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ETCS/GSM-R Quality of Service – Operational Analysis

VERSIONS & MODIFICATIONS

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0b	12-11-2003	description of MA extension	L Hansen
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1 DEFINITIONS AND ABBREVIATIONS

1.1 Abbreviations

BACC	Blocco Automatico Correnti Codificate
DMI	Driver-Machine Interface
EOA	End of Authority
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
GSM-R	Global System for Mobile Communications - Rail
KMS	Key Management System
LOA	Limit of Authority
LZB	Linien Zugbeeinflussung
MA	Movement Authority
MTBD	Mean Time Between Disturbances
NL	Non-Leading mode
NP	No Power mode
OBU	Onboard System
OS	On Sight mode
PZB	Punkt Zugbeeinflussung
QoS	Quality of Service
RBC	Radio Block Centre
SB	Standby mode
SCMT	Sistema Controllo Marcia Treno
SH	Shunting mode

SL	Sleeping mode
SRS	System Requirement Specification
STM	Specific Transmission System
TPWS	Train Protection and Warning System
TVM	Transmission Voie Machine
Um	GSM-R air interface
UN	Unfitted mode
URS	User Requirement Specification

1.2 Definitions

Disturbance	Event which leads to an operational delay in excess of the acceptable delay target attributable to an ETCS/GSM-R QoS.

1.3 References

1. ERTMS/GSM-R Quality of Service Questions to UNISIG & UNISIG Replies, EEIG ref. 04E118 Issue
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6. UNISIG SEL0452 QoS Scenario – Transmission of MA, Issue 0.3.0, October 2004
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2 PURPOSE AND SCOPE

This document has been produced by the EEIG ERTMS Users Group for the purpose of establishing the operational Quality of Service requirements necessary for the application of ETCS to the European mainline rail network. These requirements are applicable to the ETCS application layer which, in the case of Application Level 2 and above, includes the supporting GSM-R and fixed telecommunication layers necessary to connect the ETCS Onboard and trackside assemblies. The requirements quoted in this document have been derived on the basis of a top-down analysis of operational needs. This document is intended to form a basis for the derivation of technical QoS requirements managed by the ETCS and GSM-R supply industry. Note that the proposed requirements included in this document are intended for use in future updates to the ETCS requirements baseline specified in the TSI Annex A; they are not intended to take precedence over any formal requirements related to existing commercial applications of ETCS.

The requirements given in this document have been derived on the basis of the best information available to the authors. Significant national variations exist in respect of some of the proposed ETCS application principles and the relevant requirements have been specified on the basis of the most demanding conditions. It is recognised that the requirements specified in this document may need to be revised through the course of subsequent dialogue with industrial suppliers. Nevertheless, the operational QoS requirements specified in this document are considered to be sufficiently stable to be used by the industrial suppliers as a basis for the derivation of the corresponding technical requirements to be included in SUBSET-093 and any associated Class 1 specifications.

3 INTRODUCTION

The existing documents on ETCS performance and communication requirements (96E1663, 97E7377, 98E4033) contain requirements about ETCS performance, data communication architecture and related requirements together with calculations for operational scenarios in order to derive further requirements for ETCS data communication. Though they cover many aspects of QoS for ETCS Levels 1-3, they are based on the standard of knowledge which existed 6 years ago. In the meantime, new insight has been gained from the results of the various pilot lines and test programmes.

So far, the documents mentioned above cover a mix of operational Quality of Service (QoS) aspects, GSM-specific details and ETCS performance parameters, which are not sufficient to derive precise requirements for the ETCS and GSM-R suppliers. There are two dependencies; QoS of GSM-R and QoS of ETCS. The GSM-R QoS strongly impacts the QoS of ETCS which, in turn, influences the overall operational QoS of the railways. Therefore, as a first step, the European railways have defined their common operational requirements which sets a framework for overall ETCS performance. Based on these overall ETCS QoS requirements, technical requirements for the QoS of GSM-R radio transmission can be derived.

The intention of this document is to describe the operational needs of the railways. . It should be pointed out that the paper neither deals with the availability of the physical equipment nor with safety issues in accordance with the remit assigned to the QoS Working Group.

The derivation of ETCS/GSM-R QoS requirements is based on the following general approach:

- Firstly, the overall QoS requirements for railway operation based on general performance targets of the railways will be defined.
- Secondly, the influence of a range of typical operational scenarios is analysed and an apportionment of the top-level targets to the scenarios derived.
- Finally, the QoS requirements for the data transmission sub-system can be derived from the scenario based operational targets. This final step is not included within the scope of this document.

Figure 1 shows the relationship between the operational system, ETCS and the GSM-R based communication sub-systems. Each of these sub-systems contributes to the overall Quality of Service of the complete operational system.

