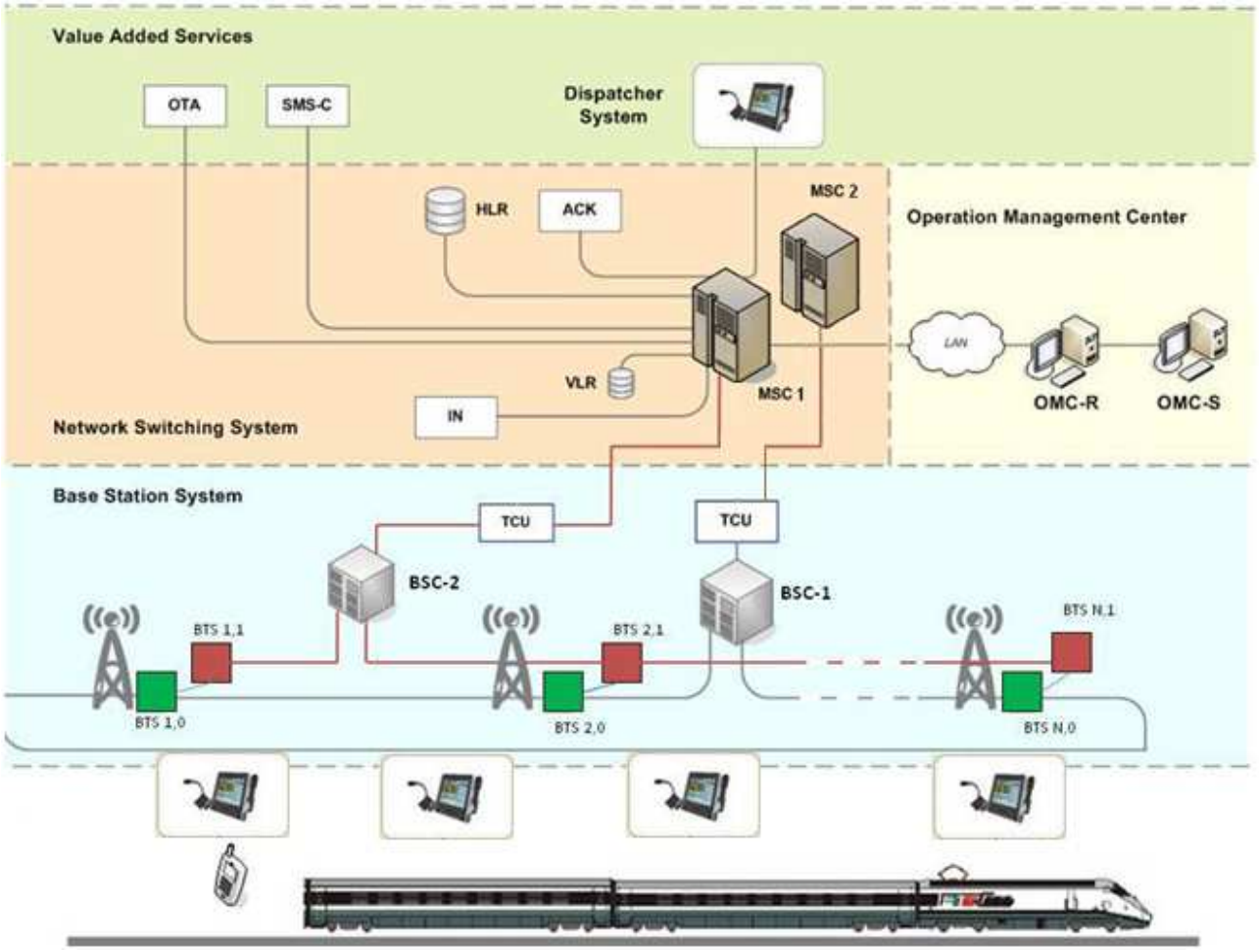

Figure 1: GSM-R system architecture

2.5.2. NETWORK SWITCHING SUB-SYSTEM (NSS)

The NSS provides the management of call switching and user mobility between GSM-R users camped in different BSS or between GSM-R users and external networks, following dedicated policies stored in HLR/VLR/EIR/GCR databases and Intelligent Network and VAS (Value Added Services) procedures .

In this project the NSS System and all Core Network are considered already supplied with another contract, but design and implementation of interface between NSS and BSS using the existing transport network are in charge of the constructor.

2.5.3. BASE STATION SUB-SYSTEM (BSS) ARCHITECTURE

The BSS subsystem is the part of the GSM-R in charge of providing radio coverage over a given geographical area as well as adequate traffic capacity. Its main roles are to provide a quality radio link to wireless users, whether it is engaged in a call in idle mode, and to send/receive the user traffic data and signaling to/from the NSS and Packet Core network.
The BSS system is made up of the following functional components:

- Any number of **Base Transceiver Stations (BTS),** in charge of periodically broadcasting system information to idle mobile users (including information about ongoing group calls happening within the cells that it manages), providing a permanent resources of access to the network to mobile users and maintaining a reliable radio link with the mobile subscribers engaged in voice calls and Circuit Services Data calls sessions.

- **Base Station Controller (BSC).** The BSC is in charge of managing the optimal allocation of radio resources of all the BTS under its responsibility, according to the radio resource allocation requests coming from the NSS.

- **Transcoding Unit (TCU).** This unit is responsible for converting the GSM coding schemes into 64kb/s G.711 coding scheme used in the fixed networks.

The following systems shall be interfaced to BSS to provide services to mobile users:

- The NSS, via the MSC. The interface between BSS and NSS is called the *A* interface, and it is an open (non-proprietary) interface.

- The OMC-R (Radio Operation and Maintenance Centre) sub system

The Configuration, Alarms Management and Performance functions must be described:

- the number and type of operations (mouse click, manual data entry into the system etc.) that must be executed and their durations in order to detect a malfunction of BTS TRX subsystem and to reset the system into operation and to erase all alarms (in this calculation, there will be considered that the replacement time of faulty cards is 0);

2.5.3.1. BASE TRANSCEIVER STATION (BTS)

The BTS shall be able to support both single cell and multi cell configuration. The proposed BTS shall be configurable for supply both omni and sectorized configuration.
Each BTS shall be supplied with a quantity of running TRX able to satisfy the traffic requirements in the station and along the line.
Each BTS shall support Traffic Channels in Full rate (FR) and Half rate (HR).
The proposed BTS shall supply a signal reception using a polarization diversity system.
Each BTS shall support TRX redundancy in hot standby configuration (in case of BTS with only 1 TRX working).
Access to the BTS must be possible from a central system (OMC-R) and locally for maintenance and management purposes.
A detailed description of the proposed BTS for the project or of alternative radiation systems such as distributed BTS is required to Contractor.

This description must include:

- Dimension of the Cabinet
- Maximum number of TRX/cabinet, TRx/Cell, TRx/antenna.
- Cables, links, multiplexer, etc. losses in dB.
- Maximum number of cells/cabinet
- MTBF of the different Network elements
- Describe the BTS' behaviour in case of a TRX breakdown
- Power consumption
- Emissive power
- Reception sensitivity

2.5.3.2. BASE STATION CONTROLLER (BSC)

The BSC is the central component in BSS system and acts as a concentrator for the links between Abis and Asub interfaces.
BSC system shall be scalable in order to assure further upgrade of traffic and of system architecture.

BSC features shall be based on following recommendations:

- The BSC shall support LAPD channels management on Abis interface
- The BSC shall support hierarchical cell structure.
- The BSC shall support Voice and data switch between MSC and BTS(s)

- The BSC shall support Clock synchronization and distribution over radio access network
- The BSC shall support control, operation and maintenance functions (for example software download) of entire BSS system.

An easy system upgrade shall be provided via SW download procedures and either line interfaces or BTS (s) shall be added without any traffic interruption.
The BSC shall assure a no single point of failure condition providing a redundancy 1+1 for all the main boards (boards directly active in the radio services) and at least n+1 for the secondary boards.

The Contractor shall provide a detailed BSC performance description. This description must include:

- Dimensions of equipment
- Power consumption
- MTBF of different structures
- Maximum Number of TRX/BTS,
- Maximum Number of cells/BTS,
- Maximum Number of BTS/BSC,
- Maximum Number of connections (A/Abis)
- Maximum Number of LAPD connections.

BSC must be dimensioned to supply adequate service to all BTS of entire line Brasov – Sighisoara.
The required GSM-R architecture is dual layer type, including two BSC that will be installed in Brasov OCC.
In case of compatibility with other BSS already in charge of CFR the constructor shall evaluate a solution for the optimization of the equipments

2.5.3.3. TCU (TRANSCODING UNIT)

Transcoding Unit (TCU) system shall be scalable in order to assure further upgrade of traffic and of system architecture.
For each traffic channel the TCU adapts the different transmission rates for speech and data calls on the radio side to the PCM 64 Kbit/s transmission rate on the MSC side. It also performs transcoding functions between the different speech coding algorithms used on the radio interface (full rate, half rate, enhanced full rate) and the interface (PCMA or μ law G.711) used within the terrestrial network.

The TCU shall support Redundancy of all the main boards and it shall be internally redounded (Boards, processors, interfaces) in order to provide No Single Point of Failure
The TCU shall support E1/T1 for Asub interface with BSC.
An optimum TCU capacity shall be proposed and described by vendor.

Maintaining all requirements and features detailed in this documentation, TCU and BSC integration in the same physical equipment should be proposed; explanation about benefit and restriction of the choice shall be given.

A detailed TCU performance description must be provided. This description must include:

- Dimensions of equipment
- Power consumption
- MTBF of different structures

TCU must be dimensioned to supply adequate service to all BTS of entire line Brasov – Sighisoara.

2.5.4. RADIO OPERATION AND MAINTENANCE CENTRE (OMC-R)

With the plan of sections 2 and 3 Simeria - Coslariu – Sighisoara an OMC-R (Radio Operation and Maintenance Centre) has been provided as element manager for the GSM-R Radio Access nodes.

In this project, the BSS systems will be implemented by an OMC-R located in Brasov and a client in the same place for maintenance operation.

The OMC-R client shall be able to perform all services of OMC-R.

Trough the OMC-R shall be possible to set all radio parameters of the connected BTS.

The OMC-R shall consist of an application providing the network operator with efficient, user-friendly tools for planning operating and maintaining a cellular network with high quality of service.

The Contractor shall provide a product description of the BSS management platform suitable for GSM-R. The information shall contain, as a minimum:

– System Layout

– Interface specifications

– Database

– Network elements Configuration Management

– Alarm management

– Performance reporting

– Capacity (Database, User, Terminals)

– Platform, on which the system is based

– Physical characteristics (size, weight, power, etc.)

– Radio parameters

– Locating information (IMSI, IMEI)

The Subscriber management system shall be described.

The storage, recovery, manipulation and data replay methods must be described.

The OMC-R shall provide an user-friendly Graphical User Interface (GUI) based interface for its application.

The ability to display network elements on a geographical map shall be supported.

An efficient way to filter alarms and extract events of the network shall be provided.

The Contractor shall provide a solution for post-processing activities in order to evaluate the network performances (KPI); graphical or numerical format of the post-processing result shall be available.

It shall be possible to define thresholds for network performance counters in order to generate alarms when the required network quality factors are not met.

There must exist the possibility to collect data concerning the following performance indicators:
- traffic inside system (including signalling), Erlang, at TRX, cell and BSC levels;
- quality of provided services (delay at recall, quality at the level of customer);
- system's availability;
- successful and unsuccessful sessions for allocation of traffic channel at the level of cell;
- average time for channel usage, at the level of cell;
- number of rejected calls at the level of cell, including the rejection code.

All of data raised must be processed by a Post Analysis System.

The OMC-R and the Post Analysis System must be interfaced with the upper level NMS System.

2.5.5. NETWORK MANAGEMENTS SYSTEM (NMS)

The network management systems shall provide management functionalities for failures, configuration, performance and security for GSM-R radio network, "Controller Terminal" subsystem and IP/MPLS transport network.

NMS shall comprises all functions and systems necessary for operation and centralized management of network.

NMS shall provide the fulfillment of the following functions:

- network operation and management;
- alarms management;
- system supervision.

NMS description shall include the description of all functions and systems as well as the description of software and hardware necessary for their fulfillment.

2.5.5.1 NMS NETWORK CONFIGURATION

The management for configuration execution shall include the system parameters and information management from software and hardware databases.

The system's execution shall be made starting from a database. This database shall include each network element and must collect its real status.

The NMS of pilot system works like umbrella system (NMS upper level); then NMS of this project must be connected directly to NMS umbrella (NMS of pilot system) and must be assured full compatibility and interfacing.

Must be provided equipments compatible with the used software with in NMS of pilot system .

The Contractor must assure interfaces towards several NMS systems of CFR.

2.5.5.2 NMS PERFORMANCE MANAGEMENT

This function refers to the global quality of network as well as to traffic monitoring.

Shall be proposed an effective tool for network quality and traffic monitoring. This tool shall permit by settings the estimation of network functionality, users and services at pre-established hours and for desired time periods. Also, it shall show the network loading peaks and a prediction function and it shall permit the system adjustment.

Shall be possible to exporting data in "CSV" format.

The following data shall be available:

- traffic channels connections;
- hangover time of traffic channels (in percents);
- number of lost connections;
- SDCCH availability and occupation;

- number of “handover”;
- number of switching between cells;
- percentage of successful/unsuccessful switching between cells;
- number of connections;
- call-back times;
- connections duration;
- connections start – end;
- connection time (MOC, MOT, etc.);
- channel occupation;
- causes for connection interruption;
- average time for connection occupation;
- number and motifs of calls loss;
- identification of traffic peaks;
- number of occupied channels during traffic peak;
- data transmission speed;
- causes of digital errors;
- percentage of traffic channel loss;
- loading of traffic channels;
- loading of signalling channels;
- number of switching instructions given to mobile equipment;
- number of switching caused by the low quality of reception or emission;
- the traffic loading on each channel and for the entire system must be graphically presented as time function.

2.5.5.3 NMS ALARMS MANAGEMENT

To guarantee the complete monitoring of all alarms shall be foresee a network status analyzing and alarms indication resolution.

