ERTMS

Functional Requirements Specification

ETCS Traffic Generator & Application Simulator

Author	EoG project team
Version	1.2
Date	7 June 2021
Status	Final

Contents

1. Introduction

1.1 ProRail background

ProRail B.V. (hereinafter: ProRail) is responsible for the railway network in the Netherlands: construction, maintenance, management, and safety. ProRail's staff ensures 24/7/365 that every day 1,200,000 passengers and 100,000 tons of cargo reach their destination by supporting 6550 trains over 7000 kilometres of railway track. The railway network truly is the beating heart of mobility in the Netherlands.

ProRail continually works to ensure mobility in the Netherlands by providing an optimal railway network. It distributes the capacity available on the railway network, controls all rail traffic, builds and manages stations, and constructs new railway lines. Additionally, ProRail is responsible for maintaining existing infrastructure, such as rail tracks, switches, signals, and railway crossings.

ProRail makes an important contribution to keeping the Netherlands mobile. To achieve this, it cooperates with passenger and cargo carriers, while ensuring that the interests of their customers are kept in mind. In cooperation with municipalities and provinces, ProRail considers how to best meet their demands for rail transportation and station facilities.
In order to prepare for the future, ProRail focusses on three ambitions:

- ProRail connects: increased mobility.
- ProRail improves: more reliable mobility.
- ProRail aims for sustainability: more sustainable mobility.

ProRail contracts activities that may be performed by market parties. ProRail focuses on specifying contract requirements, ensures a competitive environment, and manages the various contracts. For this purpose, ProRail has defined a contracting policy.
Contracting must focus on achieving cost-effective results. With new constructions, maintenance and the delivery of products and services, ProRail aims for quality and functionality at a reasonable price, as well as the highest possible return in terms of availability, reliability, and safety of the railway network. At the same time, ProRail aims for non-disruptive day to day operations. Finally, ProRail aims to make optimal use of the innovative potential in the market, focusing on continuous development to achieve improved forms of collaboration with market parties.

1.2 GSM-R

In the Netherlands ProRail owns and operates the Dutch GSM-R network. The daily operation has been outsourced. The network is used by a variety of customers (users) and applications, such as:

- European Train Control System (ETCS).
  As part of ERTMS, GSM-R provides the data communication bearer between the train and the track side systems.
- Railway safety communication.
  Voice communication between drivers and controllers including railway emergency communication.
- InfoPlus.
  GSM-R provides the communication bearer for the travel information system to inform passengers on departure times at railway stations and platforms.
- Service & Alarm poles.
  Voice communication to passengers on platforms and data communication to monitor the status of the poles.

- Various telemetry systems and alerting services.
  Examples are monitoring of objects, Service & Alarm poles, alerting systems on red light passage and switch heating.

In total, approximately 20.000 GSM-R users are active. The national network comprises approximately 400 BTS sites.

1.3 ERTMS

The railway sector in the Netherlands has chosen for a phased introduction of ERTMS. The objective of ERTMS is to contribute to a safe, reliable, punctual and sustainable railway operation. The five objectives of the ERTMS program are to support, improve and enhance: safety, interoperability, reliability, higher train speeds and capacity.

Figure 1 ERTMS deployment in the Netherlands

ERTMS will be realised from 2021 to 2031 on the following lines:

- Kijfhoek – Roosendaal – Belgium border
- OV SAAL (oost)
- Hoofddorp – Schiphol – Duivendrecht (OV SAAL west)
- Utrecht – Meteren
- Roosendaal – Den Bosch
- Eindhoven – Venlo – German border
- Meteren – Eindhoven

Early deployment for testing is foreseen on the Hanzelijn:

- Proefbaanvak Hanzelijn

Deployment is also foreseen on the Northern lines in the Netherlands:

- Early deployment line Harlingen Haven – Leeuwarden
- Northern lines (around Groningen and Leeuwarden)

The first steps (test, pilot, training) towards commercial operation are planned in 2022/2023 (Hanzelijn and Amsterdam – Utrecht). Full commercial operation starts from 2026 onwards.

ProRail plans to deploy ETCS level 2.

1.4 ETCS over GPRS (EoG)

For the deployment of ERTMS in the Netherlands two aspects related to the quality of train to track data communication are crucial:

- Provisioning of sufficient GSM-R capacity to facilitate ETCS data communication.
- Quality of the end-to-end communication link from train to track (performance) to fulfil the performance requirements of the train transport system.

The main measure to mitigate the risk of insufficient capacity and quality is the deployment of ETCS over (enhanced) GPRS further denoted as EoG.
EoG will be verified and validated in an EoG pilot project as part of the ERTMS program. The EoG pilot project is a cooperation between ProRail ICT and ProRail AM. In order to verify and validate the capacity and quality of the GSM-R network, a Traffic Generator & Application Simulator (TGAS) is necessary. The TGAS System is subject of this tender.

2. Scope and objective

2.1 Scope

2.1.1.1. This document describes the requirements of an ETCS Traffic Generator & Application Simulator (TGAS).

2.1.1.2. ERTMS uses GSM-R as a bearer for data communication. The supported CCS TSI version is Baseline 3 Release 2. This version includes the service ETCS over (enhanced) GPRS (EDGE).

2.2 Objectives

2.2.1.1. The objectives of the ETCS Traffic Generator & Application Simulator are:

1. To simulate ETCS application message transmission and reception in a live network in order to be able to verify the performance on ETCS application level.
2. To verify the limits of GSM-R operation by generating traffic volumes to such levels that the maximum capacity of GSM-R at cell level is reached.
3. To demonstrate that ETCS Quality of Service levels are maintained under a variety of traffic load conditions.
4. To acquire knowledge and understanding about ETCS application- and GSM-R network parameter settings for tuning and performance optimisation.

2.3 Compliancy

2.3.1.1. All sections or paragraphs in this document (earmarked with a numerical identification) contain either requirements or information (for explanation or illustration).

2.3.1.2. Requirements are indicated by the reference **(R)** after the relevant paragraph.

Informative statements are identified by the reference **(I)**.

2.3.1.3. The tenderer must indicate for each paragraph whether it is compliant. The tenderer shall provide a Statement of Compliance (SoC) for this purpose.

2.3.1.4. For each paragraph compliancy shall be classified as follows:

a. Compliant (for paragraphs indicated with reference **(R)**

b. Understood (for paragraphs indicated with reference **(I)**

3. Definitions

Acronym	Description
BTS	Base Transceiver Station
CCS TSI	Technical Specification of Interoperability for Control, Command & Signalling
CS	Circuit Switched
DUT	Device Under Test
EDGE	Enhanced Data Rates for GSM Evolution
EDOR	ETCS Data Only Radio
EGPRS	Enhanced GPRS
ETCS	European Train Control System
EoG	ETCS over GPRS
FFFIS	Functional Form Fit Interface Specification
FTP	File Transfer Protocol
GPRS	General Packet Radio Service
GM	General Message
IP	Internet Protocol
Iperf	Iperf is a tool for network performance measurement and tuning.
IPv4	IP version 4
KMC	Key Management Control
MA	Movement Authority
MSS	Maximum Segment Size
MTU	Maximum Transfer Unit
OBU	Onboard unit
PR	Position Report
PS	Packet Switched
QOS	Quality of Service
RBC	Radio Block Centre
RF	Radio Frequency
sFTP	Secure File Transfer Protocol
SoC	Statement of Compliance
TC	Trackside Control
TCP	Transmission Control Protocol
TGAS Application Simulator (or TGAS AS)	Onboard module of the TGAS System used for ETCS application simulation
TGAS Maintenance System	The TGAS Maintenance System facilitates (remote) maintenance for all TGAS modules
TGAS Module	A TGAS Module is the generic name of either a TGAS Traffic Generator or a TGAS Application Simulator or a TGAS Trackside Responder
TGAS Onboard Module	Generic name for a TGAS Application Simulator or a TGAS Traffic Generator
TGAS System	A TGAS System consists of all TGAS Modules (i.e. Traffic Generator, Application Simulator, Trackside Responder) and the TGAS Maintenance System.