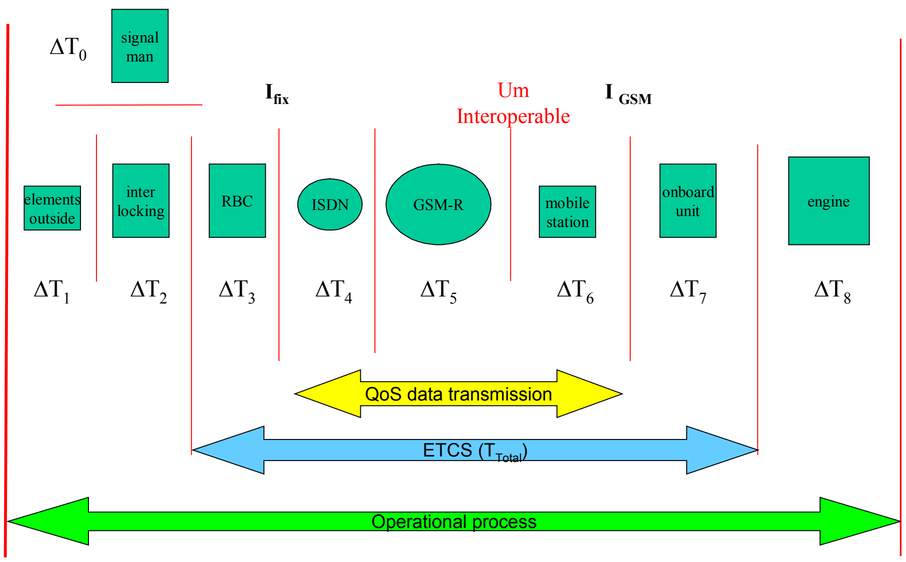


Figure 1. Timeshare of ETCS and QoS data-transmission of the whole operational process.

It is impractical to analyse every possible situation, the most significant QoS related features were investigated by means of the following principal operational scenarios:

- Extension of MA
- Transition from national train control system to ETCS level 2

- Awakening / Start of Mission

The above scenarios are analysed in detail in this document and the results used to derive appropriate operational QoS requirements.

The following subordinate scenarios are also considered. These additional scenarios are not scenarios in their own right but causal events leading to potential failure of the three principal scenarios mentioned above.

- Hand-over between two RBCs
- Loss of communication

4 LINE CATEGORIES

The significance of operational delays attributable to ETCS/GSM-R is likely to vary according to the nature of the line on which it is installed. For example, a high Quality of Service is likely to be demanded on high-speed or high-capacity inter-urban routes, even if greater capital costs are necessary to provide it. Conversely, economic considerations are likely to take greater precedence in the case of secondary lines and lightly used rural routes where occasional minor delays are unlikely to have a widespread impact. In recognition of this fact, a number of Line Categories have been defined to reflect the need for a range of target values applicable to specific Quality of Service parameters, see Table 1. These categories are representative of the nature of routes expected to be fitted with ETCS in future years.

Line Category	**1**	**2**	**3**	**4**	**5**
Typical profile	Dedicated High-Speed Line	High-Capacity Line	Low-Capacity Line	Urban Railways	Dedicated Freight
Line Speed (kph)	160-350	120-230	120-160	Up to 140	120
Typical Speed (kph)	300	200	160	120	100
Traffic	Passenger	Passenger and freight	Passenger and freight	Passenger	Freight
Traffic Density (trains per hour per direction)	15	8 (mixed traffic) 15 (passenger only)	Typically 2-10	30	Typically 12

Line Category	**1**	**2**	**3**	**4**	**5**
Typical profile	Dedicated High-Speed Line	High-Capacity Line	Low-Capacity Line	Urban Railways	Dedicated Freight
Operational processes which determine track capacity	2 successive trains (same direction)	2 successive trains (same direction) Track branch to allow overtaking at certain locations	Crossing of 2 trains of opposite direction on a single track line Change of running direction	2 successive trains (same direction) Track branch to allow overtaking at certain locations	2 successive trains (same direction)

Table 1. Line Categories

5 SUMMARY OF ETCS/GSM-R SCENARIOS AND TARGET QOS REQUIREMENTS

Moved to Section 13.1.

6 DERIVATION OF QOS REQUIREMENTS

6.1 Introduction

Figure 2 shows the interdependency of the railway's Quality of Service with the QoS of ETCS including data-transmission. Described from a bottom up perspective, there are two main dependencies: Firstly, QoS of data-transmission strongly impacts the QoS of ETCS. Secondly, the resultant ETCS QoS influences the overall QoS of the operational railway. A multitude of technical considerations determines the QoS of the data-transmission sub-system, only few of its details are know to the railways. What counts more for the railways is their obligation to meet their customers' expectations which demands an appropriate performance measure for their transport service. The requirement for a high operational Quality of service is expressed mainly by the achievement of punctuality targets. The infrastructure operator additionally has its own commercial objectives, e.g. a maximisation of track capacity. Therefore, most European railways have punctuality targets defined by their managements from which only a part can be allocated to requirements for QoS of ETCS and QoS of data-transmission following a top-down process as illustrated in Figure 2.

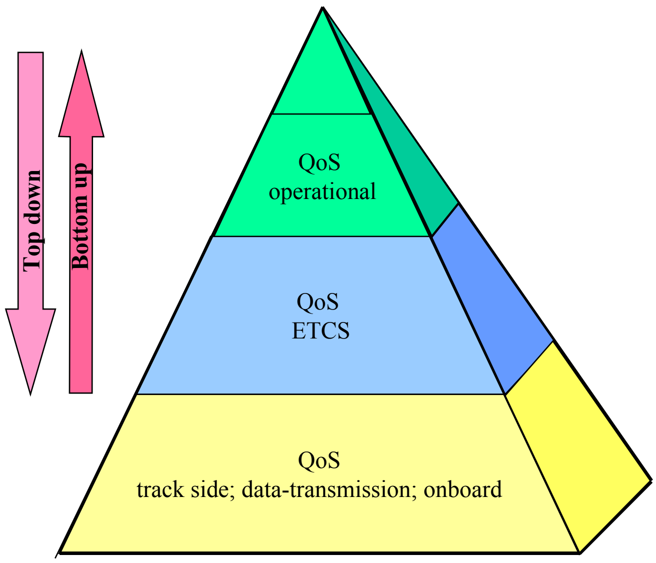


Figure 2. Interdependency of Railway System QoS.