Repeated errors shall be highlighted in order to be taken measures for their correction. Alarms shall be classified according to their priority.

All alarms and malfunctions shall be transmitted from the network elements to management, where they will be processed and classified.

To manage the delays in data transmission, the analysis shall be made in real time as far as possible, delays greater than 15 seconds are not allowed.

Each alarm shall be optically and acoustically indicated.

Network management system shall include GSM-R network management systems.

The network management systems shall provide a management functionalities for failures, configuration, performance and security for GSM-R radio network, "Controller Terminal" subsystem and IP/MPLS transport network.

2.5.6. CONTROLLER TERMINAL SUBSYSTEM CTS

This subsystem will offer calls initiation and reception functionality for IDM and traffic dispatcher at GSM-R mobile users, at the existing analogical radio systems users (for IDM) and from network external users (RC connections, free pass communications between stations). These networks will be built on independent connections, existing the possibility that they would simultaneously operate, but they will not be interconnected.

The terminal equipment will mandatory have "hands free" and a viewing and memorizing system of received calls. From dispatcher it will have implemented the conference function with subordinate stations.

CTS equipment will be interconnected with MSC in order to offer an integrated communication system

The traffic safety communications will not be switched in order to operate in case of MSC failure. RC wire and free passes will not be transmitted by GSM-R but only by fiber optic network.

All systems plus GSM-R will be connected at this controller terminal (CTS) whose interface must be a LCD device.

GSM-R system must provide the communications between IDM, engine drivers, field teams equipped with mobile terminals, RC operators as well as any other personnel equipped with mobile terminals.

A CTS for each station and maintenance point at least shall be provided.

The CTS functions must be integrated in the Safety telephone system described in the "Communication for Signaling" technical specification [29].

2.6. SPECIFIC REQUIREMENTS

The GSM-R system must comply with all GSM-R specific requirements according to EIRENE Function Requirement Specification and System Requirement Specification.

The services specified by ETSI GSM phase 2+ recommendations from the base for an interoperable solution. ASCI ("Advanced Speech Call Items") services, as they are defined by ETSI GSM phase 2+, are required in GSM-R network.

The physical/electrical characteristics of digital interfaces will comply with applicable international standards group, which will include, but it is not limited at the latest versions of ITU-R and ITU-T recommendations.

Contractor must submit a conformity declaration with ETSI 3GPP effective standards.

The GSM-R system must support ITU SS7 standard protocol.

The GSM-R system shall be represent the bearer service for train on-board intercom calls.

To meet the functionality and performance requirements of the project, the following GSM-R system services shall provided:

- Call related services advanced call handling, such as call hold, call transfer, call queuing
- Barring incoming or outgoing calls
- Charging information
- Closed user group
- Multi-level priority and pre-emption
- Data bearer service for automatic fax
- Data bearer service for general data applications
- Data bearer for text messaging services
- A multiple driver communications within the same train functionality
- All specific persons depending upon user location functionality
- Operational emergency calls functionality
- Specific mode for shunting operations providing a link assurance signal functionality
- Automatic mobile network management functionality
- Control over system configuration functionality
- Display of functional identity of calling/called party functionality
- Fast and guaranteed call set-up
- Set-up of urgent or frequent calls through single keystroke or similar functionality
- Multi-Party voice call functionality
- Access matrix functionality as specified in EIRENE documentation
- Functional numbering:

Bidder must specify the manner in which this functionality is accomplished in the proposed GSM-R network. Mandatory calling situations:

- Engine driver – engine driver;
- IDM – engine driver;
- Train ticket collector – engine driver;
- Shunting calls (it will be specified together with Entrepreneur in a subsequent phase);
- Train ticket collector – yard master;
- CFR personnel from train – CFR personnel from train;
- Maintenance personnel – maintenance personnel/train ticket collector.

The network must support **point-to-point** and **point-multipoint** transmission of text messages from the fixed terminals by mobile users

The requirements regarding “end-to-end” calls initiation performance are the following**:**

- Railway emergency calls: < 2s (this calls initiation time refers to the start of radio signal, part of “Stage 1: Alert”);
- Group calls between engine drivers from the same area: < 5s;
- All mobile-to-fixed operational calls uncovered by previous cases: < 5s;
- All fixed-to-mobile operational calls uncovered by previous cases: < 7s;
- All mobile-to-mobile operational calls uncovered by previous cases: < 10 s;
- All low priority calls: < 10s.

Radio cab

If pre-emption takes place, an indication to parties must be transmitted**.**

DSD alarm call/message must deliver information regarding location**.**

Operational radio equipment

The radio equipment must include a man-machine interface (MMI) with the following components**:**

- display;
- control panel;
- speaker;
- microphone.

MMI must be adequate for usage not only during daytime but also night time**.**

Four buttons for manipulation of stored numbers must be offered.

If the network service is no longer available, a radio signal to user will be sent**.**

Controller equipment specifications

Man-machine interface of primary controller equipment must offer the following functionalities:

- Puts in queue all received calls and call requests.

- Displays the queue in order to be viewed by controller, indicating the functional identity and appellants priority. High priority calls must be identified and submitted at the beginning of queue.
- Permits the controller to select the received calls positioned by the system inside the current queue.
- Permits the controller to establish an Emergency, public emergency or railway operational priority Call with any mobile terminal through selection on billposter.
- Permits the controller to establish, to close, to enter or to leave group calls (with Railway Emergency, Public Emergency or railway operational priority).
- Permits the transmission and receiving of text messages.

For post-incident analyses, the controller equipment must permit the recording of all voice operational calls or data transmissions**.**

Subscriber management

Railways could use different types of restrictions as an additional security measure. These facilities can be particularly important when public access inside radio system network is offered (for example, in order to prevent the public to call engine drivers or engine drivers to call passengers)**.**
Radio cab equipments must also be members of working group along the railway**.**
If necessary, additional restrictions for access matrix may be imposed**.**

Functional numbering and location dependent addressing

The functional addressing diagram must permit calls to be directed from one controller to an international train from the control area, without using another EIRENE system excepting the system that serves the respective international train**.**
There must be possible for the system to prevent certain categories of users to record functional numbers it is not allowed to use, for example**:**

- train number;
- engine driver;
- shunting team leader.

Text messaging

There must be possible the transfer of text messages between ground operators and mobile operators by means of EIRENE system**.**
The propagation time for each segment of message must be lower than 30 seconds for 95% of messages**.**

The system shall be able to support possible system upgrade to GPRS functionalities; the supplier shall provide information about its GPRS solution.

The Main voice call services to be supported by the solution shall be the follows:

- Normal Point to Point calls
- Multi party calls
- On train Staff – Train Controllers (LDA and eLDA)
- Train Controllers – On Train Staff (FN)
- On train Staff – On Train Staff (FN)
- Train Controllers – Shunting Leader (FN)
- Group communication
  - REC
  - Shunting communication (to be specified together with the Customer)
  - Train drivers plus Train Controllers
  - Maintenance groups
- Calls to/from dispatcher (PtP)
- Calls to/from train driver (PtP).

The Main Data call services to be supported by the solution shall be the follows:

- Text message bearer service
- Bearer service for general data applications
- Bearer service for automatic fax.

The GSM-R Network shall support following GSM-R Circuit data services complying with EIRENE specification: 2.4, 4.8, 9.6 Kbps transparent and non-transparent.

The Main call-related services to be supported by the solution shall be the follows:

- Closed user group
- Multi-level priority and pre-emption
- Advanced call handling, such as call hold, call transfer, call queuing etc.
- Auto answer service
- Barring incoming or outgoing calls
- Call supervisory indications

– Charging information

The Main Railroad specific features to be supported by the solution shall be the follows:

– Set-up of urgent or frequent calls through single keystroke or similar
– Display of functional identity of calling/called party , CLIP and COLP
– Fast and guaranteed call set-up
– Seamless communication support for train speeds up to 500 km/h
– Automatic and manual test modes with fault indications
– Automatic mobile network management
– Control over system configuration

ASCI calls shall be settable either as Half Rate or Full Rate/Enhanced Full Rate calls selecting the required channel on the Air-Interface.

With Half Rate up to 16 different group calls with an unlimited number of listeners can be handled by one carrier (frequency)

ASCI features where calls shall be settable up either as Half Rate or Full Rate/Enhanced Full Rate calls selecting the required channel on the Air-Interface should be described.

The preferred channel type should be definable for each Group Call Reference in the Group with reference from other GSM-R networks in operation.

The Location Dependent Addressing (LDA and e-DLA) feature shall be provided as specified in the Eirene/Morane standard. The Mandatory call cases where LDA and eLDA shall be applied are:

– Train driver – Primary Train Controller
– Train driver – Other Train Controllers
–

The proposed LDA and eLDA solution must be already in operation in a railway system from European Union or Switzerland.

The eLDA solution proposed in this document is based on external server application. The external server will provide an interface with the nation traffic management system (IRIS) in order to receive information concerning the position and the direction of the train during the call addressing of driver, or other mobile user, call associated to that train.
This external server must be part of NSS and supplied from the Pilot Project contractor.
The Contractor will plan eLDA margins according to jurisdiction’s intervals represented in each signalling sketch.

It is necessary to result at least:

- manufacturer;
- release;
- soft version;
- the infrastructure manager that uses ETCS system of level 2 that operates on the basis of GSM-R system;
- the distance on which GSM-R system is implemented.

The solution must comply with FRS 4.0 and IRS 5.0.

It shall be possible to call any operative personnel using a Function Number (FN) as defined in EIRENE number plan instead of using a MSISDN

For certain functions, standardised short codes shall be implemented for mobile originating calls. The tender shall specify how this functionality is achieved in the GSM-R network proposed.

– The call cases where the FN feature shall be provided are the following:
– Train Driver – Train Driver
– Train Controller – Train Driver
– Shunting calls (to be specified together with the vendor in a later stage):
– Train Controller – Shunting leader
– On train staff – On train Staff
– Maintenance staff – Maintenance staff/Train controller
– It shall be possible to configure expiry times in order for registered users (forgetting to de-register) to automatically be de-registered after a certain (configurable) period of time. This triggered event shall be indicated to the end user being deregistered.
– It shall be possible to allocate Voice Mail Service to functional numbers.

As described in EIRENE the functionality of Railway Emergency Calling (REC) shall comply. Priority and short call setup times shall be in accordance to the standard values given in EIRENE.

As described in EIRENE the functionality of Shunting Emergency Calling shall comply. Priority (eMLPP) and short call setup times shall be in accordance to the standard values given in EIRENE.

The call features Voice Group Call Services and Voice Broadcast Service shall be usable for Group communication. The vendor shall specify the minimum and maximum number of cell to be set in a Group area

VGCS Muting and Unmuting DTMF tones shall be supported as specified by EIRENE.

The call cases where the VGCS feature shall be provided are the following:

- Controllers - Train Drivers
- Train Drivers - Train Drivers and Controllers.
- Operational groups, such as e.g. track works groups, switchmen etc.
- Shunting group calls, including the Link Assurance Signal according to the EIRENE specification (to be specified together with the customer in a later stage)
- Line side workers – Train Drivers in the GCA.
- Between train staff on the same train without interfering neighbouring train staff.

Contractor shall comply with and describe the solution for each call case above.

The Contractor shall offer pre-emption and precedence service for high priority calls, such as Railway Emergency Calls, in case of congestion on the radio channel as detailed in EIRENE.

Further, the system shall allow for implementation of barring of certain calling combinations, such as calls from outside the GSM-R system to train drivers and vice versa. To allow complete flexibility in the system GSM standard Call Barring and Operator Determined Barring shall be provided in accordance with EIRENE specification. The vendor shall include authorisation of calls based on Functional Numbers.

The numbering plan for such calls shall follow the EIRENE specification and use interfaces set by general standards of such networks.

The numbering plan of the system shall be according to EIRENE specification and allow for easy configuration and management.

Call setup times shall comply with the EIRENE specification.

2.6.1 STANDARD COMPLIANCE

The wireless communications network is formed by the digital GSM-R radio system. This radio network will be used as a radio system for Railroad operations as well as a means for transmission of data related to automatic train control as part of railway system.

The GSM-R system to be built in this project shall comply with the EIRENE specifications. EIRENE specifies the functional requirements for a digital radio standard for the Railroads.

The proposed GSM-R system must be compliant with following specifications and standards:

- A01T00041 MORANE ASCI Options for Interoperability
- E10T6001 4 MORANE FFFS for Functional Addressing
- F10T6001 4 MORANE FFFS for Location Dependent Addressing
- F10T6002 4 MORANE FFFS for Confirmation of High Priority Calls
- F10T6003 4 MORANE FFFS for Presentation of Functional Numbers to Called and Calling Parties
- E12T6001 5 MORANE FIS for Functional Addressing
- F12T6001 3 MORANE FIS for Location Dependent Addressing
- F12T6002 4 FIS for Confirmation Of High Priority Calls
- F12T6003 4 MORANE FIS for Presentation of Functional Numbers to Called and Calling Parties
- H22T0012 MORANE Specification on Usage of the UUIE in the GSM-R Environment
- ETSI EN 301 515 Global System for Mobile communication (GSM); Requirements for GSM operation on railways
- EIRENE Function Requirements Specification (version 7.0 - PSA167D005-7)
- EIRENE System Requirements Specifications (version 15.0 - PSA167D006-15)
- MORANE P 38 T 9001 3 FFFIS for GSM-R SIM Cards specification
- Directive RoHs 2002/95/EC (Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment)
- Railway Applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) EN 50126

- Railway Applications - Communications, signalling and processing Systems - Software for railway control and protection systems EN 50128
- Railway applications. Communication, signalling and processing systems. Safety related electronic systems for signalling EN 50129
- Railway applications. Communication, signalling and processing systems. Safety related communication in closed transmission systems EN 50159-1
- Railway applications. Communication, signalling and processing systems. Safety related communication in open transmission systems EN 50159-2

3 GSM-R BSS PLANNING

3.1 RADIO COVERAGE DESIGN

The radio system shall cover the following areas:

- Along the tracks
- In the stations
- Inside the tunnels

As required by Customer, the BSS architecture previews GSM-R sites in the main stations and eventually along the tracks.