Acronym	Description
TGAS Trackside Responder (or TGAS TR)	The TGAS Trackside Responder is a device at the fixed network side which communicates with Traffic Generator and Application Simulator.
TGAS Traffic Generator	Onboard module of the TGAS System used for traffic generation
UDP	User Datagram Protocol
UTC	Universal Time Coordinated

4. References

Reference	Version	Title
[EURORADIO]	V13.0.0	Radio Transmission FFFIS for EURORADIO
[EIRENE SRS]	V16.0.0	GSM-R system requirements specification
[SUBSET-093]	July 2021 (expected)	GSM-R Bearer Service Requirements SUBSET-093
[O-2475]	July 2021 (expected)	ERTMS/GSM-R Quality of Service Test Specification
[SUBSET-037]	V3.2.0	EURORADIO FIS including changes of the Technical Opinion (OPI 2020-2) to address error corrections to the CCS TSI
[Sustainability]	-	Bijlage 1_1 Duurzaamheid

5. TGAS use cases

5.1.1.1. The TGAS Traffic Generator will be used in a test train to generate traffic with the objective to test, verify and validate the capacity of the GSM-R GPRS EDGE network along the track. **(I)**

5.1.1.2. The TGAS Traffic Generator will be used to determine fulfilment of EoG KPIs of a Device Under Test (DUT). The DUT is for example an unattended probe performing SUBSET-093 measurements or an ETCS Onboard (in real operation or under test). The DUT itself is beyond the scope of this specification. The TGAS Traffic Generator can be located in a train and/or nearby a GSM-R BTS. **(I)**

5.1.1.3. The TGAS Application Simulator (in combination with the TGAS Trackside Responder) will be used in a test train and lab environment to simulate the ETCS application. The objective is to determine the ETCS application and performance characteristics and KPIs. **(I)**

6. Generic overview of the TGAS System

6.1.1.1. The TGAS System provides two main functions:

a. Traffic Generator function: **(R)**
   TGAS will be used for generating PS traffic (scalable in volume) on the GSM-R network. The purpose is to demonstrate that an ETCS Onboard (which includes ETCS Data Only Radios (EDORs)), supporting ETCS over GPRS and using the same network, still fulfils QoS requirements under various traffic load conditions and that the GSM-R network is able to offer sufficient capacity.

b. ETCS Application Simulation function: **(R)**
   TGAS will be able to send and receive (simulated) ETCS application messages similar to Position Reports, General Messages and Movement Authorities from train to trackside and vice versa. The sequence and timing of events (receiving and sending messages) and the dialogue with the TGAS Trackside Responder is configurable.

6.1.1.2. The TGAS System consists of a TGAS Traffic Generator, TGAS Application Simulator,

TGAS Trackside Responder and TGAS Maintenance System. An overview of the architecture is shown in Figure 2. **(I)**

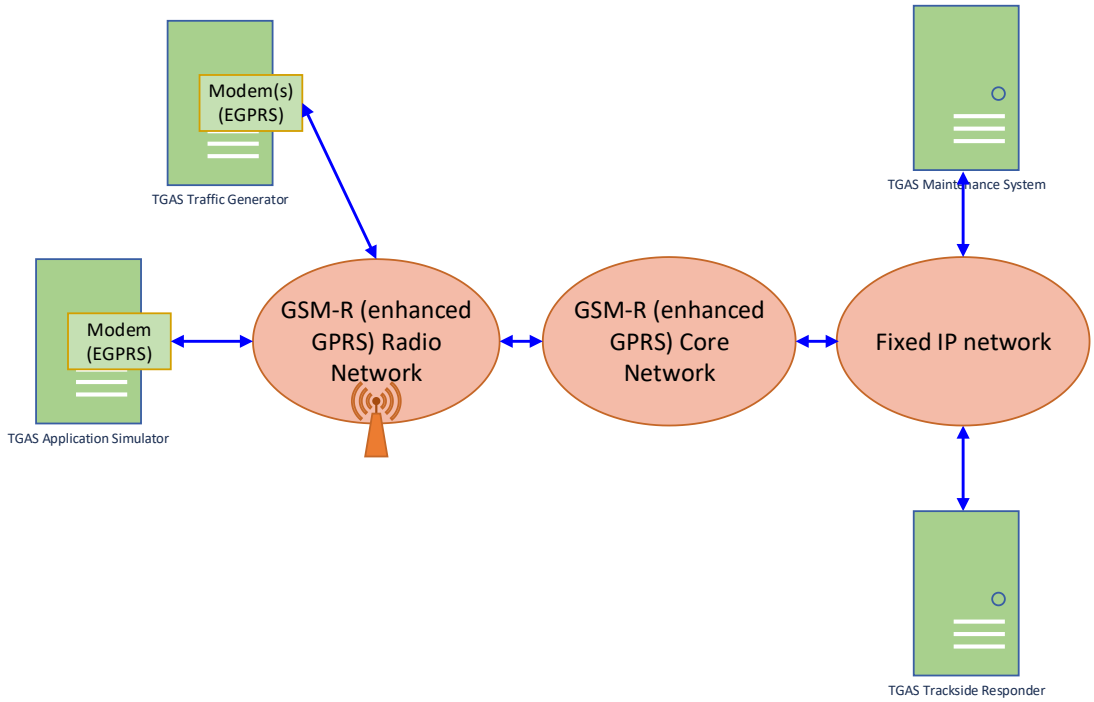

Figure 2 TGAS System overview

6.1.1.3. The TGAS System shall support packet switched traffic only. **(R)**

6.1.1.4. The TGAS System shall be able to generate traffic with a profile similar to ETCS traffic and other types of PS traffic. **(R)**

6.1.1.5. The TGAS System shall be able to simulate traffic as if this traffic is generated by multiple other ETCS trains and GSM-R users along the track. **(R)**

6.1.1.6. The TGAS Traffic Generator consists of a server connected to multiple EGPRS modems as shown in Figure 3. **(R)**

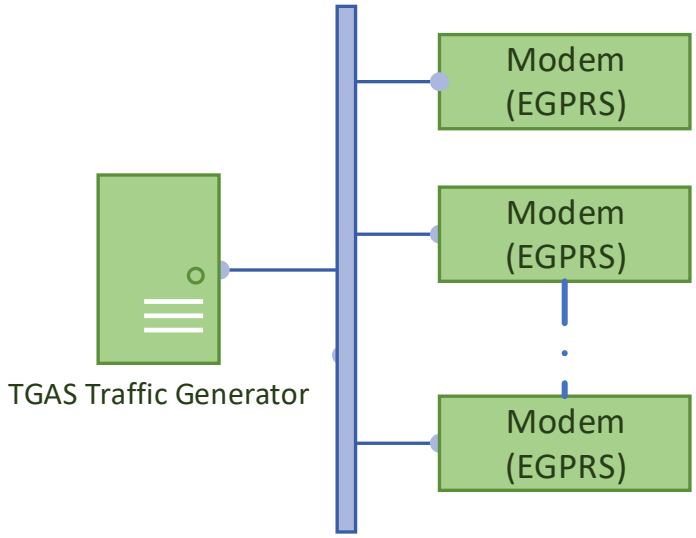

Figure 3 TGAS Traffic Generator

6.1.1.7. The modem in the TGAS Traffic Generator shall support enhanced GPRS with multislot operation. The modem shall support PS requirements of EDOR as specified in the GSM-R EIRENE SRS ([EIRENE SRS]). It is allowed that the interface between TGAS Traffic Generator and modem is proprietary (e.g. supports ethernet). **(R)**