6.2 Targets

Two global operational cases are relevant to the derivation of operational QoS requirements:

- Perfect Case – no impact on railway operational due to ETCS/GSM-R QoS
- Normal Case – specified target for probability of delay due to influence of ETCS/GSM-R QoS.

6.2.1 Case 1 ("Perfect Case"):

No significant deviation from the theoretical operational quality provided by the existing signalling system in a fully functional state (e.g. no time delay, no reduction in track capacity).. This is described in detail in Section 7.

6.2.2 Case 2 ("Normal Case"):

A real system never achieves 100% performance. A small but well defined deviation from the perfect case in the form of an accepted reduction of the theoretic operational performance needs to be considered. Maintaining the existing performance of lines presently equipped with TVM, LZB, BACC/SCMT or other national systems following application of ETCS was the principal objective used to derive operational QoS requirements for ETCS. Such a performance target is usually set by the railways' management and is often expressed as a target for punctuality. These management targets differ from railway to railway and from track category to track category. The derivation will be described using the following target as an example[1]. The mathematical approach is designed in such a way that all parameters can easily be adapted to individual railways' targets and line categories:

- 95 % of all train arrivals shall occur in time (≤ 5% with delay)
- relevant operational delay time: >5 minutes

Note that in the case of certain railways (e.g. DB), delays are measured at each intermediate station stop.

6.3 Top-Down Analysis

To map this general target to the requirements for ETCS in dependence of the different operational requirements of different line categories, it is necessary to make few assumptions about a train journey under the control of ETCS. The example will be carried

[1] The example here reflects a typical situation for DB and is given for illustrative purposes only. The calculation can be easily modified, e.g. a 98 % punctuality target for commuter lines counting any delay lager than 2 minutes.

out for Category 2 (high-capacity line), the results for other categories are shown in Table 2.

Typical journey parameters in this case are:

- typical journey length: 600 km;
- number of station stops: 10;
- journey duration: 5 hours (based on an average speed of 120 km/h)

6.3.1 Statistics of Train Arrival Times

Some trains will arrive prior to the scheduled arrival time. This can be explained by the fact that the timetable normally includes an allowance for recovery from small residual delays which commonly occur in normal operational service, e.g temporary speed restrictions. The magnitude of this recovery margin varies from railway to railway according to operational factors. Some margin is operationally necessary as it is not normally possible to guarantee that the line can always be operated at its theoretical maximum capacity. For this reason, no account will be taken of this margin in calculating targets for ETCS QoS.

A typical distribution of train arrival times is shown in Figure 3. Note that although trains arriving within 1 minute of the scheduled arrival time are considered to have arrived on time, the corresponding QoS target will cover the range 0 to 5 minutes to ensure that small delays of less than one minute are included within the scope of the technical QoS requirements, see Section 6. This is an important adjustment as the majority of QoS related delay events are likely to be of short duration; such events may not be readily detectable as discrete events due to the relatively coarse resolution of current traffic regulation systems in use on the European mainline network.

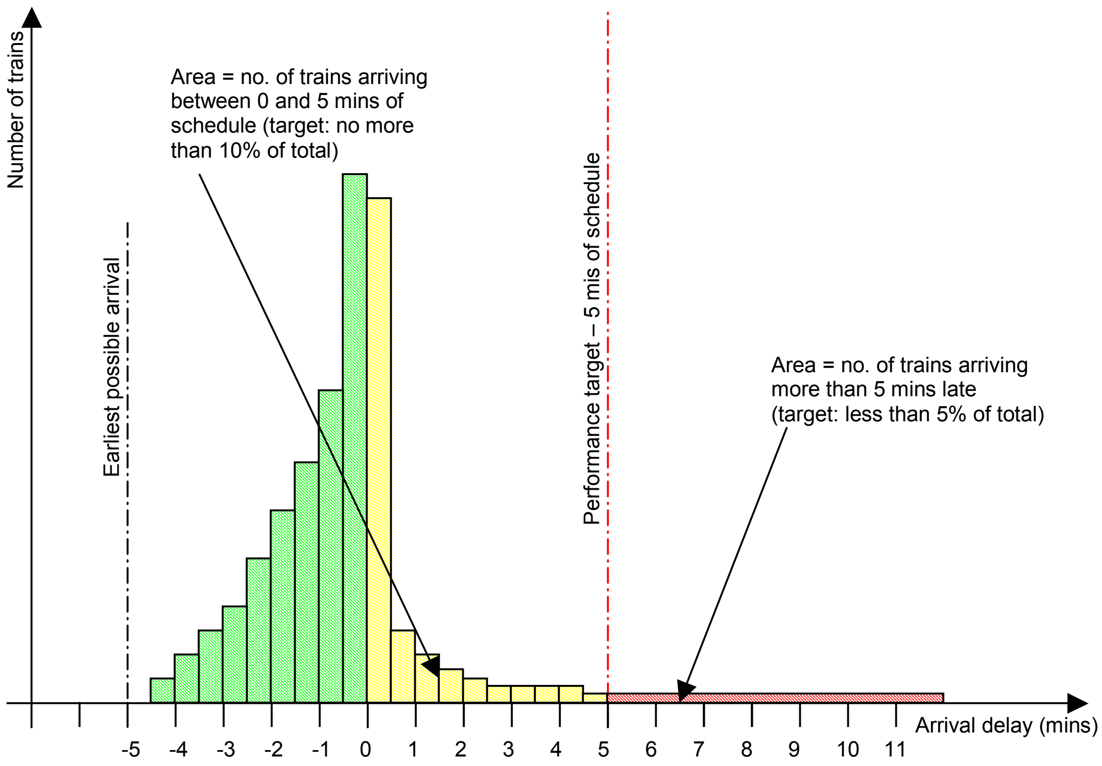


Figure 3. Distribution of Arrival Times

Figure 3 shows the distribution of train arrival times presented in the form of a histogram showing the density of trains divided into 0.5 min arrival time bands. The punctuality threshold is indicated by a vertical line passing through the 5 min delay target. The area to the right of this vertical line represents the total number of trains arriving later than the punctuality target. The area to the left represents all trains arriving inside the punctuality target.