Each site shall have two Base Stations (BTS) which will be connected to a different antenna system on the same tower.

First antenna system in mounted on the top of the tower; the second antenna system is situated under the first one at the correct distance to avoid decoupling problems.

The BTS and others devices of GSM-R site will be installed in a dedicated cabin (shelter) or control rooms with signalling devices in station site; in case of site along the tracks BTS and others devices of GSM-R site will be installed in a dedicated cabin (shelter) .

For each site GSM-R, the two BTS shall be configured in two different chain and linked to corresponding BSC, (Abis Interface) using a ring backbone transport network.

A different power supply system must be planned for each BTS.

The BSS architecture of the railway radio system is outlined in the figures below.

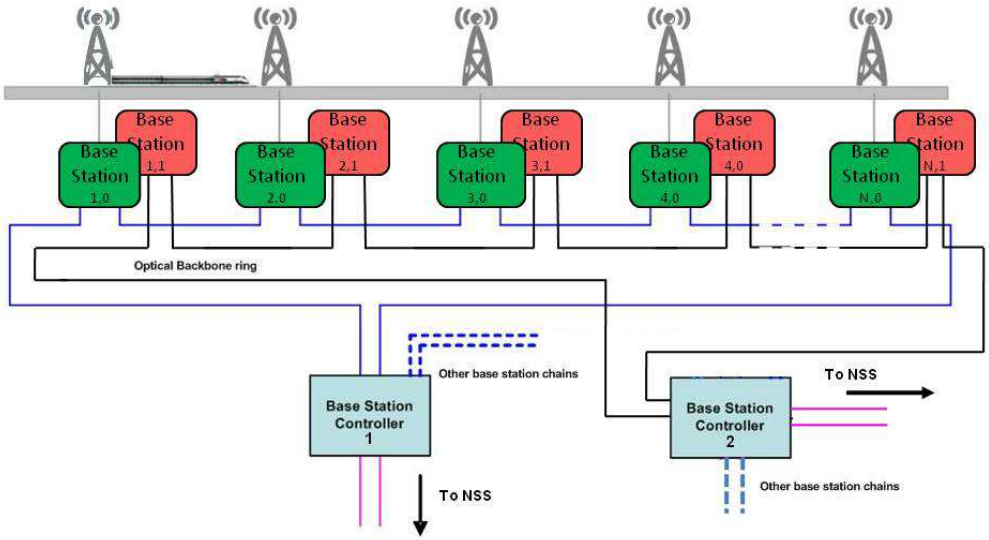

Figure 2: GSM-R BSS architecture

This solution guarantees a radio coverage based on double layer and then it assures radio signalling system of ERTMS.

In effect with two BTS installed in same site (co-siting) will be ensured a continuous and double radio signal (at the same time) for mobiles along railway line.

As showed in the following figures, in case of out of service of a single BTS, the second BTS located in the same site guarantees the same radio coverage.

Otherwise if first ring goes down (i.e. failure of entire ring of BTS: red ring or green ring) second chain guarantees the same radio coverage.

See pictures below:

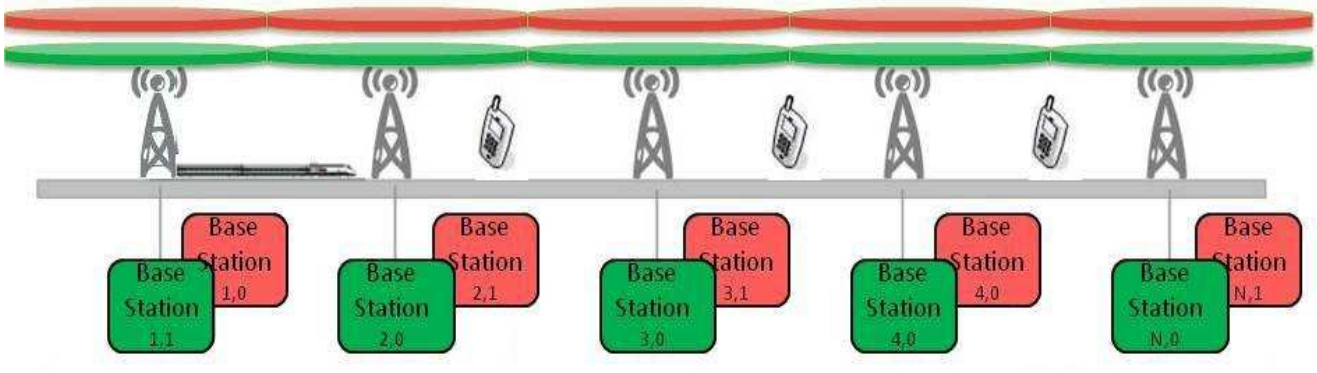

Figure 4: double radio coverage

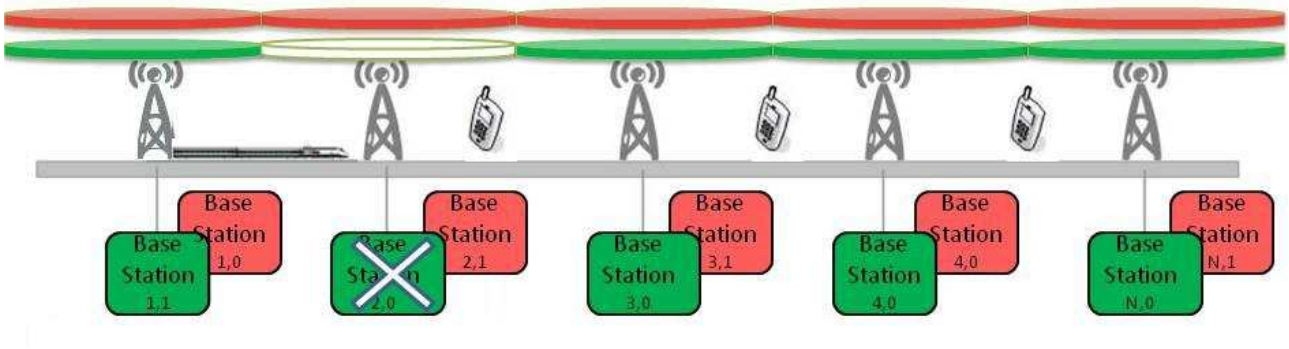

Figure 5: double radio coverage with one BTS fault

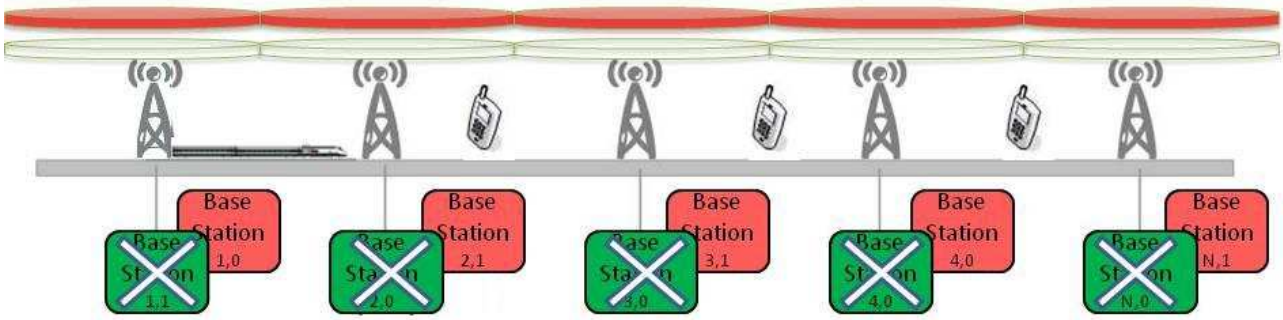

Figure 6: double radio coverage with BTSs chain out service

The entire BTSs chain shall be linked to the BSC1 and BSC2 in Brasov OCC (under particular conditions BTS can be linked to existing BSCs of Simeria or pilot project).

The BSC1 and BSC2, installed in Brasov OCC, are linked to both MSC1 and MSC2 (supplied with pilot project) located in different places, Bucharest OCC and Ploiesti, by two different TCU.

The BSCs shall control all BTS of section 1 (Brasov-Sighisoara).

To guarantee the Operation and Maintenance (O&M) services for BSS systems shall be supplied an OMC-R client (Operation and Maintenance Centre Radio) installed in Brasov OCC .

The following figure show the schematic architecture of GSM-R network before mentioned, while a more detailed plan is showed in “GSM-R architecture” document.

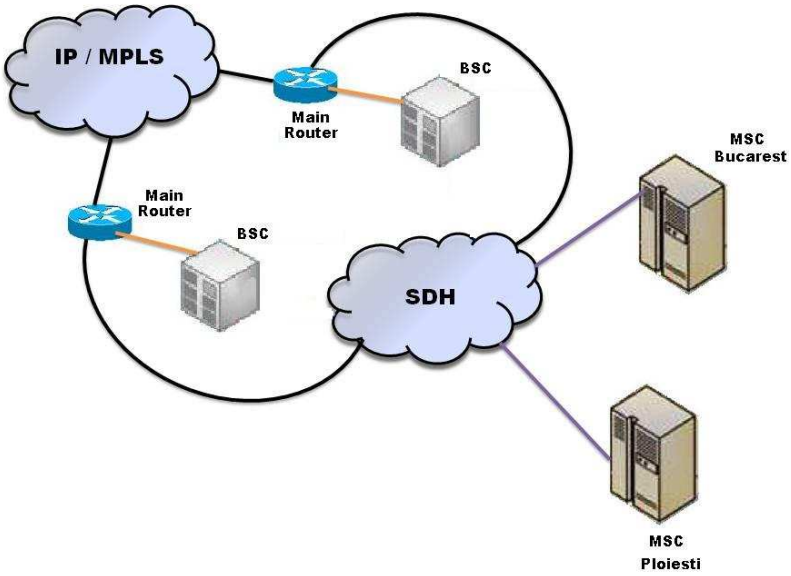

Figure 7: links BSS-NSS

3.2 LINK BUDGET

3.2.1 OUTDOOR MINIMUM FIELD

The following minimum values, from EIRENE specifications have been considered:

Coverage probability of 95% based on a coverage level of 44.5 dBµV/m (-92 dBm) on lines with ETCS level 2.

3.2.2 QUALITY OF COVERAGE

The level of radio signal must be referred on hand portable and cab radio requirements and it shall be enough to provide voice and vital data calls using hand portable and cab radio in all the areas before mentioned.

The specified coverage probability means that with a probability value of at least 95% in each location interval (length 100m) the measured coverage level shall be greater than or equal to the value declared above. The coverage levels specified above considers a maximum loss of 3 dB between antenna and receiver and an additional margin of 3 dB for other factors such as ageing.

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.

The system will be designed to provide communications at a maximum speed of 160 km/h.

3.2.3 MOBILE DEFINITION

The GSM-R network will be dimensioned for Cab Radio and General Purpose Radio mobiles with the following characteristics:

Product list	*Class*	*MS Tx PA Output Power*	*MS Sensitivity*
Cab Radio	**2**	**8 W / 39 dBm**	**-104 dBm**
General/Operational	**4**	**2 W / 33 dBm**	**-102 dBm**
Purpose Handheld	**4**	**2 W / 33 dBm**	**-102 dBm**

Table 5 Typical Devices

Specifications of 8W cab radio:

- External antenna installed on top of the cab
- Antenna height 4,5 meters above ground
- Antenna gain 2dBi
- Cable loss 2dB max

The contractor shall supply 30 GPH mobiles and 200 OPH mobiles for the roll out of network.

3.2.4 BTS DEFINITION

The following table states the parameters of the BTS

BTS sensibility	*Combiner Loss*	*Feeder Loss*	*Antenna Gain*	*Diversity Gain*
-109 dBm	**-3 dB**	**-3 dB**	**18 dBi**	**1,5 dB**

Table 6 Typical BTS

Different types of sectorial antennas can be used in the radio design. Antennas are GSM /GSM-R band (Frequency range 870 – 960 MHz) with vertical or cross polarization. Width can vary (30°, 65° or 90°) according adjacent tracks coverage topology.

For link budget, 18 dBi gain / 65° beam width is selected.

The link budget is used to compute the maximum path loss corresponding to a specific equipment configuration and application. It is based on a path loss calculation between the BTS (transmitter) and the mobile (receiver).
Two path losses are calculated: the uplink path (Mobile to BTS) and the downlink path (BTS to Mobile).
The inputs needed to perform this calculation are organized in three categories:

1. The general parameters (BTS related, antenna heights etc.) that will be independent on kind of service;
2. The parameters that will depend on the kind of service (e.g. mobile type)
3. The engineering margins that will depend on the kind of service, the speed of the train and which ensure the required QoS (Quality of Service) is met.

Useful outputs of the link budgets are the balanced EIRP and the outdoor minimum field.

Typically it is necessary to provide coverage to different types of mobile equipment configurations. In according with the equipment types defined and the service to be provided, the worst link budget is calculated and the worst case is considered.

This means that if we dimension the link budget on the worst case, the requirements of the best case will be, obviously, satisfied.

To develop link budget, several margins have to be taken in account; main of them are described below:

Overlapping Margin: The overlapping margin is a design margin. The aim of this margin is to provide at the border of a cell an extra coverage to allow the fast mobile to perform a handover and a cell reselection.
The overlapping margin is added to the OMF (Outdoor Minimum Field) to ensure that the overlapping between two neighbor cells is sufficient to perform the handover and cell reselection procedures in good condition. It depends on the duration of the process, the cell parameters setting and on the speed of the train.

Quality Margin: This is a margin which ensures that the receiver provides the BER (Bit Error Rate) specified at the requested train speed for the specified service (voice, circuit switched data or packet switched data.) The high speed GSM-R environment introduces Doppler shifts which results in a non stationary channel response. The quality margin is added to account for this.

Fading/Shadow Margin: In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation.

The impact of obstacles on RF propagation results in a log-normal field strength distribution centered on the mean value. This phenomenon is known as slow fading or shadowing. The shadow margin is the margin applied to the Overlapping Margin (in addition to the design margins) to attain the required outdoor quality inside the coverage area.

In the following theoretical link-budget all of referred margins are collected in two main voices:

- Interference margin for all interferences and fading
- Engineering margin which collect all other margin. The value associated to this category is conservative to guarantee critical situations.