6.1.1.8. The TGAS Application Simulator consists of a server connected to a single EGPRS modem with a serial (EURORADIO) interface. **(R)**

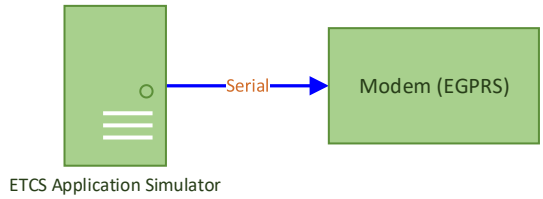

Figure 4 TGAS Application Simulator

6.1.1.9. The modem in the TGAS Application Simulator shall support enhanced GPRS with multislot operation. The modem shall support PS requirements of EDOR as specified in the GSM-R EIRENE SRS ([EIRENE SRS]). **(R)**

6.1.1.10. The two main functions of the TGAS System (i.e. Application Simulation and Traffic Generation) may be provided as an integrated system (i.e. a system combining the functions) or by a system comprising separate hard- and software modules. The level of integration is not further specified here and is considered to be vendor specific. **(I)**

6.1.1.11. It shall be possible to use the TGAS Traffic Generator and the TGAS Application Simulator at the same time. **(R)**

7. TGAS Traffic Generator

7.1.1.1. ProRail uses GSM-R packet switched traffic for a variety of packet switched applications (not only for ETCS).
The TGAS Traffic Generator shall be able to generate different types of traffic:

a. TCP traffic with a traffic pattern similar to ETCS PS traffic. **(R)**

b. TCP traffic (e.g. variable length IP packet transfer and file transfer). **(R)**

c. UDP traffic. (e.g. variable length IP packet transfer). **(R)**

With this mixture of generated traffic profiles, a train station environment can be emulated.

7.1.1.2. The TGAS Traffic Generator shall consist of five GPRS EDGE modems as a minimum. **(R)**

7.1.1.3. The TGAS Traffic Generator shall be able to emulate traffic as if it is generated by 10 ETCS capable trains with 20 emulated TCP/IP sessions in total (simulation of one session to the RBC and one to the KMC). **(R)**

7.1.1.4. Each modem shall support 4 simultaneous TCP/IP sessions as a minimum. **(R)**

7.1.1.5. Each TCP/IP session for ETCS shall be capable of transferring 4 Kbps of (emulated) ETCS traffic in up- and downlink. **(R)**

7.1.1.6. The Traffic Generator shall support a cumulative throughput of 400 kbps (downlink) and 100 kbps (uplink) as a minimum. **(R)**

7.1.1.7. Each TCP session shall be able to generate a minimum of 30 emulated ETCS messages (TCP packets) per minute in the uplink. **(R)**

7.1.1.8. Each TCP session shall be able to generate a minimum of 15 emulated ETCS messages (TCP packets) per minute in the downlink. **(R)**

7.1.1.9. Each modem shall be able to generate the maximum traffic for upload and download according to the GPRS EDGE specification (coding scheme MCS-9). This corresponds with approximately 60 kbps/timeslot. **(R)**

7.1.1.10. It shall be possible to generate maximum EGPRS/EDGE traffic using all GSM timeslots for all modems simultaneously. **(R)**

7.1.1.11. The TGAS Traffic Generator shall be capable of generating TCP/UDP traffic based on Iperf. **(R)**

7.1.1.12. The TGAS Traffic Generator shall support Iperf functionality as detailed in https://iperf.fr/iperf-doc.php (binaries and documentation). **(R)**

7.1.1.13. Iperf main functionality shall be supported. As a minimum: **(R)**

a. Generation of IPv4 traffic (TCP and UDP).

b. Bandwidth adjustment.

c. Jitter and delay measurements.

d. Adjustment of maximum MTU size of MSS.

e. Perform tests with a specific TCP or UDP port

f. Setup multiple TCP/UDP streams between nodes.

g. Apply QOS values and monitor QOS behaviour.

7.1.1.14. It shall be possible to configure the TGAS Traffic Generator as an Iperf client (and the TGAS Trackside Responder as an Iperf server). **(R)**

7.1.1.15. It shall be possible to reverse the initiation of Iperf traffic between the TGAS Traffic Generator and the TGAS Trackside Responder. **(R)**

7.1.1.16. The TGAS Traffic Generator shall be capable of performing file transfers based on sFTP. **(R)**

7.1.1.17. The TGAS Traffic Generator shall be able to simultaneously support TCP/IP simulated message transfer, UDP/IP, Iperf and sFTP information exchange. **(R)**

7.1.1.18. It shall be possible to configure (per TCP/IP session): **(R)**

a. The size of IP packets (payload length).

b. The frequency of sending IP packets (number of packets per minute).

c. A random time interval between transmission of two consecutive packets. The time interval shall range from 1 to 600s.

7.1.1.19. It shall be possible to configure, upload and activate a test script for traffic generation which is automatically executed: **(R)**

a. A test script contains a sequence of commands/primitives for traffic generation which are executed sequentially.

b. Scheduling of test script activation at a specific time/date shall be possible.

c. Scheduling of test script activation when passing a specific location (geographic fence) shall be possible.

d. It shall be possible to define and activate multiple test scripts which may run simultaneously.

7.1.1.20. Uploads of scripts shall be possible (i.e. send scripts from TGAS Maintenance System to TGAS Traffic Generator and TGAS Trackside Responder). **(R)**

7.1.1.21. A test scripts consists of a series of commands (with parameters, such as message size, frequency of transmission, time interval) executed at a relative time (elapsed time relative to the start time of the script). Commands are: **(R)**

a. Initiate or terminate TCP session (for message transfer as specified in par. 8.1.1.5).

b. Initiate or terminate UDP session.

c. Initiate or terminate Iperf measurement.

d. Initiate or terminate sFTP session.

7.1.1.22. The content of a test script is for example: **(I)**

a. At t=0s, setup TCP connection and transfer 10 messages per minute (with length 100 bytes) to the TGAS Trackside Responder.

b. At t=60s, setup an sFTP session and transfer 10 Mbyte of data.

c. At t=100s, setup a second TCP connection and transfer 20 messages per minute (with length 1000 bytes) to the TGAS Trackside Responder.

d. At t=120s, perform Iperf measurement.

e. At t=500s, setup UDP connection and transfer 40 messages per minute (with length 10 bytes) to the TGAS Trackside Responder.

f. At t=6000s, terminate all TCP and UDP connections.

8. TGAS Application Simulator

8.1 General requirements

8.1.1.1. The TGAS Application Simulator will be used to test and verify a connection similar to a connection that an ETCS onboard will experience. With the TGAS Application Simulator trust is built that a real ETCS application is able to meet the expected performance. **(I)**

8.1.1.2. The TGAS Application Simulator shall be capable of sending a pattern of ETCS like messages over packet switching (enhanced GPRS). **(R)**

8.1.1.3. The TGAS Application Simulator shall be able to send control and command messages for error handling and controlling the TGAS Trackside Responder. **(R)**

8.1.1.4. The TGAS Application Simulator communicates in an interactive TCP/IP session with the TGAS Trackside Responder. **(R)**

8.1.1.5. The TGAS Application Simulator shall be capable of transmitting the following application messages: **(R)**

a. Position Report (PR).

b. Acknowledgement (AK).

c. Trackside Responder Control (TC).

d. Error message (ER).