Most railways have only a single punctuality target which takes no account of the cause of delay. Indeed, the cause of delay is of no interest to the end user, his only concern is whether or not he arrives at his destination within the published punctuality target. If he arrives late, he may be entitled to some form of financial compensation. The railways normally apportion the delay allowance, i.e. the difference between the scheduled arrival time and the punctuality target, to different generic causes. For example, DB apportions 10% of the delay allowance to signalling-related causes. Hence, the signalling engineer is given a single delay budget to cover all causes of signalling related problems. This approach is entirely appropriate to the technology in use today which performs its various internal processes in readily quantifiable units of time. Measurable delay is therefore almost always the result of an equipment failure. In contrast, ETCS depends on GSM-R for transmission of track-to-train and train-to-track messages, the nature of which makes precise predictions of internal process cycle times difficult to make with absolute certainty. Data transmission cycle times via GSM-R are subject to a statistical distribution about a mean value. This means that although most messages will be transmitted within a quantifiable band around the mean transmission time, a small proportion of messages could experience significant delay. This is especially true if the GSM-R safe connection is temporarily broken as a result of a dropped call. The effect of this statistical distribution is that some operational delay is likely to be experienced even though the ETCS and GSM-R systems are fully functional and completely free of any equipment failures. Hence, a proportion of the delay allowance that is normally allocated to the signalling system needs to be held in reserve to cover a small but finite amount of delay caused by the nature of the GSM-R air gap interface.

The extent of the operational delay caused by the statistical nature of the ETCS/GSM-R is likely to be very small. These delays are not expected to contribute significantly to the normal punctuality target of 5 min delay. However, it is very likely that small delays will arise in the range 0 – 5 mins even if there are no other causes of delay. For example, a journey that might arrive on time with today's technology could be delayed by a few tens of seconds if ETCS were in operation given the same operational circumstances. No punctuality targets exist at present for small delays in the range 0 – 5 mins. This leads to the obvious conclusion that present day punctuality targets for train arrival times are simply not relevant to the establishment of top-level QoS targets for ETCS. For this reason, an alternative target has been derived for ETCS QoS covering the range 0 – 5 mins.

In the absence of any corporate punctuality targets for delays of less than 5 minutes, an appropriate target value is considered to be twice that for the proportion of trains arriving more than 5 mins late, i.e. 2 x 5% = 10%.

A second vertical line is shown 5 mins on the early side of the scheduled arrival time. This line represents the earliest possible arrival time if no delay whatsoever occurs during the course of the journey. As noted above, an operational margin is built into the timetable to cover normal operational delays which can reasonably be expected to occur during the journey. For example, temporary speed restrictions are normally imposed following rail replacement or tamping operations. This kind of delay is unavoidable on the network as a whole since a certain proportion of the network must be maintained at any given time according to a fixed schedule. This operational margin is shown here for reasons of explanation only, this margin is reserved for operational delays and is not intended to be used to mitigate against delays caused by the behaviour of the signalling system.

6.3.2 Allocation to ETCS QoS

These criteria apply for the whole railway operation, only a small amount of it is really available for ETCS. Therefore, in the following analysis a top-down process will be used to determine the share of the overall system target which can be apportioned to ETCS. It has to be noted that the following allocation is only an estimate which seemed reasonable to the participating experts. Variations in the method of allocation do not have a large impact on the final result (see Table 2 for the sensitivity of the allocation). The allocation is done as follows:

A) Allowed are 5% disturbed trains with a delay of **more than 5 min**

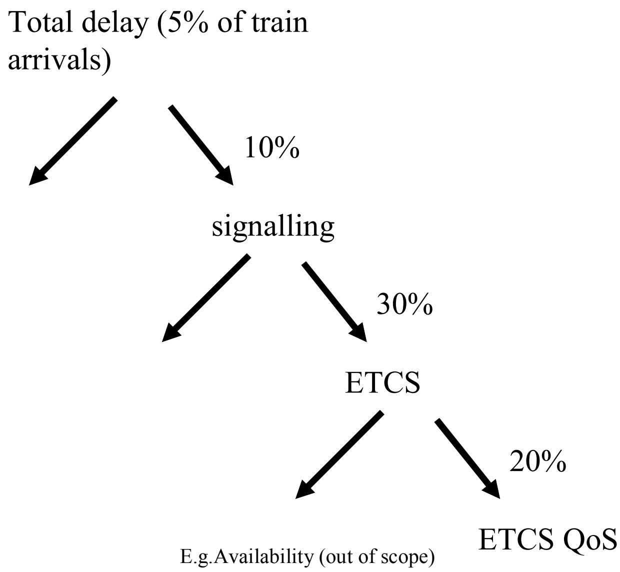


Figure 4. Allocation for delays of more than 5 minutes.