3.2.5 LINK BUDGET DETAILS

Link Budget	**Cab radio**				**Mobile**			
	Uplink		Downlink		Uplink		Downlink	
Coverage at 95 % required			-92	dBm			-92	dBm
Body Loss			0	dB			-3	dB
Coverage			**-92**	**dBm**			**-89**	dBm
BTS Power TX			47	dBm			47	dBm
Combiner Loss			-3	dB			-3	dB
Feeder Loss			-6	dB			-6	dB
Antenna Gain			18	dBi			18	dBi
Antenna Height loss			0	dB			-5	dB
Max Power Tx from BTS (EIRP)			**56**	**dBm**			**51**	dBm
Path Loss Max			**148**	dB			**140**	dB
BTS sensibility	-109	dBm			-109	dBm		
Combiner Loss	-3	dB			-3	dB		
Feeder Loss	-6	dB			-6	dB		
Antenna Gain	18	dBi			18	dBi		
Engineering Margin	-6	dB			-6	dB		
Diversity Gain	1,5	dB			1,5	dB		
Interference Margin	-3	dB			-3	dB		
Minimum RX level to BTS	**110,5**	**dBm**			**110,5**	**dBm**		
MS TX power	39	dBm			33	dBm		
Antenna Height loss	0	dB			-5	dB		
Body Loss	0	dB			-3	dB		
Max MS TX power	**39**	**dBm**			**25**	**dBm**		

Path Loss Max	**149,5**	**dB**		**135,5**	**dB**	

Table: 7 Link Budget

As showed in the table, maximum value of path loss allowed is 135, 5 dB: the value of path loss allowed of 135,5 dB ensures the outdoor coverage for both 8W cab radio and 2W handsets along the tracks.

This value of path loss allowed of 135,5 dB is calculated for threshold of coverage at 95% in the time and space (interval of 100 meter) and this is the value for calculate the theoretical inter-site distance.

3.2.6 RADIO PROPAGATION MODEL

Okomura-Hata radio propagation model has been used in this project for radio design of path loss. This model is applicable in a lot of scenarios and the following formula gives the value of path loss according to Okomura-Hata model:

$$P_{loss} = k_1 + k_2 \cdot \log(d) + k_3 \cdot \log(H_{ms}) + k_4 \cdot \log(H_{ms}) + k_5 \cdot \log(H_{eff}) + \\ + k_6 \cdot \log(H_{eff}) \cdot \log(d) + k_7 \cdot Diffn + C\_loss$$

Formula 1: Okomura-Hata Model

Below the meanings of each *ki* parameters:

- **d:** It is the distance between a BTS and MS (Mobile Station).
- **Hms** : It is the height between MS respect to ground.
- **Heff** : Effective antenna height
- **Diffn :** Diffraction loss calculated with Epstein, Peterson, Deygout or Bullinton.
- **k1 and k2:** it is the intercept (dBm) and slope of log(d) function
- $\mathbf{k_3}$: Effective Height of MS
- $\mathbf{k_4}$: Multiplier factor of Okomura Hata for Hms.
- $\mathbf{k_5}$: Corrective factor of Heff
- $\mathbf{k_6}$: Corrective factor for log(Heff)·log(d)
- $\mathbf{k_7}$: Corrective factor for a estimate diffraction value
- **C _ Loss**: Clutter

Two models of radio propagation have been performed tuned by radio measurements along railway in Italy:

- **GSM-R_Sub-Urban**: It describe a low sized urbanized clutter.
- **GSM-R_Rural**: It describe an open flat/hill surface clutter.

It is possible to describe in a reduction mode the equation, like linear function of logarithm of distance (in meter) between transmitter and receiver:

$$P_{loss} = -(A + B \cdot \log(d))$$

Formula 2: Approximated Okomura-Hata model

By the resolution of equation we obtain the values of intercept (A) and slope (B) that describe the propagation model.
After that, by real measurement and tests made along Italian Railway, the values of intercept A and slope B have been estimated as follow:

Path Loss Coefficients	***Sub-Urban model***	***Rural model***
Intercept A	0.9	5.6
Slope B	-36.3	-34.6

Table 8: Okomura-Hata Coefficient

For this design, considering the link budget path loss obtained before (135, 5 dBm), applying the table's values it is possible to calculate the pure theoretical value of "d".

3.2.7 COVERAGE STRATEGY

The radio design for outdoor coverage has to be performed as a double radio layer. To cope with the high mobility of the train, a sufficient overlapping of cells is required to ensure that handover and cell reselection will be realized without interruption of communications.
This topic is particularly relevant in GSM-R as users engaged in a voice group call in "dedicated mode" perform a cell reselection when moving from one cell to the next cell.

An overlapping margin of 2.6dB has to be taken in the link budget for that purpose.
The height of the pylons/towers has been set to 30m along the track. This conservative figure allows controlling more effectively the radio propagation in all type of environments.
Cross polarized antennas and polarization diversity is used to maximize the sensitivity of the BTS and increase the quality of coverage.
The radio coverage of tunnels requires a specific engineering study. The complexity of the technical solution to be implemented depends on the physical characteristics of each tunnel (dimensions, cross section shape, length, etc.).
The main inputs needed to design the tunnel coverage solution are:

- The size and shape of the tunnel
- The environment of the tunnel
- Straightness / levelness of the tunnel
- The availability and size of technical rooms
- The number of rail tracks inside the tunnel
- The presence of overhead power lines
- If the tunnels are isolated or grouped in clusters
- Maximum train speed inside the tunnel
- Wall nature (concrete, stoned, fleecy...)

3.2.8 SITE PLANNING

According to the link budget calculated before, considering that this result is pure theoretical and matching it with experienced cell planning the following inter-site distance have been chosen in this plan:

- Sub-Urban model: inter-site distance will be about 5.700 meters.
- Rural model: inter-site distance will be about 12.000 meters.

Taking into account this result and the following conditions:

- Site located in the main stations (as required by the Customer);
- engineering margins;
- topographical surface of the entire line;
- Brasov as starting point,

GSM-R sites have been planned according to following table:

Prog.	Site number	*Site name*	*km p.k.*	*Quantity of Cabin/Shelter*	*Inter-site distance m*
34	SITE 23	SIGHISOARA	282+034	1 (GSM-R & Signalling)	n.a.
35	SITE 22	ALBESTI	277+132	1 (GSM-R & Signalling)	4,902
36	SITE 21	VANATORI	272+413	1 (GSM-R & Signalling)	4,719
37	SITE 21bis	VANATORI (1)	269+000	2 (GSM-R)	3,413
38a	SITE 20b	Tunnel MURENI	266+700	1 (GSM-R)	2,3
38a	SITE 20a	Tunnel MURENI	265+700	1 (GSM-R)	1
40	SITE 19	FELEAG	262+000	2 (GSM-R)	3,7
41	SITE 18	ARCHITA	258+453	1 (GSM-R & Signalling)	3,547
42a	SITE 17b	Tunnel ARCHITA 2	253+896	1 (GSM-R)	4,557
42b	SITE 17a	Tunnel ARCHITA 2	253+670	1 (GSM-R)	0,226
43a	SITE 16b	Tunnel ARCHITA 1	252+398	1 (GSM-R)	1,272
43b	SITE 16a	Tunnel ARCHITA 1	251+904	1 (GSM-R)	0,494
44a	SITE 15b	Tunnel BEIA	250+285	1 (GSM-R)	1,619
44b	SITE 15a	Tunnel BEIA	249+623	1 (GSM-R)	0,662
45	SITE 14	PALOS	243+800	2 (GSM-R)	5,823
46	SITE 13	CATA	237+542	1 (GSM-R & Signalling)	6,258
47	SITE 12	HOMOROD-CATA	234+500	2 (GSM-R)	3,042
48a	SITE 11d	HOMOROD TUNNEL	231+500	2 (GSM-R)	3
48b	SITE 11c	HOMOROD TUNNEL	229+850	1 (GSM-R)	1,65
48c	SITE 11b	HOMOROD TUNNEL	228+200	1 (GSM-R)	1,65
48d	SITE 11a	HOMOROD TUNNEL	226+550	2 (GSM-R)	1,65
49	SITE 10	Racos	221+842	1 (GSM-R & Signalling)	4,708
50	SITE 10bis	Ex. Line Km 228+550	228+550 *(*)*	2 (GSM-R)	n.a.
51	SITE 10ter	Ex. Line Km 227+650	227+650 *(*)*	2 (GSM-R)	n.a.
52	SITE 10quat	Ex. Line Km 226+500	226+500 *(*)*	2 (GSM-R)	n.a.
53a	SITE 9d	ORMENIS TUNNEL	220+100	2 (GSM-R)	1,742
53b	SITE 9c	ORMENIS TUNNEL	217+782	1 (GSM-R)	2,318
53c	SITE 9b	ORMENIS TUNNEL	215+466	1 (GSM-R)	2,316
53d	SITE 9a	ORMENIS TUNNEL	213+150	2 (GSM-R)	2,316
54	SITE 8	APATA-ORMENIS	211+000	2 (GSM-R)	2,15
55	SITE 7	APATA	207+046	1 (GSM-R & Signalling)	3,954
56	SITE 6	MAIERUS	200+000	2 (GSM-R)	7,046
57	SITE 5	FELDIOARA	192+117	1 (GSM-R & Signalling)	7,883

Prog.	Site number	*Site name*	*km p.k.*	*Quantity of Cabin/Shelter*	*Inter-site distance m*
58	SITE 4	BOD	183+308	1 (GSM-R & Signalling)	8,809
59	SITE 3	STUPINI	176+418	1 (GSM-R & Signalling)	6,89
60	SITE 2	BRASOV BIS	173+300	2 (GSM-R)	3,118
61	SITE 0	BRASOV DARSTE	167+000	2 (GSM-R)	3,57
62	SITE 1	BRASOV OCC	169+730	1 (GSM-R & Signalling)	n.a.

(*) *Existing line*

Table 9 GSM-R Site Dislocation

In the Table above:

- Prog: number of site continuing by section 2 – 3
- Site number : site number in this section
- Site name : name of sites along the section 1
- Km, p.k. : Kilometer and progressive of the line
- Quantity of cabin/shelter: number of cabin /shelter along the line
- Intersite: Inter-distance between two sites

All sites have been positioned in main stations; where the inter-distance between main stations is too big or orography conditions are critical a GSM-R site is planned in correspondence of halts or along the line.
For radio coverage in Vanatori, to guarantee the radio coverage for existing Odhorei line a site called Vanatori Bis (see the table above) shall be provided; the site Vanatori Bis guarantees a radio coverage in direction Odhorei and for the line Brasov-Sighisoara.
A GSM-R sites with single BTS is planned for each side of following tunnels: Archita 2, Archita 1, Beia and Mureni.
For the radio coverage of Homorod and Ormenis tunnels there will be two BTS inside the tunnels.

To guarantee the radio coverage between Brasov and Stupini an intermediate GSM-R site shall be provided; this site will reduce the conventional inter-distance used above.
Along the line there are some interconnections, so an extension radio coverage shall be provided, in fact for the interconnection from Cata – Rupea and Racos – Rupea a double site at the entrances of Homorod Tunnel shall be provided; for the interconnections between Racos – Augustin will be provided a different solution, in fact at the entrance of Ormenis Tunnel (Sighisoara side) will be provided three sites along the interconnections of the existing line (see table above); for the interconnection from Apata – Augustin a double site at the entrance of Ormenis tunnel (Brasov Side) shall be provided.
These extensions will allow to link via radio the train with signalling systems.

In Brasov shall be provided three GSM-R Sites: Brasov, station (for station coverage), Brasov bis for Feldioara direction, Brasov Darste to guarantee radio coverage for incoming trains to Brasov.

3.2.9 RADIO SITE DESIGN

Radio sites will be designed in accordance to the radio coverage requirements and local regulations and standard (for example concerning Tower maximum height and kind of profile) where applicable.
Radio site shall comprise:

- Tower (height and type);
- Antenna System;
- Feeder cable;
- Surge arrestors;
- Lightning final;
- Earthing devices;
- Supervision system;
- Power Supply system.

GSM-R sites in main stations will use the same cabin (shelter) or room of signaling system. Sites along the tracks will use a single cabin for each Base Station (BTS), only one tower but two different antennas system(to have an higher level of redundancy).

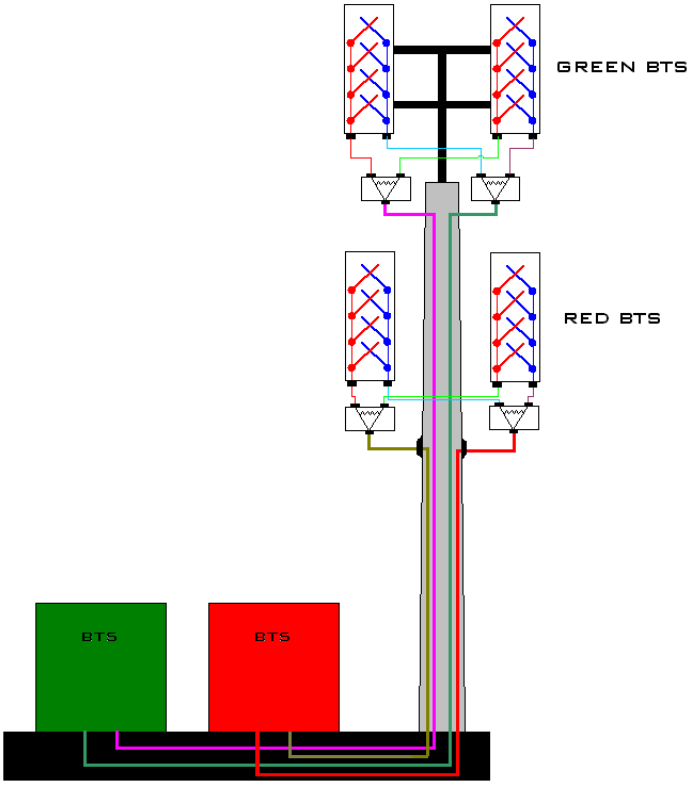

Figure 8: Example of GSM-R radio sites with 2 BTSs

3.2.10 RF WIRING

Technical characteristics (performances, security, etc.) of cables and other external equipment of the BTS (jumpers, feeders, coupling system, etc.) used for the roll out are described below:

Antenna type:

- Frequency range 870-960 cross polarization 18 dBi gain (Width 65°);

Jumpers:

- Head of mast (antennas) Length 3m section 1/2" with connectors 7/16"
- BTS Length 2m section 1/2" with connectors 7/16" 4

Feeders

- Length 30m section 7/8".
- In case of use of greater distances, feeder size will be 1”1/4

3.2.11 EQUIPMENT CABIN

The electronic equipment requires a stable atmosphere to operate and so protection is required against wide variations in temperature and humidity as well as dust.
Equipments (BTS, signalling and others devices) will be housed inside a cabin or shelter to guarantee a correct protection and maintenance.
The cabin will have:

- Backup DC power supply;
- Environmental controls;

Power will be supplied by 25 kV_{AC} of electric traction; it will be transformed in 230 V_{AC};
Inside the cabin, this power 230 V_{AC} will be filtered and rectified to supply cabin/shelter energy (Air conditioning, light, etc.) and it will be converted in 48V_{CC} to supply in particular BTS and IP device.
In case of GSM-R site along the line an UPS device of 6 hours only for BTS and IP devices must be previewed; for GSM-R devices co sited with signaling system the common UPS must guarantee 6 hours of power supply of BTS and IP devices

A supervision system for the cabin/shelter shall be supplied to check/alarm violation (door aperture) and environmental conditions (smoke, high temperature, etc).