8.1.1.6. The first two messages are similar to the corresponding ETCS messages. The TC message is used to control the TGAS Trackside Responder. The ER message is used to indicate errors and failures. **(R)**

Note:
The TGAS Application Simulator does not support an ETCS Safety Layer or ETCS protocol stack. **(I)**

8.1.1.7. The TGAS Application Simulator controls its modem via AT commands. A TCP stack is used for transferring application messages in user data packets. **(R)**

8.1.1.8. A TGAS application message is embedded in a TCP segment as TCP payload. **(R)**

8.1.1.9. The interface between the TGAS Application Simulator and its modem shall be serial. The interface shall at least support all AT commands of the PS part of the EURORADIO FFFIS (refer to [EURORADIO]). **(R)**

8.1.1.10. It shall be possible to specify the transmission frequency of application messages and the time interval between transmission of those messages. **(R)**

8.1.1.11. It shall be possible to randomise the application message length and the time interval between the transmission of application messages. **(R)**

8.1.1.12. The TGAS Application Simulator shall provide means to simulate data path loss (e.g. lack of GPRS or RF coverage). **(R)**

8.1.1.13. All communication events (including message transmission) shall be logged with content and timestamp for later analysis. **(R)**

8.1.1.14. Log files shall periodically be reported to the TGAS Maintenance System. **(R)**

8.1.1.15. The TGAS Application Simulator shall be able to setup multiple simultaneous TCP/IP sessions (a minimum of 10 simultaneous sessions shall be supported). **(R)**

8.1.1.16. The behaviour of the TGAS Application Simulator shall be controlled with a specific script for a planned test. **(R)**

8.1.1.17. The following commands and responses shall be supported as a minimum: **(R)**

a. GSM-R Network Registration and deregistration.

b. GPRS attach (two different APNs shall be supported) and detach.

c. PDP Context Activation and deactivation.

d. PS Service Setup.

e. DNS queries and responses.

f. Data transfer (TCP).

8.1.1.18. The TGAS Application Simulator shall support DNS conform Subset-037. **(R)**

a. Send DNS requests.

b. Receive DNS responses.

8.1.1.19. The TGAS Application Simulator shall be able to read the TXT field of a DNS response and retrieve and store its content (conform [SUBSET-037]) in a log file. **(R)**

8.1.1.20. The TGAS Application Simulator shall be capable of reading the TCP parameter values in the DNS response TXT field and dynamically adjust the TCP parameters of its TCP stack accordingly. **(R)**

8.1.1.21. The response to the ETCS DNS query contain a TXT field which is used for suggested specific transmission protocol parameters. **(I)**

8.1.1.22. Specific TCP parameters are indicated by the "tp" named list of the DNS record's TXT field. Each entry of this list matches, in order, to a TCP parameter which is s "configurable per connection". I.e. for "tp=<p1>,<p2>,<p3>,<p4>,<p5>;" the following correspondence holds (refer to [SUBSET-037]): **(R)**

a. <p1> : TcpKeepAliveTime

b. <p2> : TcpKeepAliveInterval

c. <p3> : TcpKeepAliveProbes

d. <p4> : TcpUserTimeout

e. <p5> : Max TCP segment size

8.1.1.23. The TGAS Application Simulator shall be capable of monitoring and log GSM-R radio layer messages (GSM-R L3 messages). **(R)**

8.1.1.24. It shall be possible to switch GSM-R L3 logging on or off (configuration action by the TGAS Maintenance System). **(R)**

8.2 TGAS Application Simulator script requirements

8.2.1.1. It shall be possible to configure, upload and activate a test script for application simulation which is automatically executed: **(R)**

a. A test script contains a sequence of commands/primitives for application simulation which are executed sequentially.

b. Scheduling of test script activation at a specific time/date shall be possible.

c. Scheduling of test script activation when passing a specific location (geographic fence) shall be possible.

d. It shall be possible to define and activate multiple test scripts which may run simultaneously.

8.2.1.2. Uploads of scripts shall be possible (i.e. send scripts from the TGAS Maintenance System to the TGAS Application Simulator). **(R)**

8.2.1.3. A test scripts consists of a series of commands (with parameters, such as message size, frequency of transmission, time interval) executed at a relative time (elapsed time relative to the start time of the script). Commands are: **(R)**

a. Initiation of AT commands over the serial interface (e.g. GPRS attach/detach, PDP context activation/deactivation).

b. Initiate and terminate TCP session.

c. Send and receive DNS requests and responses.

d. Send an Application Message (TCP) with a defined content.

e. Respond to an Application Message (received from the TGAS Trackside Responder) if required.

f. Initiate cyclic transmission of PR messages to the TGAS Trackside Responder (the time interval between transmission of messages can be fixed or randomised, as well as the PR message length, the parameters of transmission are defined in Table 2).

8.2.1.4. In case of acknowledged cyclic message transmission (PR messages) a retransmission scheme shall be applicable. If a (configurable) guard time expires before the corresponding AK message has been received, the original message is retransmitted (up to a configurable number of times). **(R)**

8.2.1.5. It shall be possible to enable or disable the retransmission scheme. **(R)**

8.3 Interaction between TGAS Application Simulator and TGAS Trackside Responder

8.3.1.1. The initiative of establishing a communication session for ETCS application simulation resides with the TGAS Application Simulator. The TGAS Application Simulator always takes the initiative to setup a TCP/IP connection. **(R)**

8.3.1.2. The TGAS Application Simulator invokes an application simulator script which starts by setting up a TCP/IP connection with the TGAS Trackside Responder and starts exchanging application messages. The format of the messages is defined in par. 8.4. **(R)**

8.3.1.3. The TGAS Trackside Responder receives those messages and depending on the content invokes one of the following specific actions: **(R)**

a. Responds to a received message with an ACK message.

b. Responds to a received message with an ER message in case of an error.

c. Initiates a message exchange to simulate transfer of General Messages.

d. Initiates a message exchange to simulate transfer of Movement Authorities.

e. Evaluates the content of a received TC message or MessageCommand field (in a PR message) and takes action (e.g. reset an application session, terminate a process etc.).