Note: The behaviour of the Eurobalise system is excluded from this analysis, i.e. the derivation of ETCS QoS parameters in this document assumes error-free Eurobalise transmission. The ETCS QoS at the base of Figure 4 takes account of all ETCS time-variable processes, i.e. RBC and Onboard processing time and the complete transmission path between them (fixed datacommunications networks and GSM-R).

According to historic statistical evidence, only one-third of operational delays are caused by technical problems. The remainder are usually linked to human factors and environmental conditions which are beyond railway's control, e.g. storm and suicide.

The contribution of the equipment can be split into rolling stock, track and signalling, of which a 10% share is apportioned to signalling. This 10% can be shared as follows; 30% for ETCS, 30% for interlocking including points and signals and 30% for other components like level crossings. Note, the apportionment to signalling includes the ETCS Onboard Assembly.

In the final step we need to distinguish between disturbances which lead to delays of less than or greater than 5 minutes. A delay > 5 minutes is normally a result of an equipment failure, mainly caused by availability problems. For this reason, the weighting factor applicable to ETCS QoS effects is set at 20 %. The remaining 80% of delay is allocated to equipment availability effects.

By contrast, an ETCS related delay between 0 and 5 minutes is much more likely to be due to an ETCS QoS effect. The weighting used for delays of between 0 and 5 minutes will therefore be set to 80% of the next highest level above. This case is described in Figure 5:

B) Allowed are 10% disturbed trains with a delay of **between 0 and 5min**

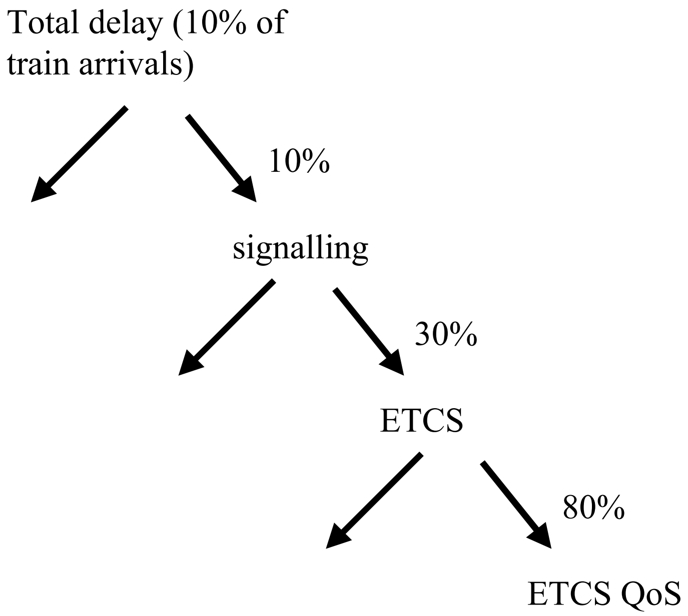


Figure 5. Allocation for delays of between 0 and 5 minutes.

6.3.3 Possibility of Disturbance

The possibility of disturbance to a train's progress is determined by the simple relationship:

$Q_{ETCS\ QoS} = t_d$ / MTBD

where:

t_d = train operation time for one train journey (for example, 5 hours)

MTBD = mean time between disturbance of this element

$Q_{ETCS\ QoS}$ = the probability of a disturbance due to ETCS QoS effects

Hence, provided Q_{ETCS} is known, the corresponding MTBD can be derived. As described above the relevant $Q_{ETCS\ QoS}$ is determined by:

$Q_{ETCS\ QoS} = 0.05 \bullet 0{,}1 \bullet 0.3 \bullet 0.2 = 0.030$ % of trains with operational delay > 5 minutes

$Q_{ETCS\ QoS} = 0.10 \bullet 0{,}1 \bullet 0.3 \bullet 0.8 = 0.24$ % of trains with operational delay in the range 0-5 minutes

Solving for MTBD[2] leads to:

MTBD = t_d / 0,0003 = 16 667 h (QoS problem with delay > 5 minutes)

MTBD = t_d / 0,0024 = 2083 h (QoS problem with delay in the range 0-5 minutes)

Note: The usual term used in this kind of analysis is MTBF (Mean Time Between Failures) but in the sense of QoS we are not concerned with equipment failures but rather with temporary disturbance. Therefore the term “MTBD” is adopted.

6.3.4 Allocation to Scenarios and Causes of Delay

Deleted, see Section 13

6.3.5 Calculation for all Line Categories

The following table, Table 2, contains the MTBD targets for all line categories derived in the same way as the above example for line Category 2. For urban railways a punctuality target of 98 % arrivals in time with less than 2 minutes delay was set.

[2] t_d = 5 h (journey time),

Category	Journey Length [Km]	Journy Duration [h]	Punctuality Target / max. delay	Disturbance Duration [Min]	Acceptable Delay Share	Share Of Signalling	ETCS	QoS ETCS	Probability For Disturbance by QoS	MTBD [h]
Pure High Speed	600	3	<5% / > 5 min	5	5%	10%	30%	20%	3E-04	10 000
	600	3	<10% / 0-5 min	0-5	10%	10%	30%	80%	2.4E-03	1250
High Capacity Line	600	5	<5% / > 5 min	5	5%	10%	30%	20%	3E-04	16 667
	600	5	<10% / 0-5 min	0-5	10%	10%	30%	80%	2.4E-03	2 083
Low Capacity Line	200	4	<5% / > 5 min	5	5%	10%	30%	20%	3E-04	13 333
	200	4	<10% / 0-5 min	0-5	10%	10%	30%	80%	2.4E-03	1 667
Urban Railways[3]	50	1	98% / < 2 min	2	2%	10%	30%	30%	1.8E-04	5 555
	50	1	96% / <1 min	0-2	4%	10%	30%	90%	1.08E-03	926

Table 2. Calculation of acceptable mean time between disturbances (MTBD) of ETCS data-transmission for different line classes.