3.3 BSC and TCU

For this plan two BSCs must be supplied both in the OCC of Brasov.
Each BSC will be linked to a different TCU: BSC1 to TCU1 located in Bucarest near MSC1 and BSC2 to TCU2 located in Ploiesti near MSC2.
The document “GSM-R architecture” shows the links between BTSs and BSC and between each BSC with corresponding TCU and MSC.
Contractor must assure correct Standard Interfaces between BSS subsystem, supplied with this project, and NSS subsystem, supplied with other project.
In case of different supplier of BSS and NSS Systems, the Contractor must assure IOT tests to guarantee the system interoperability.

The Contractor could evaluate the possibility to link BTS to existing BSCs of Simeria or pilot project in case of same HW supplier. In this case BSCs and TCUs upgrade must be implemented.

3.4 SITE DEFINITION AND PLANNING APPROVALS

The system performance must correspond with the requirements of circuit switched data for ETCS L2 for a train speed of 160 km/h.
The key performance indicators and their target values are presented in the below table **:**

Os parameter	**Value**
Minimum level of signal (probability 95%)	- 92 dBm
Delay in connection establishing for calls generated by mobile equipment	< 5 s (95%), < 7.5 s (99%) (EIRENE FRS section 3.4)
Error probability in connection establishing (per try)	$< 10^{-2}$ (ERTMS/ETCS SRS subset 093 section 6.3.3.)
Bit error rate in clear channel of 4,8 kb/s	$< 10^{-4}$ (GSM 05 05)
End-to-end delay (of a 30 bytes frame)	< 500 ms. ERTMS/ETCS SRS subset 093 section 6.3.4.
Connection loss probability	$< 10^{-2}$ per hour ERTMS/ETCS SRS subset 093 section 6.3.5.

It is required that the network performance would comply the recommendations from Subset-093 and the details regarding any anticipated or potential non-compliance in relation to the recommendations.

3.4.1 CALL RESPONSE TIME

GSM-R radio system must be designed in accordance with call response times specified in EIRENE FRS and in UNSIG specifications for ERTMS/GSM-R.
Call response time will also include the time necessary for translation of any functional numbers into internal numbers for GSM-R radio system.

3.4.2 HANDOVER PERFORMANCE

When a user terminal passes from one cell to another, the handover process must be completed in maximum 300 ms.
The success rate of handover process must be at least 99,5% for a successful completed handover defined as a handover completed in the time period defined above.

3.4.3 SERVICE AVAILABILITY

GSM-R radio system must reach a service global availability of at least 99,95%.

This global availability must cover including the availability of CTS subsystems, transport network, but it will exclude the cut-outs in electric energy supply, planned cut-outs and radio mobile equipments availability.

Contractor shall collaborate with the Customer in order to obtain the approval of the radio design and ultimate the acquisition of each necessary site.
The radio coverage design shall be finalized following a detailed survey along the track to be covered.
The Contractor will prepare a Radio planning using a tool to develop more accurate predictions of path loss, coverage and interference taking into account terrain data and clutter data for the areas under analysis and eventual presence of existent base station sites.
In general, mobile radio planning tools work to 50% confidence level. In order to convert the 95% confidence levels quoted in the EIRENE specifications to 50%, a conversion margin must be used.
The corresponding 50% confidence level for the above requirement can therefore be calculated as follows:
≈ 14dB + -92dBm
≈ - 81dBm (at 50% confidence)
The Contractor shall state the propagation model to be used in this project.
The Contractor shall deliver documentation about the tuning process applicable for the radio propagation model proposed.
The Contractor shall provide a list of references where the vendor has performed the radio planning for GSM-R.
The Contractor shall provide details and references about tools and methodologies internally used for the radio planning analysis. For network planning, the coverage level is defined in terms of time and area where the minimum signal criteria are achieved.
The radio coverage performance shall follow the EIRENE recommendations.
The Contractor shall perform the Link budget calculation which allows estimating maximum allowable path loss and cell radius.
The Contractor shall indicate, with detailed documentation, all the systems parameters that have an influence on radio planning.
The Contractor shall execute all the drive tests necessary to correctly tune the system provided.
The Contractor shall do frequency planning activity after the signature of the contract, all data about channel/transceiver features (channel separation between TRXs in the same cell, channel separation between control channels for first and second order neighbor cells, channel separation between traffic channels for first/second order neighbor cells, etc.), handover data threshold and algorithm.

The Contractor shall provide a Database with all necessary configuration parameters related to each radio network elements for site commissioning and network integration activities.

For Radio Planning the Contractor will take into account all requirements before mentioned and in particular following parameters must be respected.

Particular care must be taken about interference (co-channel or adjacent channel).

The following are the minimum required planning data for radio network planning:

- **C/Ic ≥ 25 dB** co-channel interference
- **C/Ia ≥ 7 dB** adjacent channel interference

The network must be designed for Uplink/Downlink balance.

The Contractor must respect for the radio planning and roll out of GSM-R network all values of referenced parameters indicated in ETSI, EIRENE Specifications and UNISIG Subset 034, 048, 093, 108 and new integrations (*QoS, BER, GOS, drop rate, call set u success rate, handover success rate, handover time*, etc.).

In particular ERTMS requirements must be respected too for *call set-up time, call success rate, end-to-end delay time*.

3.4.4 TRAFFIC MODEL

Main requirement of traffic model is guarantee a sufficient number of channels for ERTMS, considering that channel for transmission of ERTMS stream is called *vital channel*:

- 1 *vital channel* and 1 no vital channel must be available for each circuit track where there is not an RBC handover;
- 2 *vital channels* and 1 no vital channel must be available for each circuit track where there is an RBC handover.

In this configuration low priority is given to traffic for maintenance and others functions.

As ETCS level 2 will be implemented, each BTS must be configured with 2 TRX at least to guarantee sufficient traffic channel for signalling.

3.4.5 CELL PLANNING OUTPUT

For Cell Planning the Contractor will take in account all requirements before mentioned and in particular the Contractor must supply a file/database with a standard format (for example PLANET or ATOLL, or others similar) with the following information for each site:

1. Site code
2. Site name

3. Coordinate UTM X
4. Coordinate UTM Y
5. Site altitude
6. Numbers of sectors
7. Azimuth
8. Tilt
9. Antenna type
10. Antenna eight for sector
11. Power to antenna jumper (dBm)
12. Propagation model applied
13. Carriers number per sector
14. ARFCN
15. GOS per sector
16. LAC
17. BSC and MSC of reference
19. Flag:
    - site in station
    - site along the tracks
20. Adjacent Cell

Following maps must be supplied, A0 format and scale 1:100.000, with coverage/interference requirements:

1. Coverage map with RX_LEVEL (level received of field):
2. Interference map “C/Ic”,
3. Interference map “C/Ia”, a=+/-1,

Maps must follow tracks with a width of 1 km

Coverage prediction maps must be calculated on cell basis with a radius of 40 km.

Sources files must be available for Customer.

3.4.6 ROLL OUT AND TESTING FOR GSM-R NETWORK

During roll out of the GSM-R Network Contract shall provide all spare parts necessaries.

Contractor shall execute with success all tests of EIRENE libraries and of supplier for testing GSM-R network before delivery.

Contractor shall execute with success all tests to guarantee the compliance with Technical Specifications for Interoperability.

Contractor must give all assurances as provided by law and it shall supply 10% of spare parts.

4 BACKBONE TRANSPORT NETWORK

4.1 INTRODUCTION

The backbone transport network shall be designed to carry all railway communication traffic: GSM-R, Signalling system, Supervision system, Railway Safety Telephone systems, Video control system and so on.

Two optical fiber cables will be laid one on each outer side of the Railroad track and they will be used to realize optical rings along the entire Railroad line.

These optical rings will be the physical layer for backbone transport network and an IP/MPLS network will be implemented.

A transport equipment, based on IP/MPLS technology, shall be foreseen in each sites/stations to guarantee the transport of the railway traffic coming from the different services: GSM-R; ERTMS and so on.

The Backbone Transport Network shall be dimensioned in order to accommodate all the traffic coming from the different subsystems and it shall be a ring network to guarantee high availability.

Each transport equipment of optical ring will be interfaced with other IP devices to carry out applications and services coming from other railway sites located along the track.

The result is a unique IP/MPLS network that is able to transport both the GSM-R and signalling ERTMS and other applications and services.

IP/MPLS protocol will be applied to routing procedure of entire network of Corridor IV.

4.2 IP/MPLS NETWORK

In this project a backbone network will be applied to connect all technological sites to guarantee high data transfer rates with an elevate grade and quality of service.

The transport network will rely on IP/MPLS technology with switching of packages and will be able to provide the simultaneously transmission of voice, video and data services with extensive and configurable QOS mechanisms.

Other applications or services such as CCVT, VoIP, Train Control, Platform Display/Signalling, Traction Supply Control shall be transported by this IP/MPLS network.

This feature, with help of Optical Fibers, may connect long network segments (several kilometers).

IP/MPLS is a mechanism in high-performance telecommunications networks which directs and carries data from one network node to the next. MPLS makes it easy to create "virtual links" between distant nodes. It can encapsulate packets of various network protocols. MPLS is a highly scalable, protocol agnostic, data-carrying mechanism. In a MPLS network, data packets are assigned labels. Packet-forwarding decisions are made solely on the contents of this label, without the need to examine the routing table.

In each site/station shall be foreseen two transport equipments, based on IP/MPLS technology, called Cell Site Gateway (CSG) to guarantee a different link to each BTS. All CSG will be linked to perform a ring network with a rate of 1Gbit/s.

For this project in Sighisoara, Brasov OCC, Feldioara, Cata, in addition to the CSG, shall be installed two main routers (called main core) for redundancy of ring protection.

In particular for Brasov OCC shall be provided two CSG (High Capacity) for interface several services of the OCC to main routers.

In each station shall be in general several services such as: Video surveillance , SCADA RTU, Safety Telephone, D&M, IXL and CTC services, etc.

The document “Backbone network architecture“ shows the details and links described before.

Besides, between two consecutives stations, there could be some level crossings, traction substation and sectioning post; these locations (except sectioning post) together sites/stations shall be supervised by a Video surveillance services, managed by OCC. In traction substation and sectioning post also the SCADA RTU and the safety telephone system will be linked using the backbone network.

All these services shall be linked by a secondary backbone network formed by Ethernet switches called service switches and connected to a sub ring between two CSGs (as showed in the following figure). All switches will be linked by Optical Fiber cable to realize a Gigabit Ethernet (IEEE 802.3z) LAN.

In this way a redundant link is assured; sub rings shall be linked in alternate mode, so that all traffic of the sub network, can be shared in order to avoid congestion problems.