8.3.1.4. A typical example of such an information exchange is shown in Figure 5. **(I)**

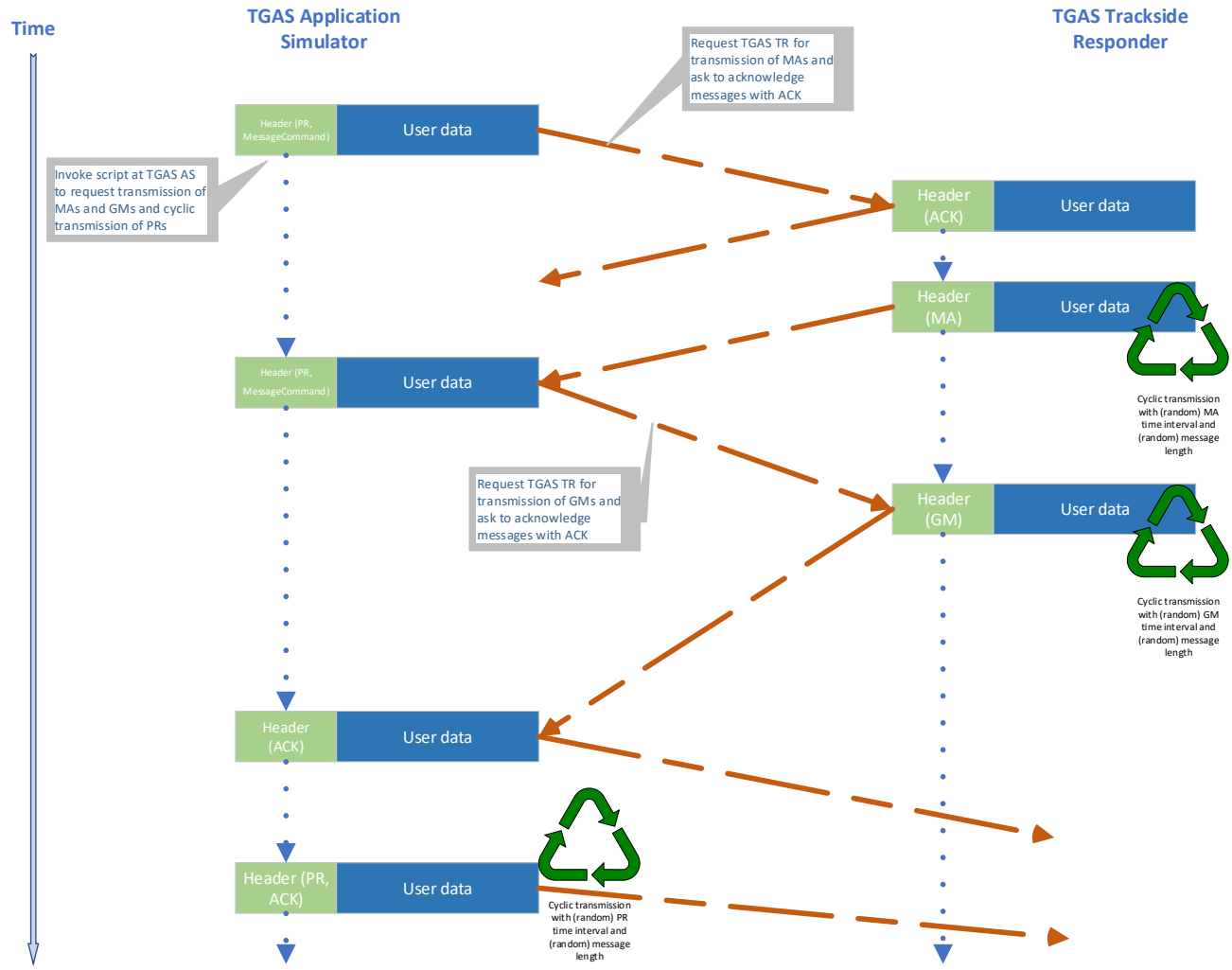

Figure 5 Interaction between TGAS Application Simulator and TGAS Trackside Responder

8.3.1.5. The message exchange is governed by a SessionID. Messages with the same SessionID have a specific relationship and belong to the same "train". **(R)**

8.3.1.6. Each TCP/IP connection corresponds with a single Session in a 1-1 relationship. **(R)**

8.4 TGAS Application Simulator message format

8.4.1.1. Application messages (TCP user data) shall consist of header data and user data of variable length. **(R)**

8.4.1.2. All header fields and user data are coded as alphanumeric characters (in single octets, ASCII coding). **(R)**

8.4.1.3. An application message is composed of: **(R)**

a. A Header with fixed and variable length fields.

b. A user data field.

8.4.1.4. Message structure: **(R)**

Table 1 TGAS Application Simulator message structure

Field name	Format	Range	Description
SessionID	Fixed length of 2 characters	00 to 99	Identification of a session. A sessions is intended to emulate the ETCS traffic of a train.
MessageID	Fixed length of 2 characters	MA GM AK PR TC ER	Identification of message. MA, GM, AK and PR are "ETCS" application messages. TC is a control message intended to instruct the TGAS Trackside Responder to perform a certain action. In case of occurrence of a failure MessageID = ER will be returned.
MessageLength	Fixed length of 3 characters	000 to 999	Total length of message (including header and user data)
Timestamp	Alphanumeric, fixed length of 17 characters in the following format YYYYMMDDHHMMSS mmm	Character sequence consisting of Year, month, day, hour, minute, second, millisecond	Timestamp of message transmission, UTC time, resolution 1 millisecond.
M_ACK	Alphanumeric, fixed length of 1 character	0 (no AK required) 1 (AK required)	Indicator for requesting an Acknowledgement Message. If set (M_ACK = 1) the opposite side (onboard or trackside) is required to respond with an Acknowledgement message (AK).
MessageCommand	Alphanumeric, variable length	-	Instruction for the TGAS Trackside Responder to perform an action (e.g. sending messages of different types, lengths and time intervals. If MessageID = TC, ER or AK, MessageCommand = NA.
User data	Alphanumeric, variable length, optional depending on MessageLength	-	Continues repetition of character string "0123456789" If MessageID = TC, the user data field contains one or more instructions for the TGAS Trackside Responder. If MessageID = AK, the corresponding MessageID and timestamp of the received message shall be included in the User data field. If MessageID = ER an error has occurred, the error code and its description shall be included in the User data field.

8.4.1.5. The purpose of the MessageCommand is to initiate cyclic transmission of messages of the TGAS Trackside Responder with the following specific properties: **(R)**

a. The message type and session (MessageID and SessionID).

b. The time interval between transmission of messages (the time interval can be fixed or randomised).

c. The message length (the message length can be fixed or randomised).

d. An indication if the transmitted message is required to be acknowledged.

e. An indication if messages which are not acknowledged in time shall be retransmitted.

f. A timer indicating the total duration of cyclic message transmission of the TGAS Trackside Responder. If this timer expires, message transmission for the session is aborted.

8.4.1.6. The format of the messages transmitted by the TGAS Application Simulator and TGAS Trackside Responder complies with Table 1. **(R)**

8.4.1.7. If the MessageCommand field is not applicable (i.e. there is no intention to invoke any message transmission or MessageID = TC, AK or ER) the MessageCommand field is coded with the alphanumeric string NA. **(R)**

8.4.1.8. The MessageCommand field consists of a string of alphanumeric subfields. Each subfield is separated by a field separator. **(R)**

8.4.1.9. The field separator between subfields in the MessageCommand field is defined as "," **(R)**

8.4.1.10. The format of the subfields in the MessageCommand field complies with Table 2. **(R)**

8.4.1.11. The MessageCommand field consists of the following subfields: **(R)**

a. SessionID (Table 1).

b. MessageID (Table 1).

c. TxTimeInterval (Table 2).

d. TxTimeIntervalRange (Table 2).

e. TxMessageLength (Table 2).

f. TxMessageLengthRange (Table 2).

g. M_ACK (Table 1).

h. GuardTimer (Table 2).

i. NrOfRetransmits (Table 2).

j. TxDuration (Table 2).

Table 2 MessageCommand subfields

Subfield name	Format	Range	Description
TxTimeInterval	Numeric, integer	0 - 999	Time interval between cyclic transmission of messages in seconds
TxTimeIntervalRange	Numeric, integer	0 - 999	Range of time interval (number of seconds) in case the time interval is variable. If set to 0 the length of the time interval is fixed.
TxMessageLength	Numeric, integer	0 - 999	Message length (number of alphanumeric characters)
TxMessageLengthRange	Numeric, integer	0 - 999	Range of message length (number of alphanumeric characters) in case the message length is variable. If set to 0 the length of the message is fixed.
GuardTimer	Numeric, integer	0 - 999	Guard timer in seconds. If the guard time expires before the corresponding AK message has been received, the original message is retransmitted (up to NrOfRetransmits times). If M_ACK = 0, retransmission does not take place.
NrOfRetransmits	Numeric, integer	0 - 99	If NrOfRetransmits is set to 0, messages shall not be retransmitted (retransmission is disabled).
TxDuration	Numeric, integer	0 - 2592000	Indicates the total duration of cyclic message transmission in seconds. The maximum value is 30 days in seconds.