[3] Due to a different punctuality target for urban railways, the QoS ETCS part is estimated to have a share of 30% of delays of more than 2 minutes and 90 % for delays of less than 2 minutes.

6.4 ETCS QoS Targets, Apportionment to Scenarios

The top-down analysis described above leads to a range of MTBD requirements depending on line categories and the consequence of a disturbance. In the following chapters these requirements will be described in detail for the relevant scenarios.

It is recommended that these requirements be compared with the results gained from the ETCS level 2 pilot lines to explore the potential opportunities for optimisation of the application principles for ETCS/GSM-R.

Table 2 lists the top-level ETCS QoS targets by line category. The scenarios used as a basis for the analysis of specific ETCS QoS parameters are:

- Awakening and Start of Mission Procedure
- Entry into Level 2
- MA Extension

Note: the MA Extension scenario is used solely to determine the time allowance which needs to be allowed by the signalling system to ensure that a new Movement Authority is delivered before the train reaches the braking Indication Point associated with the existing Movement Authority. Provided the signalling system is designed to accommodate the worst-case MA update cycle time, no QoS effects are expected from this scenario. Late delivery of a new Movement Authority, i.e. an update cycle time beyond the worst-case update time determined in the scenario, is assumed to be a consequence of a failure of one of the remaining QoS affecting scenarios, e.g. Loss of Communications.

These scenarios are described in detail in the remaining sections of this report. As mentioned in Section 6, two target values are required for each of these scenarios:

Perfect Case – no loss of performance due to ETCS QoS effects. Nevertheless, certain base values for ETCS QoS parameters must be determined in order to derive ETCS and GSM-R application design principles and to quantify the impact of ETCS on line capacity, e.g. GSM-R bit error rate, MA update time.

Normal Case – used to specify acceptable deviations from the perfect case based on compliance with the top-level QoS delay targets defined in Section 6.

The top-level ETCS QoS targets defined in this report must be apportioned between the relevant scenarios listed above. Rather than set arbitrary targets based on, say, an equal weighting to each scenario, it is appropriate to understand the sensitivity of each scenario in terms of its contribution to the potential delay to a given journey. For example, the Entry into Level 2 scenario, which occurs only infrequently on a given journey, is likely to have far less impact on potential delay than the MA Extension scenario which occurs much more frequently. This relationship is shown in Figure 6

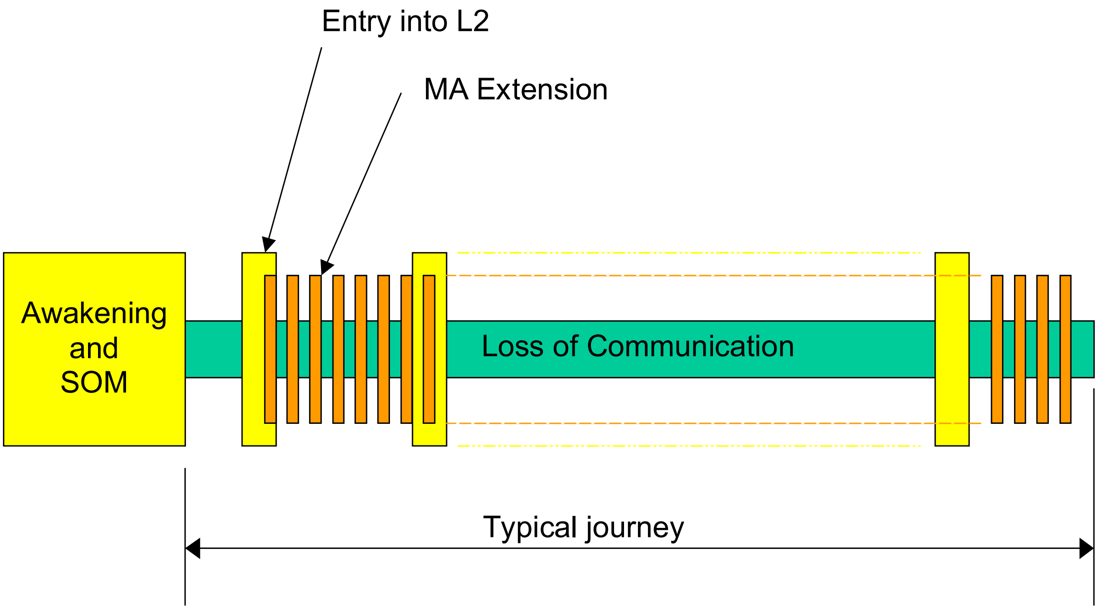


Figure 6. Scenario Sequence

In addition to the frequency with which the scenario occurs, it is also necessary to understand the consequence in terms of operational delay should the scenario fail to meet the 'perfect case' target. Hence:

> *Total delay due to ETCS QoS effects = f(scenario failure rate, consequential delay) for each of the ETCS QoS scenarios.*

The analysis in this report considers each scenario in turn with the objective of determining the contribution of each scenario to potential journey delay based on normal case criteria. Once the relative sensitivity of the scenarios is known, the top-level ETCS QoS targets given in Table 2 can be apportioned to each scenario. Note: for convenience, the ETCS QoS targets given in Table 2 will be expressed in the form of per hour values in the remainder of this report.