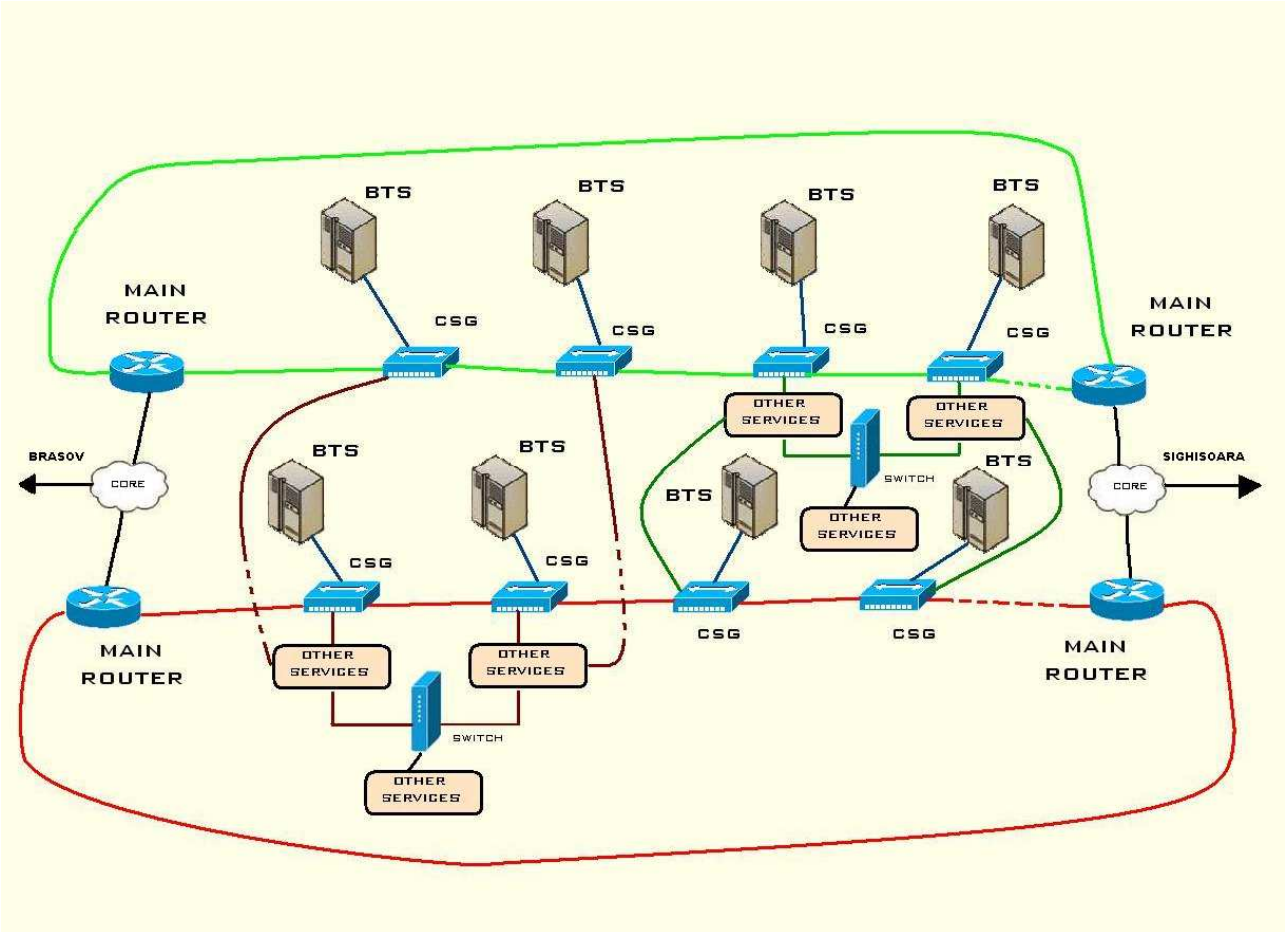

Figure 10: Typical Backbone Architecture

All the detail regarding the system linked using the IP/MPLS network are represented in the document “Backbone network architecture“

4.3 ARCHITECTURE AND NODES

The Backbone Transport Network shall be dimensioned in order to accommodate all the traffic coming from the different subsystems and it shall be a ring network to guarantee high availability.

As showed on document “Backbone Transport Network Architecture” the topology of network will be built by two main rings with different optical fibers of two distinct optical fiber cables laid the first one along the track and the second overhead the pylons of contact line.

Two CSG nodes will be supplied for each site: the first one will be connected to the first BTS ring/chain (for example Green chain) and the second one will be link to the second BTS ring/chain (Red chain).

GSM-R mobile communications must be end-to-end transmitted through service tunnels by means of transport network made of the two types of equipments.
The service tunnel is defined as the data unit in which services (e.g. TDM and Ethernet) had been encapsulated and insulated by the transport level (e.g. represented by MPLS labels). The service tunnel can be generated in many ways, on the basis of some different transport technologies. Regarding the transport on package basis, TDM traffic must be emulated and encapsulated in Pseudo-Wire (PW3) service tunnels in order to be transported within the network. The service tunnel must be configurable in a flexible manner.

The transport network and subnetwork architecture, based on double rings remarks the same philosophy of GSM-R with double radio coverage.
The CSG nodes linked in cascade will generate a traffic IP/MPLS with a rate of 1Gbit/.

To manage the Safety Systems of Homorod and Ormenis tunnels, two CSG with high capacity (greater than standard used above) shall be provided for each entrance to the tunnel; they shall be linked to conventional CSG along the line and in the same place.

To guarantee the radio coverage of GSM-R system, more CSG shall be provided inside the tunnels.

CSG routers shall be able to manage the IP/MPLS traffic of the CSG 1Gbit/s ring network and each main router can send incoming traffic to Simeria OCC and Brasov OCC on a superior ring network with a rate of 10Gbit/s.
Each CSG and main core will be able to support MPLS technology and standard TCP/IP services, both with large capability and full-size resource for further services; these devices shall be able to support mixed services including E1 TDM and Ethernet services too.

In particular the main routers of Brasov OCC and Sighisoara, will be able to interface existing SDH network in order to send the signaling/GSM-R traffic towards MSC1 and MSC2. The SDH link of Brasov OCC will be considerate the primary connection and the SDH link of Sighisoara the secondary connection in the table of traffic.

Document "Backbone Transport Network Architecture" shows with more detail all links above described.

4.4 BACKBONE NETWORK INTERCONNECTION

To guarantee the radio coverage of the interconnection between Ormenis-Racos, two new cables along the interconnection shall be provided, the first cable on the down line and the second (return way) on the up line; the first cable will start from Racos and will linked to each CSG inside the sites along the interconnection, the second cable will assure the ring path protection that will return on the main line inside the site of Ormenis Tunnel (Sighisoara side).
These cables will need to guarantee the functionality of GSM-R system along the interconnection, so for this reason along the interconnection shall be provided two CSG for each site along the interconnection (six CSG total).

4.5 CSG (CELL SITE GATEWAY) OR LOCAL ROUTER AND MAIN CORE ROUTER

Each CSG shall support the following main characteristics:

1. modular chassis
2. at least 8 Fast Ethernet (10/100) Copper Interfaces
3. at least 6 Gigabit Ethernet interfaces, at least 3 with support (SFP)
4. at least 16 E1 RJ45 channel ports

For safety system for tunnel, CSG shall have the same characteristics with double capacity at least.

Main core devices will have following main characteristics

1. modular chassis
2. fast replacement modules (control module, supply module, interfaces module)
3. at least 8 slots for interfaces modules
4. switching capacity of at least 720 Gbps (Half Duplex) (at least 40 Gbps per slot)
5. at least 24 Fast Ethernet ports (10/100) Base TX
6. at least 48 Gigabit Ethernet 1000 Base SFP ports
7. at least 48 Gigabit Ethernet ports (10/100/1000 Base RJ45)
8. at least 4 10 Gigabit Ethernet Long Haul Ports
9. at least 60 E1 RJ-45 channel ports
10. at least 8 STM-1 TDM channel ports

All devices shall be redundancy at level of interfaces modules, control modules and at the level core equipment; it is necessary a redundancy mechanism at level of IP/MPLS pseudowire and at level software; it is required a TCP/IP protocols for diagnostic and maintainability.

Each device shall implement queuing mechanisms and traffic-shaping mechanisms configurable per service, per forwarding class. Quality of service policy must be provided and guarantee to manage entire backbone network.

The node size and switching capability shall be dimensioned to provide a high grade of reliability respect to the safety critical traffic and communications.

In the proposed system, each node shall be equipped with suitable interfaces according to the subsystem traffic and considering at least 25% of available interfaces for further expansion.

CSG (Cell Site Gateway) or Local Router must permit the use of at least 32 configured VRFs, with support for:

- MBGP VPN, RFC 4364**;**
- CSC VPN and Inter-AS VPN (Option a, B and C);
- 802.1Q, at least 250 VLANs.
- Q-in-Q;

CSG shall offer performances for:

- L2 traffic;
- Ethernet Connectivity Fault Manager (CFM) 802.1ag;
- Link OAM IEEE 802.3ah and IEEE 802.3 Clause 57;
- Ethernet Connectivity Fault Manager (CFM) 802.1ag;
- Ethernet Local Management Interface (E-LMI);
- BFD for OSPF, ISIS, BGP and static routes.

Equipments must be interconnected by level 2 Ethernet type technology and the support for Synchronous Ethernet and MLPPP on CSG is mandatory.
The support for Synchronous Ethernet is mandatory for all equipments offered for the transport solution and it must be always used for interconnections between equipments even if alternative techniques for the distribution of synchronized information are also used.

The main cores must have aggregation functionality and backbone/core capabilities.

CSG must support operating temperatures between -20 and 60°C.

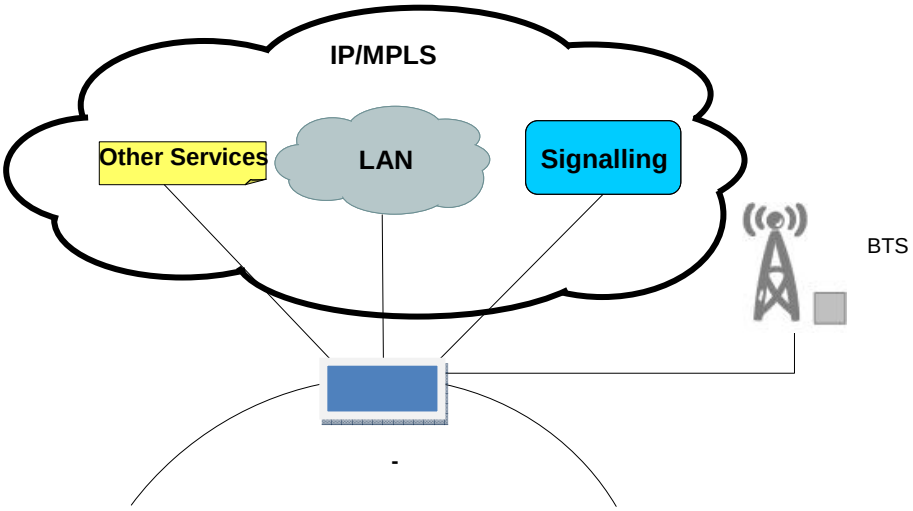

Figure 11: node for station site

4.6 SERVICE SWITCH

All service switches will be linked by Optical Fiber cable to realize a Gigabit Ethernet (IEEE 802.3z) LAN. They will be interfaced with CSG at start and at the end of chain.
The interruption of bus link will not cause out of service because the chain of switches can configure itself again using one of two initial or final CSG.
For this application the Contractor shall provide IP equipment compliant at least with the following requirements:

- Equipments should support Power over Ethernet (PoE) IEEE802.3af standards for Administrative Voice Communications subscribers
- Switched architecture supporting IEEE802.1q and IEEE802.1p standards for VLAN and priority management. VLAN management will be applied at port level with tagged (802.1q) or untagged mode
- Spanning Tree Protocol IEEE802.1d standard;
- Rapid Spanning Tree (IEEE 802.1w)
- Multiple Spanning Trees (IEEE 802.1s)

- Link Aggregation support towards lower level system components (Access layer);
- Security management at port level (MAC-address control)
- Data traffic priority management by IEEE802.1p and TOS.

4.7 FUNCTIONALITIES

For CSG and Main Core are required particular functionalities to assure all services above described.
In particular following functionalities must be supported for both CSG and Main Core:

- OSPF V2 routing protocol compliant with RFC 2338;
- IS-IS routing protocol compliant with RFC 1142;
- traffic-engineering for OSPF and IS-IS routing protocols;
- TDM PW over MPLS, compliant with CESoPSN RFC 5086 & SAToP RFC 4553;
- Ethernet PW over MPLS compliant with RFC 4447 and RFC 4448;
- at least 100 GRE tunnels for SAToP, CESoPSN, Ethernet over MPLS compliant with RFC 2784 and 4023.

In particular following functionalities must be supported for Main Core:

- BGPv4 routing protocol compliant with RFC 1771 and 1772;
- Multiprotocol extension to BGP-4;
- CSC VPN and Inter-AS VPN (Option A, B and C);
- prioritization of prefixes from IGP routing protocol (ISIS or OSPF);
- multileveled hardware routing table that would permit a quick convergence regardless of the number of prefixes from BGP table;
- use of at least 1024 configured VRFs, with support for mBGP VPN, RFC 4364;
- VPLS services compliant with RFC 4762;
- Non-Stop Forwarding, known as Graceful Restart (the router capacity, in case of a malfunction at the control level or in case of a forced switching, to continue to switch packages using the existing forwarding information, dynamically updated) for all implemented routing protocols and for the signalling mechanism associated to MPLS protocol.

For equipments that compose the transport network the redundancy at the level of interfaces modules, control modules and at the level of core/equipment must be assured**;** the following reliability conditions must be respected in particular for main core:

- Redundancy mechanisms at the level of IP/MPLS pseudowire;
- Protection mechanisms of multi-chassis type;
- multi-chassis protection mechanisms;
- Redundancy cooling;
- APS support between ports from the same interface module;

- LAG support between ports from the same module;
- LAG support between ports from different modules;
- MLPPP support for uplink ports;
- MLPPP support for access ports;

The following reliability conditions must be respected in particular for CSG and main cores:

- MPLS;
- LDP**;**
- Protection for LSPs MPLS**;**
- PW Active/Standby support**;**
- ECMP**.**

The following reliability conditions must be respected in particular for CSG and main cores:

- MLPPP support for ports configured as unlink;
- MLPPP support for ports configured as access.

4.8 QUALITY OF SERVICES

The Main Core Router must implement queuing mechanisms and traffic-shaping mechanisms configurable per service, per forwarding class. The intention is that the shaping mechanism would absorb the traffic excess at the level of service entrance, only allowing the entrance into the transport network of a default bandwidth guaranteed at the level of service.
For main core shall be possible to have the feature of QoS Flow Identification Service, so that the access traffic for a specific service will be able to be classified on the basis of the following parameters:

- IEEEDot1P/Q Mapping
- IP DSCP Mapping
- MPLS EXP mapping

IP/Ethernet interfaces from the central equipment must support a multileveled QoS, with parent QoS class in which child QoS classes apply.
IP/Ethernet interfaces from the central equipment must support at least 18000 queues.

Cell Site Gateway Router must implement queuing mechanisms and traffic-shaping mechanisms configurable per service, per forwarding class. The shaping mechanism would absorb the traffic excess at the level of service entrance, only allowing the entrance into the transport network of a default bandwidth guaranteed at the level of service.

CSG will support buffering mechanisms at the level of entrance and exit from a certain service, without affecting the transmission capacity at the level of physical connection. Up to 4 queues/

forwarding levels will be able to be configured at the level of service, each with its own CIR, PIR, CBS, MBS and Forwarding Class attributes.

4.9 SYNCHRONIZATION

More synchronous options are available for communication networks working in Romanian railway at the moment:

- Synchronization using the information present on the line or physical connection: PDH/SDH or Synchronous Ethernet, External Synchronization.
- Band synchronization: Inbound ACR (Adaptive Clock Recovery),.