8.4.1.12. The purpose of the TxTimeIntervalRange is to create subsequent message transmissions with a random time interval. **(R)**

8.4.1.13. If TxTimeIntervalRange > 0 the time interval between subsequent message transmission is randomly distributed (uniform random distribution) between TxTimeInterval – TxTimeIntervalRange/2 and TxTimeInterval + TxTimeIntervalRange/2. **(R)**

8.4.1.14. If TxTimeIntervalRange = 0 the time interval is fixed to TxTimeInterval. **(R)**

8.4.1.15. The purpose of the TxMessageLengthRange is to create subsequent message transmissions with a random message length. **(R)**

8.4.1.16. If TxMessageLengthRange > 0 the message length is randomly distributed (uniform random distribution) between TxMessageLength – TxMessageLengthRange/2 and TxMessageLength + TxMessageLengthRange/2. **(R)**

8.4.1.17. If TxMessageLengthRange = 0 the message length is fixed to TxMessageLength. **(R)**

8.4.1.18. GuardTimer and NrOfRetransmits control the retransmission scheme. The retransmission only applies if M_ACK = 1. **(R)**

8.4.1.19. If NrOfRetransmits = 0 retransmission is disabled. **(R)**

8.4.1.20. TxDuration indicates the total duration of the message transmission. After expiry of TxDuration message transmission for that specific session and message type is terminated. **(R)**

8.4.1.21. All subfields of the MessageCommand are mandatory. The structure of the MessageCommand string is: **(R)**
<SessionID>,<MessageID>,<TxTimeInterval>,<TxTimeIntervalRange>.<TxMessageLength>,
<TxMessageLengthRange>,<M_ACK>,<GuardTimer>,<NrOfRetransmits>,<TxDuration>

8.4.1.22. A typical example of the content of MessageCommand is:
01,MA,20,10,250,0,1,5,3,3600. This means that the TGAS Trackside Responder is asked to create or join session 01 in which it transmits Movement Authorities to the TGAS Application Simulator for a total duration of 3600s with a fixed length of 250 octets. The transmission time interval between messages is randomly distributed between 10 and 30s with a mean of 20s. The MA is acknowledged with an AK message by the TGAS Application Simulator. Retransmission is applicable with a guard timer of 5s and a maximum 3 retransmissions in case of a message timeout.
The TGAS Application Simulator sends out the following Position Report to initiate this type of cyclic MA transmission (the [] bracket are included for readability, they do not exist in the transmitted message):
[**01**][**PR**][**053**][**20210507121100345**][**1**][**01,MA,20,10,250,0,1,5,3,3600**] **(I)**

8.4.1.23. The TGAS Trackside Responder then, as a response, cyclically sends out the following message (the [] bracket are included for readability, they do not exist in the transmitted message):
[**01**][**MA**][**250**][**20210507121100345**][**1**][**NA**][**012345678901234567890123**…] **(I)**

8.4.1.24. The local message processing delay time for the TGAS Application Simulator shall be less than 80 ms (Time message in – Time message out). **(R)**

8.5 Trackside Responder Control message (TC)

8.5.1.1. With the TC message it shall be possible to control the TGAS Trackside Responder for a specific Session (identified by SessionID). **(R)**

8.5.1.2. The TC message is sent by the TGAS Application Simulator. **(R)**

8.5.1.3. The message format of the TC message is defined in Table 1 with MessageID = TC and MessageCommand = NA. The User data field contains one or more commands which are evaluated by the TGAS Trackside Responder and for which appropriate action is taken. **(R)**

8.5.1.4. The following commands shall be supported: **(R)**

a. Reset a specific Session (identified by SessionID).

b. Reset the TGAS Trackside Responder (reboot).

c. Abort a specific TCP/IP connection (identified by TCP port and IP address).

d. Change TCP MTU size.

e. Invoke failure condition in TGAS Trackside Responder operation (e.g. shutdown an Ethernet port which halts data transmission for a session).

f. Abort an application session process (identified by a specific SessionID and/or MessageID) without terminating the corresponding TCP/IP connection.

g. Request for sending an individual message (MA or GM).

h. Start (cyclic) message transmission (as detailed in MessageCommand).

i. The tenderer is requested to provide a list of possible events that will influence message transmission in order to be able to simulate abnormal behaviour.

8.5.1.5. Commands in the User data fields shall have the following structure: **(R)**

a. <CommandName>.

b. <CommandName> = <Value>.

8.5.1.6. In case of a sequence of commands, all commands are separated by a fieldseparator "," **(R)**

8.5.1.7. Commands are further and finally defined in the development phase of the project. **(R)**

9. TGAS Trackside Responder

9.1.1.1. The TGAS Trackside Responder shall be able to: **(R)**

a. Communicate with the TGAS Application Simulator and TGAS Traffic Generator as specified in section 7 and section 8.

b. Setup and answer TCP/UDP sessions.

c. Send and receive TCP/UDP messages.

d. Execute instructions contained in a MessageCommand field of a Position Report sent by the TGAS Application Simulator.

e. Execute instructions contained in the User data field of a TC (Trackside Control) message sent by the TGAS Application Simulator.

f. Respond with specific messages based on messages received from the TGAS Application Simulator and invoke corresponding actions (e.g. respond with AK message).

g. Respond with specific messages based on messages received from the TGAS Application Simulator with an ER message in case of an error.

h. Run test scripts for traffic generation as defined in section 7 and log events (as defined in section 11.

9.1.1.2. The TGAS Trackside Responder shall be capable of transmitting the following application messages: **(R)**

a. Movement Authority (MA).

b. General Message (GM).

c. Acknowledgement (AK).

d. Error (ER).

9.1.1.3. The TGAS Trackside Responder shall be capable of generating TCP/UDP traffic based on Iperf (as defined in section 7). **(R)**

9.1.1.4. It shall be possible to configure the TGAS Trackside Responder as an Iperf server. **(R)**

9.1.1.5. The TGAS Trackside Responder shall be capable of performing file transfers based on sFTP. **(R)**

9.1.1.6. The TGAS Trackside Responder shall be able to simultaneously support TCP/IP simulated message transfer, UDP/IP, Iperf and sFTP information exchange. **(R)**

9.1.1.7. It shall be possible to configure (per TCP/IP session): **(R)**

a. The size of IP packets (payload length).

b. The frequency of sending IP packets (number of packets per minute).

c. A random time interval between transmission of two consecutive packets. The time interval shall range from 1 to 600s.

9.1.1.8. The TGAS Trackside Responder shall as a minimum be able to simultaneously support: **(R)**

a. Three TGAS Application Simulators.

b. Two TGAS Traffic Generators.