7 EXTENSION OF MA

7.1 Description

At the End Of Authority (EOA), the location to which the train is authorised to move, the train needs a Movement Authority (MA) extension to proceed. Details of the structure of the MA are given in the ETCS SRS 2.2.2, SUBSET 026-3, Chapter 3.8, particularly in chapter 3.8.3. Further information on the length of the associated radio messages can be found in Chapters 7.4.2.4 and 8.7.2.

In the ETCS SRS Chapter 3.8.2 (MA request in level 2/3) [4] it is stated:

> *It shall be possible for the on-board equipment to request a new Movement Authority in Levels 2 and 3. The parameters for requesting a new MA shall be given by the RBC. The following possibilities shall be available: a) A defined time before*

the train reaches the indication limit for the EOA/LOA assuming it is running at the warning speed. b) A defined time before the timer for any section of the MA expires. It shall be possible to define whether the MA request shall be repeated until a new MA is received or not and if so, the time between each repetition.

Hence, the infrastructure manager has a choice of using train initiated MA extension request, a defined time prior to needing a new MA, or, alternatively, new MAs can be generated automatically by the RBC in response to a change of interlocking output, i.e. the route being extended ahead of the train's position. A detailed consideration of the factors influencing this choice lies beyond the scope of this document but the analysis which follows assumes the initiating event is detection of a change at the interlocking output. The analysis is equally applicable to the train initiated MA update process except that the MA request must be received before the change of interlocking output occurs. This condition is satisfied by using a value of T_MAR which takes account of both the MA update response time and the time taken for the MA request to be transmitted and interpreted by the RBC.

Figure 7 illustrates the whole chain of interfaces and actions which need to be considered for the process of a MA update or extension:

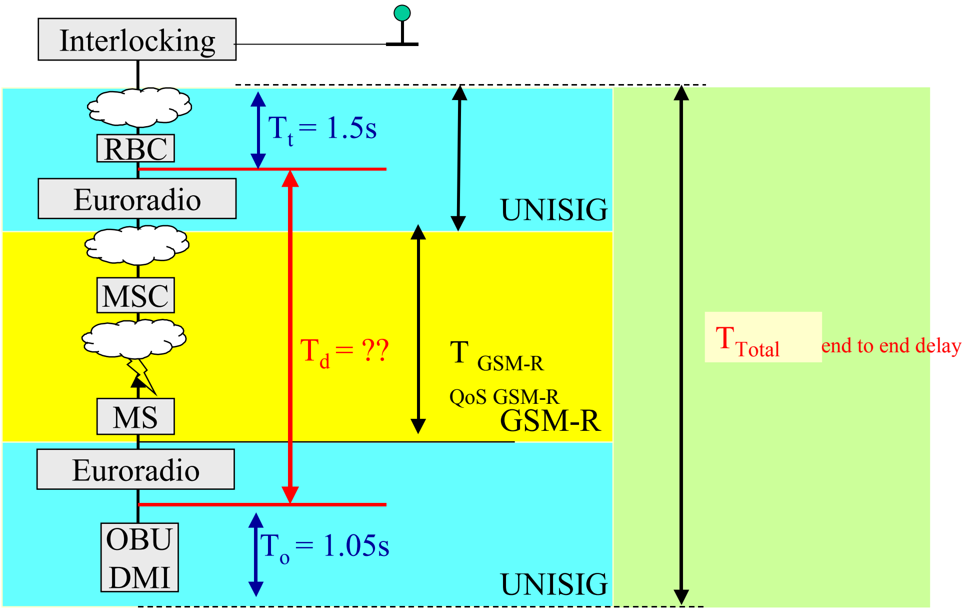


Figure 7. ETCS MA Update Transmission Path

In this context, the end-to-end delay of MA transfer and processing time, T_{Total}, means the total time delay from the interface between the interlocking and RBC to the interface between ETCS onboard unit and the driver.

The time for the trackside, the GSM-R part and the ETCS Onboard unit include for example the following items:

- data transmission from interlocking to RBC

- RBC-delay
- Euroradio delay
- T_{GSM-R} - data transmission from RBC to mobile, including any necessary data retransmission due to GSM-R cell handover process
- ETCS data length
- mobile station behavior
- EURORADIO behaviour (e.g. HDLC procedure in case of transmission interference)
- signal processing time of ETCS onboard (including Euroradio and DMI update time)

In the following analysis the sum of $T_{Trackside}$ (T_t), T_d (includes T_{GSM-R} and Euroradio) and T_{OBU} (T_o) will be called T_{Total}. The derivation of the mean values of T_t and T_0 is addressed within the scope of UNISIG document SEL0452 v0.3.0 [6].

7.2 Analysis

In principle, a MA could be transmitted as soon as it is available, though giving a MA implies locking a route for safety reasons. If this occurs too early this could lead to a reduction in track capacity (due to the locked route not being available for another train).

The principles underlying the MA extension process differ from railway to railway. We have chosen an end-to-end operational view (T_{Total}) which takes into account both the headway and capacity of the line.

Comparison with existing train control systems was the starting point for the evaluation of MA update time. This leads to a value of T_{Total} of the order of 4 s for the “normal case”, which means that everything is working as designed, free of any equipment failures or radio propagation problems. The value of 4 s is based on the existing train control systems for high-speed lines, which means that a derivation from this towards higher values is possible in case of lines with lower traffic density.