The proposed equipments shall support the following on the line synchronization mechanisms comply with ITU-T G.8261 or IEEE 1588v2:

- PDH (applicable for CSG).
- SDH (applicable for Main Core).
- SyncE (Synchronous Ethernet) (applicable for CSG & Main Core).
- Inbound ACR (applicable for CSG & Main Core).
- “Precision Time Protocol” IEEE 1588v2 (applicable for CSG).

The proposed equipments must support the following external synchronization mechanisms:

- 2 MHz time input (applicable for CSG & Main Core).
- 2 MHz time output (applicable for CSG).
- MHz/10 MHz time input/output (applicable for Main Core).

4.10 BACKBONE TRANSPORT NETWORK MANAGEMENT SYSTEM (TNMS)

An adequate management system must be supplied to assured a centralised supervision of all devices of Backbone Transport Network

The proposed management system will provide:

- Support for configuration, viewing, diagnosis of many types of services. including PW of TDM, Ethernet type, across a packages network that uses IP/MPLS.
- Quick provisioning, configuration of services using graphic intuitive interfaces of point-and-click type.
- Easy to use user interface on basis of GUI, with default “Configuration Patterns”.
- Reduction in operational expenses, by means of centralized testing & diagnosis and servicing mechanisms (Service OAM).
- North-bound interfaces in order to facilitate the integration with the existing OSS applications.

- Redundancy and synchronization mechanisms between the management system database and cores being under supervision.
- Full FCAPS support.
- SNMP V1, 2 and 3 support.
- Automatic discovery of network elements.

The management system must have a high availability by use of geographical redundancy for hardware platforms. The redundancy must be automated.
In case of a malfunction at the active system, the management system must switch on stand-by system without needing the user intervention.

The proposed management system must provide the complete management of network cores elements, supporting the following:

- Equipments management.
- Inventory and reporting.
- Security management.
- CLI session (Telnet/SSHv1/SSHv2) for NE access.
- Secure transfer of files, backup and restore procedures for the configurations from NE.
- Surfing in equipment's physical/logical structure.
- Statistics.
- Alarms management.

Graphical User Interface (GUI) access on different platforms, including PC basic standard platforms shall be provided with following features at least:

- Display of equipment and alarms status.
- Configuration and administration of applications for network management.
- Simplification of equipments, services and subscribers configuration execution and administration using the wizard.
- Configuration, administration and monitoring at the level of SLA and at the level of equipment using performance counters.
- Construction and administration of security policies for access to routers and for operations executed by management system users.

It shall be possible perform the Provisioning of devices too: the configuration of the following types of services from GUI must be available at least:

- Services provisioning: IP routing, L2 point-to-point (PW) services, L2 VPN multipoint-to-multipoint (VPLS) services, L3 VPN services (IP VPN).
- Assisted provisioning using wizards.
- Patterns for services provisioning.
- LSP tunnels and MPLS paths management.
- QoS, Fitering, Routing Policies Management.
- Surfing at the level of service.

The proposed management system shall support the configuration of the following protocols from GUI without needing to use CLI for each network element:

- OSPF.
- ISIS.
- BGP.
- MPLS.
- LDP.
- IGMP.
- PIM.
- RSVP.

The proposed management system shall allow the following tests at least:

- A complete set of OAM instruments could be configured and launched from GUI without needing to use CLI for each network element.
- Ability to plan that OAM tests would automatically run, without needing the operator intervention.
- OAM tests results to be accessible from GUI.
- OAM tests results to be stored in the management system database.
- Capability to apply multiple OAM tests for a certain object and to program OAM tests in order to be executed at an established moment.

Statistical data collection from network elements are required:

- per-port;
- per-service;
- per-QoS filter;
- per-forwarding class.

The management system will provide statistical data collection at protocol level and graphic displaying in real time of performance statistics.
For statistical data displaying on GUI shall be able their exploitation in HTML or CSV files.

The proposed management system will provide displaying of a map for a physical topology which shows the physical connections between the network elements and maps with topology at the level of service that indicate the logical connectivity of services between nodes.

The access to management system must be sure; user accounts must fulfil the following requirements:

- Control of access on user name and password basis.
- Complex passwords.
- Expiry of a password in a predefined period.
- Ability to automatically block accounts when an unsuccessful logging exceeds a default verge.
- Ability to manually block accounts.
- Ability to monitor current sessions.

- Ability to locate the access and actions of all users.
- Ability to restrict users access to certain operations.
- Ability to restrict users access to certain network areas.

The proposed management system must support firewall between its key components and encrypting of data transmitted between its key computers too.

Alarms management system shall be provided: alarms shall be displayed on GUI in real time and an easy filtering of alarms must be possible in virtue of a few options such as, but without limiting to, alarms severity, production moment, network element etc. Alarms correlation is required: the lower level alarms being correlated with the most important alarms with the highest level.
The proposed management system must permit the following actions at least:

- rising and dropping of alarm intensity in virtue of threshold settings.
- operators to know, to erase or to add text notes associated to individual alarms.
- individual alarms ignoring.
- default settings changing concerning the classification depending on alarms severity.
- easy search inside database containing the history of all alarms

The management system will have to make the difference between alarms triggered at equipments that are already in operation and alarms triggered at equipments that are in process of commissioning.
The proposed management system must provide a database with the history of all alarms that had been erased/cleared away. The dimension of this database must be configurable.

The proposed management system must support the existence of a northbound interface (NBI) for interfacing with OSS systems.

4.11 RESILIENCE AND AVAILABILITY

The system in scope shall guarantee No Single Point of Failure and high availability performance.

Any node shall be carrier class with the common parts fully redundant:

- 1+1 hot backup protection for System control and communication
- 1+1 hot backup protection for Cross-connection
- 1+1 hot backup protection for Power

The Contractor shall indicate the MTBF of each single module of the entire transmission system: a RAMS document is required about all TLC systems.

As the GSM-R radio system is used for safety critical applications, such as operational voice communications between train dispatcher and train driver as well as for automatic train control ETCS, an enhanced redundancy concept for the backbone transmission network is taken into account in this project.

Basically each BTS is connected to the BSC via a logical loop and the protection mechanism is performed at the application level between the BTS and BSC themselves. Therefore two completely independent paths, both from an optical fiber cable and an equipment perspective, are requested within the backbone transport network. As general approach the Backbone Transport Network shall be able and dimensioned to implement network protection schemes for any of the services involved in the network.

4.12 UPGRADEABILITY

Bearing in mind all the existing and foreseeable needs, the backbone Transport Network shall follow the most adapted solutions for short, medium and long term needs.

In particular, the backbone transport architecture shall allow easy configuration modification (addition or removal of a node, of access interfaces, modification of routing) without intervention of the manufacturer.

4.13 ROLL OUT AND TESTING FOR BACKBONE TRANSPORT NETWORK

During roll out of the Network Contract shall provide all spare parts necessaries.

Contractor shall execute with success all tests of standard and of supplier libraries for testing network before delivery.

Contractor shall execute with success all tests to guarantee the compliance with Technical Specifications for Interoperability.

Contractor must give all assurances as provided by law and it shall supply 10% of spare parts.

5 RBC LINK

Radio Block Center RBC of section 1 will be linked with MSC1 and MSC2 through existing SDH network of Brasov.

For this connection adeguate SDH link will be available in Brasov OCC.

A redundant SDH link is available connecting RBC to IP/MPLS network of Brasov –Sighisoara through the other existing SDH connection of Sighisoara.

For the purpose to offer a complete functionality, RBC shall be connected with both MSC for functionality in load sharing, for example in case of failure of MSC, RBC shall switch on the other MSC without human intervention in less than 30 seconds.

6 TRAINING COURSES FOR BENEFICIARY PERSONNEL.

The Contractor shall provide Training about all TLC Systems for CFR personnel in order that the systems would be efficiently operated and maintained. The following subjects will be covered at least:

- GSM-R system use for voice services.
- GSM-R system use for data services.
- Interface with ETCS as a part of ERMTS.
- Operation and maintenance of GSM-R network and use for this purpose of system's management facilities.
- QoS management and use for this purpose of system's management facilities.
- Radio planning for GSM-R network and use for this purpose of system's management facilities.
- Operation and maintenance of IP/MPLS network.
- Cell Site maintenance.
- GSM BSS Performance Management.
- GSM BSS Technical Description.
- GSM BSS Operation and Maintenance.
- GSM OMC-R Administration.
- GSM-R System Technical Description.
- GSM-R BSS Dimensioning.
- GSM-R BSS Parameters Optimization.
- TNMS Operation and Maintenance.
- Measurements for Wireless Networks.

Courses shall be structured in the following steps:

- Training shall be executed in three series and 2 groups containing 6 persons, each will participate for GSM-R network part.
- The first series will mandatory start the training session before works starting.
- Training shall have to contain the services commutation procedure for BSS sub system and interface with and MSC as well, procedure which shall be executed by participants.

All trainings shall be comprise by theoretical and practical courses and each participant shall be attested by a documentation for courses.

7 SYSTEM'S ACCEPTANCE

The Contractor shall provide all TLC systems according with standard specifications mentioned in previous paragraphs.
Moreover to complete the roll out of entire GSM-R and backbone networks acceptance tests are required to verify compliance to technical specifications.
The system's acceptance will be made through the following activities:

- FAT (Factory acceptance test)
- Installation tests
- Functional acceptance
- System's performance acceptance

7.1 FAT (Factory acceptance test)

During first FAT, the Contractor is obliged to test all elements, units and individual pieces of the system in order to be proved the full conformity with the specifications from supplied documents. Beneficiary is entitled to attend all FATs executed by Contractor.

7.2 Installation tests

Tests made at installation are executed in order to be provided the equipments integrity after delivery and installation.
After the execution of these test, the hardware configuration, interoperability of various cards and the fact that installation comply with specifications are validated.
The Contractor will be responsible for testing procedure of all equipments from GSM-R and backbone network.

7.3 FUNCTIONAL ACCEPTANCE

The Contractor will submit a typical functional testing plan of "end-to-end" integrated system; that world contain typical testing situations and their description.
The Contractor will propose a functional acceptance plan for GSM-R and backbone network acceptance. CFR may add additional tests at the proposed plan.
The Contractor will submit the network testing plan with a detailed description of testing situations and eventual requirements regarding CFR involvement in these tests.

7.4 SYSTEM'S PERFORMANCE ACCEPTANCE

For the acceptance testing of system's performance, key performance indicators (KPI) that are determined by the network's specific engineering must be identified.
In this category, the following KPI indicators will be included:

- Call initiation time.
- All other delays.

The Contractor will submit a proposal regarding the manner in which these KPIs will be demonstrated within the context of CFR network. This test proposal will be submitted to CFR for approval.
In the second category of KPIs will be included:

- Radio coverage level.
- Success rates of call initiation.
- Interruption rates of call.

CFR will follow these KPIs in order to assure itself that they will be targeted for the installed network. These KPIs will be calculated on the basis of some accurate measurement practices and on the basis of a statistical specimen of relevant dimension.

For FAT, tests that would execute an adequate exposure of GSM-R network to all requirements will be selected in order to be proved the compliance with effective standards and signed contract. Tests will be structured in order to audit the services necessary for system to operate according to EIRENE standard. Services will be audited in the following order:

a) Voice services:

- point-to-point voice calls;
- public emergency calls;
- broadcast calls;
- group calls;
- conferences.

b) Data services:

- transport service for general data applications.
- transport service for ETCS level 2 application
- call service

c) Call services:

- private users group;
- eMLPP;
- advanced management of calls such as waiting call, call transfer, queue;
- interdiction to make a call or to receive a call;
- call supervisory indications.

d) Specific railway applications:

- location function call;
- call by functional numbering;

- railway operational emergency calls.

e) Specific railway characteristics:
- functional identity displaying;
- execution of rapid and guaranteed call.

All tests will be executed inside installation locations, in the presence of beneficiary. At tests completion, a report which will indicate the test result: passed, failed, delayed will be laid down.

7.5 DOUBLE COVERAGE

Audit of an accurate traffic management in conditions of double coverage is a key requirement of CFR.
CFR wishes to obtain experience regarding system's behaviour in conditions of double coverage. These tests will be executed in nominal module and in spoiled module. In the nominal module, there must be proved that mobile terminal stays in one level in idle manner, in VGCS and in point-to-point call status. In the spoiled module, there must be proved that mobile terminal accurately moves from the spoiled level on a secondary level and it will come back the first. The demonstration must be made not only for idle manner, but also for VGCS and for point-to-point call status.

7.6 OAM PERFORMANCES

The Contractor shall prove the details supplied in his project regarding the procedure and necessary time for detection of a malfunction, returning the system in operation status and alarms erasing (BSS).

7.7 TRAINS FOR TESTS

CFR will make available test trains for a limited number of attempts in order to be executed performance and functional acceptance tests.

8 SERVICES

The Contractor will guarantee that he will give support for the proposed system during its whole lifespan. This support will include software corrections and maintenance services supplying.

If not specified in other sections of tender book, the system's lifespan will be minimum 20 years from the commissioning date.
The Contractor will supply at least the following testing equipments:

- Radio spectrometer.
- Traffic analyzer for transport network.
- Tester for GSM-R terminals.
- OTDR and powermeter.
- GPS with L1/L2 type GPS GNSS RTK Stonex S9 Rover Generation 2.
- 5 toolbox for electronic person including multimeter, soldering station, different tools
- optical fiber welding tool

9 MEASUREMENT SYSTEMS

To guarantee the functionality and monitoring of the entire networks GSM-R ERTMS, an equipments measurement systems shall be foreseen.

The system will aim to monitor and troubleshoot the GSM-R system through a collection and analysis of data, coming from several collection tools.
A test drive and system Monitoring and analysis shall be foreseen:

These Measurement systems shall achieve the following characteristics, at least :

- Synchronized Supervision GSM-R, ETCS and Interlocking subsystems.
- Identification of anomalies with automatic and manual analysis.
- Prevention of inefficiency and analysis of degradation.
- Support for parameters configuration.
- Automatic analysis of daily train rides / trips.
- Reporting of both operational and managerial level.
- Statistics on all services and all network equipment.