9.1.1.9. The local processing delay time for the TGAS Trackside Responder shall be less than 80 ms. **(R)**

10. Installation, configuration and maintenance

10.1 General

10.1.1.1. ProRail will provide enhanced GPRS connectivity via GSM-R and a fixed network with sufficient bandwidth to enable communication between the TGAS Traffic Generator/ TGAS Application Simulator and the TGAS Trackside Responder. **(I)**

10.1.1.2. ProRail will provide SIM cards for the TGAS onboard Modules. **(I)**

10.1.1.3. ProRail will provide a LAN network in Railcentre Amersfoort. **(I)**

10.1.1.4. ProRail will provide a DNS server as part of the LAN. **(I)**

10.1.1.5. ProRail will provide any required public SIMs (4G, 5G) and internet connections. **(I)**

10.1.1.6. ProRail will provide an interface to the GPS antenna in the measurement train. **(I)**

10.1.1.7. ProRail will provide an interface to the odometry system in the measurement train. **(I)**

10.2 Installation and physical requirements

10.2.1.1. ProRail will provide hardware installation options for the TGAS Traffic Generator and the TGAS Application Simulator in the measurement train (MP Jules). **(I)**

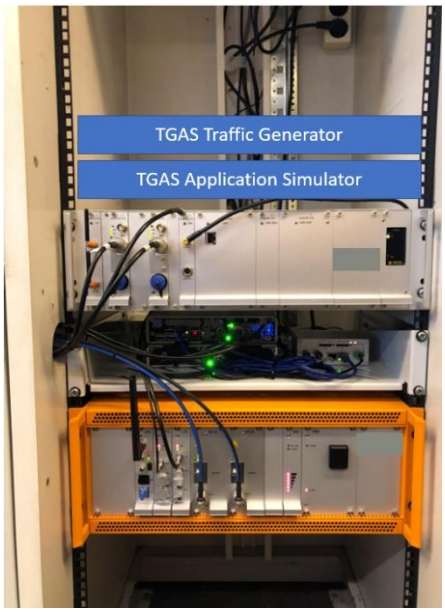

Figure 6 Free slots in the 19" rack of the MP Jules measurement train

10.2.1.2. It shall be possible to mount the TGAS Modules in a 19" rack, so that they can be installed in a test train. **(R)**

10.2.1.3. In the test train 230V AC-power outlets are available to power the TGAS Modules. **(I)**

10.2.1.4. The TGAS Modules shall be portable, so they can be used in: **(R)**

a. A test train.

b. Near the railway track (in an outdoor environment).

c. A lab environment.

10.2.1.5. TGAS Modules shall be able to be equipped with external antennas for standalone operation (e.g. if all external antenna connections in the test train are occupied). When a TGAS Module is used in a test train, external antennas could be attached to a window of the train during operation. **(R)**

10.2.1.6. A TGAS Module shall be able to cope with a power loss of several minutes, so it is able to shutdown properly (and save its measurement and configuration data) and/or shall be able to function autonomously for at least 5 minutes. **(R)**

10.2.1.7. The TGAS Trackside Responder will be located at the ProRail Railcentre in Amersfoort. **(R)**

10.2.1.8. The TGAS Trackside Responder which resides at the datacentre is a standalone system with an ethernet connection or may be hosted on a virtual server (VMware ESXi-server version 6.7.0). **(R)**

10.2.1.9. In case a virtual server is used, the physical sever will be provided by ProRail. **(I)**

10.2.1.10. If the TGAS Trackside Responder can only be installed on a separate physical server; the server height shall have a maximum of 1U and shall be installed in a 19" datacentre rack. **(R)**

10.2.1.11. Tenderer shall provide all installation services required to deploy the TGAS System. **(R)**

10.2.1.12. An overview of the TGAS physical network architecture is shown in Figure 7. **(I)**

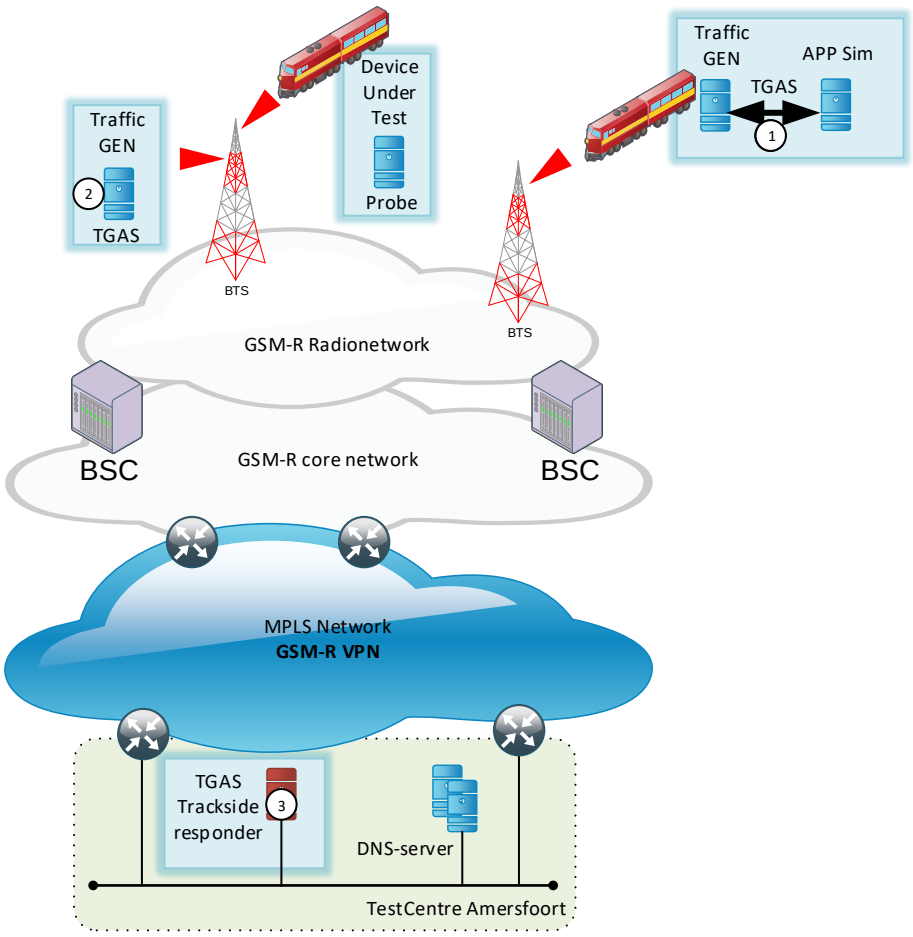

Figure 7 TGAS System architecture

10.3 Configuration and maintenance

10.3.1.1. The TGAS Traffic Generator and TGAS Application Simulator shall be able to function in both unattended mode and attended mode. In unattended mode the TGAS Traffic Generator and TGAS Application Simulator shall begin operation when power is provided and automatically start with the scheduled test scripts. **(R)**

10.3.1.2. In order to configure the TGAS Modules with the required test scripts, it shall be possible to communicate to the TGAS Modules remotely over the air. This shall be possible via a public mobile internet service (e.g. 4G/5G) and optionally via EGPRS. **(R)**

10.3.1.3. The TGAS Maintenance System shall be accessible via a secure internet connection. **(R)**

10.3.1.4. Configuration shall be possible with a GUI. **(R)**

10.3.1.5. The TGAS Trackside Responder shall be able to be (remotely) configured with the required test scripts using a GUI over a secure internet connection. **(R)**

10.3.1.6. It shall be possible to configure the mentioned tests with a test script or multiple test scripts via a GUI. **(R)**

10.3.1.7. For configuration purposes, it shall be possible to communicate to the TGAS Traffic Generator, TGAS Application Simulator and TGAS Trackside Responder directly using a console or Ethernet connection. **(R)**

10.3.1.8. During operation it shall be possible to remotely (re)configure the TGAS Traffic Generator, TGAS Application Simulator and TGAS Trackside Responder. **(R)**

10.3.1.9. During operation it shall be possible to remotely check the status of the TGAS Traffic Generator, TGAS Application Simulator and TGAS Trackside Responder. **(R)**

11. Monitoring and logging

11.1.1.1. Monitoring and logging is applicable to all TGAS Modules. **(R)**

11.1.1.2. The following events shall be logged: **(R)**

a. Communication events (e.g. setup, terminate or abort TCP sessions).

b. Transmission of user data (for the TGAS Application Simulator and TGAS Trackside Responder).

c. Error events.

d. Configuration actions and results.

e. Scripting errors.

11.1.1.3. For the TGAS Application Simulator and TGAS Trackside Responder it shall be possible to log application messages (generated in the simulation process). It shall be possible to turn this type of logging on or off. **(R)**

11.1.1.4. It shall be possible to automatically upload logging data to the TGAS Maintenance System for later analysis. **(R)**

11.1.1.5. It shall be possible to store logging data in the TGAS Maintenance System for at least six months. **(R)**

11.1.1.6. It shall be possible to log in to TGAS Modules from the TGAS Maintenance System and collect and retrieve logging data. **(R)**

11.1.1.7. It shall be possible to log in to the TGAS Maintenance System via a secure internet connection (e.g. ssh) which is provided by ProRail and fulfils ProRail security policies and access the TGAS Modules from the TGAS Maintenance System and collect and retrieve logging data or perform configuration actions. **(R)**

11.1.1.8. Events shall be logged with timestamp (date/time), GPS position and speed. **(R)**

11.1.1.9. Events of the TGAS Application Simulator shall in addition be logged with CellID. **(R)**

11.1.1.10. Position and speed information may additionally be retrieved through the odometry interface of the measurement train. **(I)**

11.1.1.11. The resolution of time in the logging timestamp shall be 1 ms. **(R)**

11.1.1.12. The logging shall be provided in XML or txt format to ensure interchangeability with other reporting systems. **(R)**

11.1.1.13. It shall be possible to create reports and statistics from the generated logging of the TGAS Onboard Modules and the TGAS Trackside Responder (e.g. number of messages sent per unit of time and cumulative throughput). **(R)**

11.1.1.14. Reports shall as a minimum provide: **(R)**

a. Information about message delay times versus location for all message types.

b. Information about the delay time distribution (mean, standard deviation, 99-percentile).

c. Information about the realised throughput versus location and/or time.

d. Information about events versus location.

e. Iperf statistics.

f. Information about cumulative statistics (number of messages sent per message type, number of TCP connection setups, number of TCP connection terminations, traffic volume sent, number of errors etc.).

11.1.1.15. It shall be possible to present these reports in graphical form. **(R)**

11.1.1.16. It shall be possible to monitor and log data of the connection between TGAS Trackside Responder and fixed IP network. **(R)**

11.1.1.17. It shall be possible to monitor and log data of the connection between TGAS Application Simulator and modem. **(R)**

11.1.1.18. It shall be possible to monitor and log data of the connection between TGAS Traffic Generator and modems. **(R)**

12. Service & Support

12.1 Hard- and software support

12.1.1.1. The tenderer shall provide hard- and software support for the TGAS System. **(R)**

12.1.1.2. Tenderer shall provide regular software updates to repair imperfections and defects. **(R)**

12.1.1.3. Tenderer shall deploy new software releases of subsystems (e.g. GSM-R modems). **(R)**

12.1.1.4. Tenderer shall provide regular software upgrades to enhance and improve functionality. **(R)**

12.1.1.5. It shall be possible to upgrade and downgrade the TGAS System software within four hours. **(R)**

12.1.1.6. It shall be possible to upgrade and downgrade the firmware of the EGPRS/EDGE modems within four hours. **(R)**

12.1.1.7. Tenderer shall, in case of incidents or failures, provide support during office hours (5x8 hours per week during working days). **(R)**

12.2 Project support, analysis and training

12.2.1.1. Tenderer shall be able to offer (on a project basis): **(R)**

a. Consultancy services.

b. Support for troubleshooting.

c. Performance analysis.

12.2.1.2. Tenderer shall be able to extend its product portfolio for future development (e.g. FRMCS) and additional functionality related to KPI performance management. **(R)**

12.2.1.3. Tenderer shall provide system documentation, manuals and training services for ProRail personnel and third parties responsible for TGAS operation. **(R)**

12.2.1.4. Tenderer shall provide hourly rates for three types of skills: **(R)**

a. Project management.

b. Engineering, development and troubleshooting.

c. Installation and test.

13. Provisioning (bill of material)

13.1.1.1. The tenderer shall provide two TGAS Trackside Responders (one active, one test/spare/backup). **(R)**

13.1.1.2. The tenderer shall provide two TGAS Application Simulators (one active, one test/spare/backup). **(R)**

13.1.1.3. The tenderer shall provide three TGAS Traffic Generators (one active for the measurement train, one active along the track (portable), one test/spare/backup). **(R)**

13.1.1.4. The tenderer shall provide two TGAS Maintenance Systems (one active, one test/spare/backup). **(R)**
Note: The TGAS Maintenance System may be provided as a service.

13.1.1.5. Tenderer shall be able to provide additional TGAS modules. **(R)**

14. Planning

14.1.1.1. The complete TGAS System shall be developed, delivered, deployed and accepted within 9 months after granting the contract. **(R)**

14.1.1.2. Indicative lead times for delivery of TGAS System components after granting the contract are shown in Table 3. **(R)**

Table 3 TGAS System delivery lead times

TGAS System	Indicative lead times for delivery
TGAS Traffic Generator	4 months
TGAS Application Simulator	9 months
TGAS Trackside Responder	6 months
TGAS Maintenance System	9 months

15. Assessment criteria Functional Requirements Specification

15.1 Introduction

15.1.1.1. The award criterion for the contract is Best Price-Quality Ratio (BPKV). Tenderers can earn virtual discounts on the tender price depending on the score on the qualitative requirements. The contract will be awarded to the tenderer with the lowest virtual tender price. **(I)**

15.1.1.2. This section contains qualitative requirements which will be assessed and scored conform the tender model as described in the "Leidraad" and the "Inschrijfbiljet". **(I)**

15.1.1.3. The qualitative part comprises of three constituents. Per constituent and dependent of the score per constituent a virtual discount is applied. **(I)**

a. Functionality (Solution description, architecture design, Statement of Compliance). (maximum 15 pages).

b. Project plan comprising aspects of development, deployment, risk analysis, maintenance and support. (maximum 5 pages).

c. Sustainability (Sustainable logistical movements and sustainable business operation) (maximum 2 – 4 pages, refer to [Sustainability]).

15.1.1.4. The maximum score of all constituents is 1000 points. The maximum score for functionality is 700 points, for the project plan 200 points, for Sustainability 100 points. **(I)**

15.1.1.5. For every requirement of the FRS, the maximum achievable score is indicated in Table 4. **(I)**

15.2 Inschrijfbiljet

15.2.1.1. The tenderer shall comply with quality and pricing as specified in the Inschrijfbiljet document. **(R)**

15.3 Maximum score Qualitative Requirements

15.3.1.1. Maximum score per qualitative requirement is indicated in Table 4. **(I)**

Table 4 Maximum score for quality requirements

Reference (paragraph)	Requirement	Maximum score
6	Generic overview of the TGAS System	50
7	TGAS Traffic Generator	100
8	TGAS Application Simulator	
8.1	General	50
8.2	TGAS Application Simulator script requirements	25
8.3	Interaction between TGAS Application Simulator and TGAS Trackside Responder	25
8.4	TGAS Application Simulator message format	25
8.5	Trackside Responder Control message (TC)	25
9	TGAS Trackside Responder	100
10	Installation, configuration and maintenance	
10.1	General	10
10.2	Installation and physical requirements	20
10.3	Configuration and maintenance	20
11	Monitoring and logging	100
12	Service & Support	
12.1	Hard- and software support	25
12.2	Project support, analysis and training	50
13	Provisioning (bill of material)	25
14	Planning	50
Project plan	Project plan (deliverable by tenderer)	200
Sustainability	Sustainability document (deliverable by tenderer), see Bijlage 1.1 Sustainability	100
Total		1000