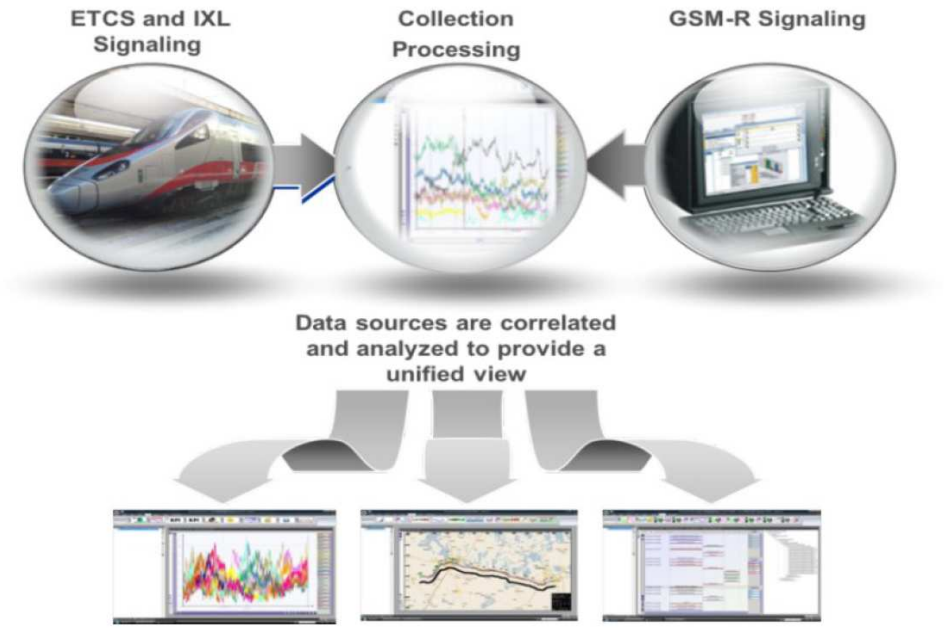

Figure 12 Typical Functionality of Measurement System

9.1 DRIVE TEST SYSTEM

The verification of the RF efficiency and the Quality of Service (QoS) of a wireless communication system is a task that needs to monitor many parameters, in order to verify different aspects and functionalities.

The drive test shall allows to perform different kind of tests and measurements over different technologies and different networks.

This system shall be an effective tool for tracing digital networks, shall collects measurement results and geographical coordinates (with helping of a GPS receiver) and stores them on a hard disk.

Measurement results, shall provide useful information for network tuning, verification, and maintenance purposes. Results shall be efficiently and easily viewed with the Replay functionalities, or analyzed by using a post-processing tool.

The Drive Test system shall be able to manage different devices simultaneously. The system shall provide the following features:

- Real-time data capture
- Multiple devices support
- Independent measurement
- Independent device splitting
- Multi-technology compliancy (ie GSM, GSMR)
- Closed-loop scanners/trace mobile support
- Automated testing procedures with
- Easier export and post-processing
- GIS support
- Accurate RF measurement operating at more than 300 km/h speed
- Voice Quality testing ETSI compliant (PESQ algorithm)

9.1.1 MOBILE SUPPORT

The drive test system will support the widest variety of GSM-R UEs and CAB radios available on the market.

For large part of them it shall supports trace interface to perform engineering campaigns and ordinary AT command as well to use them as common UEs.

They shall be combined in tests in any number and any possible configuration to perform test from simple coverage to multiple handset benchmarking.

9.1.2 HW Configurations

It shall be provided with a wide variety of possible configurations, depending on requirements in terms of :

- Test to be performed
- Scenarios to be implemented
- Portability requirements
- Terminal type

Figure 13 Typical Measurement System

9.2 MONITORING AND ANALYSIS SYSTEM

9.2.1 (BSS) SUB-SYSTEM

The Monitoring and analysis system shall provide a combination of analysis accuracy and process automation like:

- Automatic Call Drop analysis due to on-board systems, ground systems or GSM-R network
- Handover control, testing wrong sequences, release not due to better cell or ping-pong
- Call Setup overview in terms of time needed to establish connection, availability of signallling channels and traffic channels
- Interference detection due to co-channel, adjacent channel or third party.

The BSS System shall provide a wide range of KPIs typical, it shall allows at the same time to separate common traffic counters from ETCS counters being the last subdue to a wider range of constraints.

All measurements, events and KPIs shall be displayed on maps, charts, ladder diagrams or tables.

All layouts shall be synchronized and measurements are geo-located and correlated to their position along the track.

Furthermore the system shall suggest possible malfunction causes speeding up the troubleshooting.

9.2.2 MONITORING ETCS SYSTEM

ETCS system shall provide process automation and system intelligence to perform:

- Automatic odometry testing
- Highlight missing information points
- Hotspot TNV Contact timeouts
- Analyse RBC Handover, particularly those performed with the same MT
- Check TSR (Temporary Speed Restrinction) threshold override within the same movement authority
- Test acknowledge within the same Movement Authority of CES and UES messages
- Verify Movement Authority reduction due to occupied stretch
- General train trip analisys

9.2.3 MONITORING IXL SYSTEM

IXL system shall provide process automation and system intelligence to perform test, monitor and troubleshooting for the interlocking interface

9.3 GLOBAL FEATURES

The collection and analysis system, shall submit various subsystems, treated below.

9.4 DATA COLLECTION

The systems shall collect a great set of functionality specifically for railways operators.
In the figure below there is a schematic view of all that the systems shall analyze.

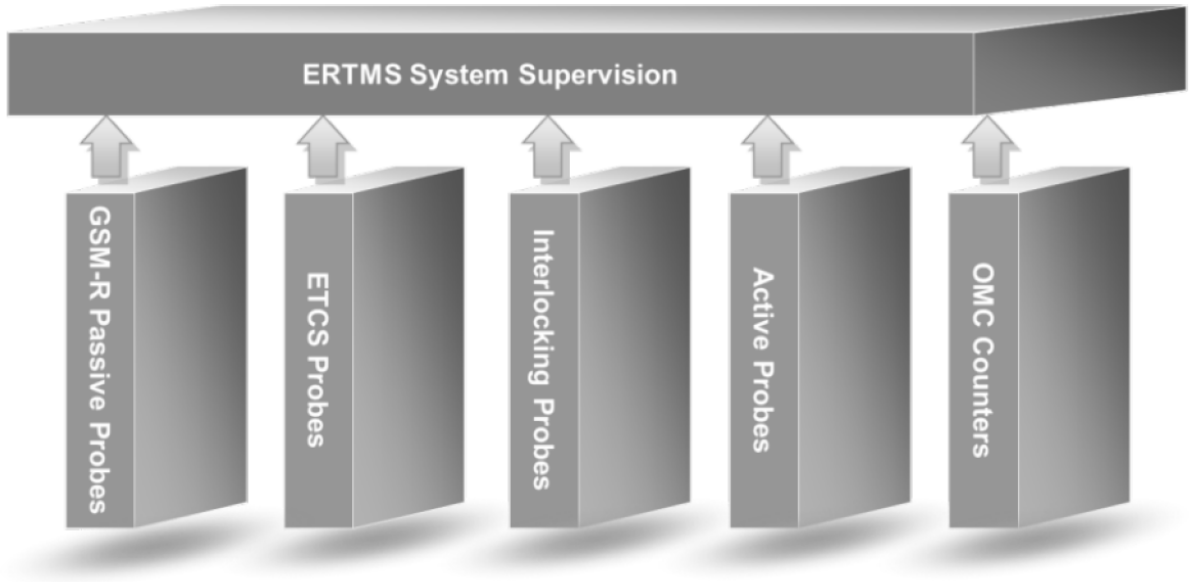

Figure 13 Typical functionality of probes

9.5 PASSIVE PROBES

System shall have a module to capture the messaging exchanged between GSM-R /ETCS/ IXL network devices.

9.6 ACTIVE PROBES

The system shall have the possibility to generate artificial traffic to stimulate the network and verify its response.
Shall have the possibility to monitor GSM-R service and roaming partners or to benchmark telecom operators service coverage.

9.7 ACQUISITION SYSTEM

Measurement System shall be able to monitoring the following GSM-R ERTMS subsystems:
The system shall monitor all the interfaces that converge on a single or more than one network element.

1. **GSM-R SUBSYSTEM**

Interface	Between
Abis	BSC-BTS
A	BSS-MSC
IN	MSC and SCP
B	MSC-VLR
C	GMSC-HLR or SMSG-HLR
D	HLR – VLR
E	MSC- MSC
Gb	PCU –SGSN
Gn	SGSN - GGSN
Gi	GGSN external

2. **ETCS SUBSYSTEM**

   The system shall monitor all the interfaces b/w the MSCs with RBCs to identify the connections established by the convoys for the whole length of the route monitored (RBC-MSC).

3. **IXL SUBSYSTEM**

   The system shall monitor all connections between the information points and Euro-Balises alongside the track and RBCs to identify state changes that occurred along the line.
   The flow of data acquired will be correlated with other signals, to obtain an unified of ERTMS.

4. LEGAL DATA RECORDER

The system shall import, analyze and correlate data recorded from the Legal Data Recorder or any other chronological recorder certified and installed in operator's backhaul.

5. ON BOARD LOGS

The system shall import, analyze and correlate data recorded at the EVCs.
It will be necessary to implement a mechanism to acquire from the convoys the files generated from a central site from which it is possible to proceed with the import.

6. CORRELATION OF CALL MESSAGE FLOWS

The acquisition systems shall recognizes the stream from a different GSM-R ETCS subsystems.

The correlation shall be:

- For GSM-R voice or data calls on interfaces A,Abis and eventually on all other involved interfaces: B,C,D,E.
- For a packet switched connection GB, Gi and Gn.
- For ETCS data calls on the ISDN interface between the MSC and RBC with the de3coding and the temporal correlation of the ETCS traffic with the GSM-R one.
- For ETCS calls, shall be required to verify on the network interface towards the interlocking, the relationship of the messages from Eurobalises or beacons with ETCS flow.

This relationship allows to reconstruct the flow of all messaging belonging to a specific call be it voice, data, packet or ETCS.

9.8 POST PROCESSING PLATFORMS

The system shall collect the measurement from :

- Capturing system (Probe/s)
- Existing platforms (LDR, OMC-R, etc.)
- Field measurement

After data import shall perform the following parameters:

- Measurements storage.
- Data analysis.
- Alarm management.
- Report generation

- Queries generated by client platforms.

9.9 ANALYSIS LAYERING DEPENDING ON USER SKILLS

According to training course, the system shall have a layered approach to allow unskilled personnel to access the system and get a summary idea of how the network is performing.

9.10 ANALYSIS PERSPECTIVES

The systems shall be able to analyze, real traffic, user traffic, fault and anomalies.
In the figure below there is an example of analysis perspective of the entire system.

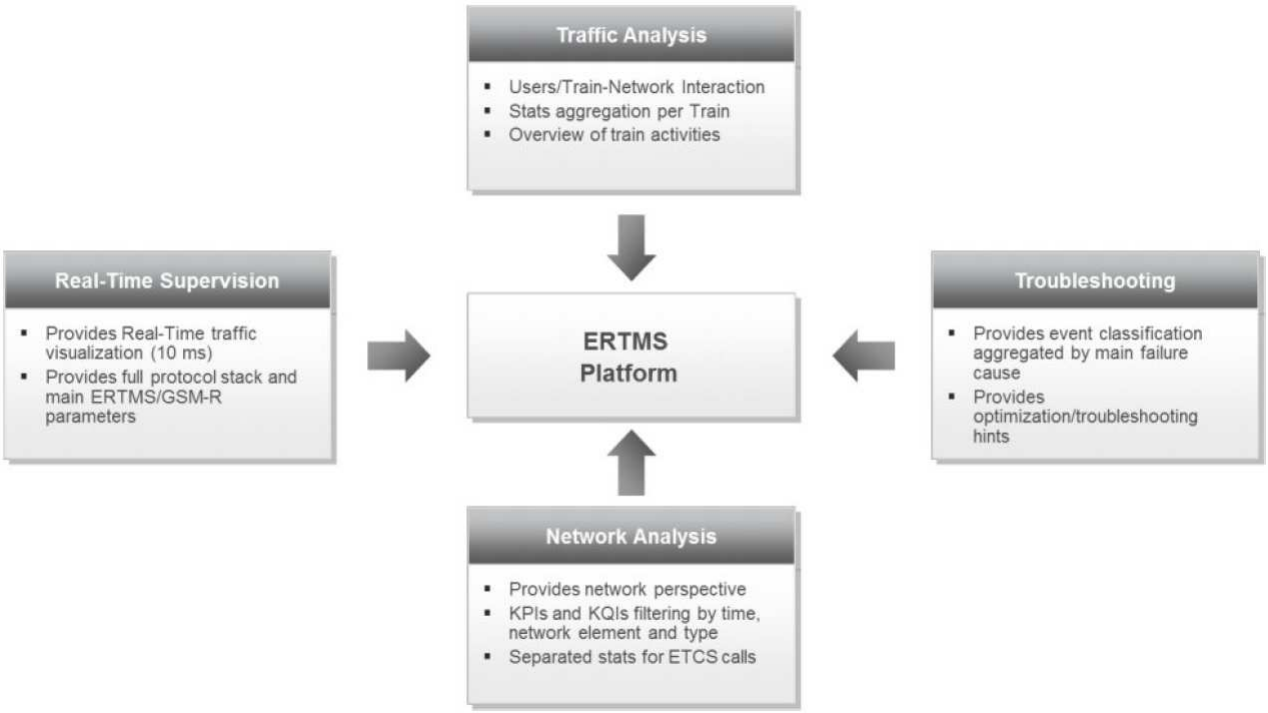

Figure 14 example of analysis perspective

10 INSTALLATION AND COMMISSIONING

This service presupposes the physical installation of equipments supplied by the Contractor in each access location or core .

The Contractor shall provide installation and commissioning supervision. At first commissioning (first site), the Contractor will lay down a proposal regarding the acceptance model; this proposal that must be subject for CFR approval. All further commissioning must be made on the basis of model approved by CFR.

After each commissioning, bidder must lay down a folder that must contain the most important documents for installed equipments. Folder will contain cabling and installation plans as well as the used settings. At each commissioning, CFR personnel must also attend.