Since data-transmission by radio is a process which is subject to statistical laws, the need for a criterion for the “perturbed state” was also investigated. The maximum tolerable transfer and processing time for a movement authority (MA) or MA extension was deduced from two points of view:

a) an acceptable value for the processing time for a MA which does not cause any train delay.

b) an acceptable value for the processing time for a MA which does not decrease the existing track capacity.

Both points were investigated and discussed, the criterion finally chosen was: *The calculated value for the track capacity is not reduced by more than 0.5 train path every tenth day.*[4]

This criterion can be applied on lines with different headways or required track capacities, respectively and leads to a value for the maximum acceptable processing time for a MA. Those two variables are the only ones relevant to this calculation, a different speed does not affect the results. To take into account the statistical nature of data transmission it was assumed that the derived value is a **mean** value not a maximum value.

Rules of statistics could be applied here. The distribution of the mean values of T_{Total} per day (i) could be described by a distribution function $f_i(x)$ with a mean value μ_i. On 9 days μ_i = 4 s and on the tenth day a larger value depending on the required track capacity. If one further assumes that the distributions are independent of each other, they could be described by one distribution function with a mean value as in column (3) of Table 3. This mean value is the acceptable mean value for T_{Total}. Details can be found in [7].

7.3 Quality of Service Requirements

The QoS criterion T_{Total} for MA transfer and processing time for each track category requires the fulfillment of the average value of column (3) and the maximum values of columns (4) to (6) :

Headway [min]	**Trains / h and direction**	**Mean Value** [s]	**Δt smaller or equal 4 s**	**Δt smaller or equal 7 s**	**Δt smaller or equal 12 s**
(1)	(2)	(3)	(4)	(5)	(6)
2	30	4,02	49,7%	93,2%	99,9967%
4	15	4,07	48,7%	92,9%	99,9964%
7,5	8	4,24	45,3%	91,7%	99,9948%
30	2	7,83	2,8%	34,0%	98,1576%

Table 3. QoS criterion T_{Total} for MA transfer depending on track category.

Average value and distribution function can be illustrated as shown in Figure 8 for two of the defined line categories:

[4] In reality, of course, this does not mean the loss of a track (which could not be sold then) but rather leads to a reduction of time reserves.

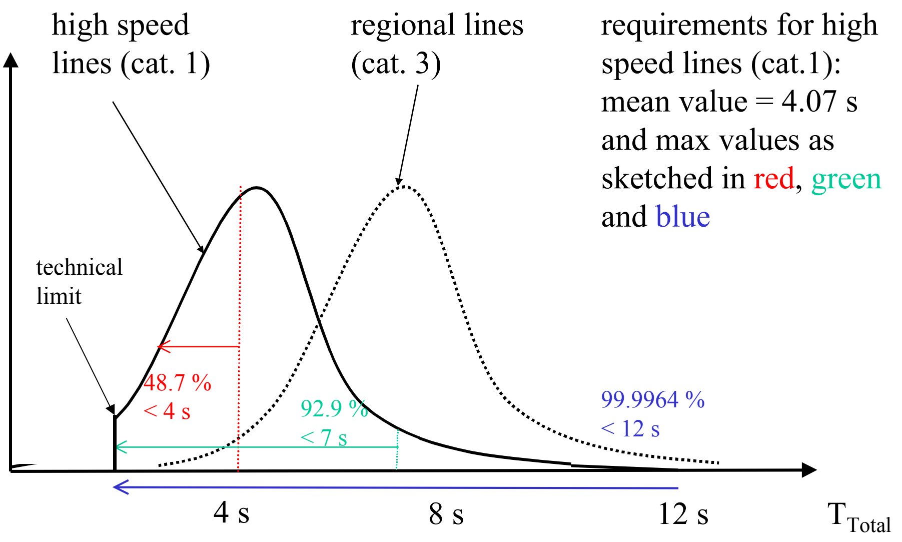


Figure 8. Statistical distribution of MA extension time.

Normally, ETCS Level 2 will be applied on lines without lineside signals. However, in certain circumstances, lineside signals will also be installed as described in the ETCS SRS (Chapter 2). Where lineside signals are also installed, these signals may be switched off or a special aspect used if a route is set for an ETCS equipped train. Some railways may not switch off the lineside signal aspects in which case the driver will receive information both from the lineside signals and the ETCS DMI. In these cases, the time difference between the aspect change and the corresponding DMI update should be reduced as much as possible for ergonomic reasons. A time difference of less than 5s should be achieved wherever possible.

7.4 Influences of MA Extension Scenario on ETCS / GSM-R QoS

From an operational point of view, late MA update results in a new MA only being received and displayed on the DMI after the Indication Point has been passed. Late update occurs when the MA update cycle exceeds the target value. The mean update time cannot be used as the performance target since this will result in delay in 50% of cases. A suitable target value must therefore be specified which will ensure that the top-level target is achieved, taking account of the apportionment of the top-level target between the relevant scenarios.

A bottom-up analysis can also be carried out based on a detailed study of the behaviour of the ETCS and GSM-R sub-systems. UNSIG documents UNISIG_ALS_ERQoS v.0.1.0 [5] and UNISIG_ALC_COM_SEL0452 v0.3.0 [6] provide such an analysis. The target value suggested by UNISIG in [6] covers the range 4.1s to 5.0s mean for a Baud rate of 4800 bit/s a BER of 10^{-4} and an MA length of 250 to 500 octets. This value does not allow for any perturbing effects such as HDLC frame repetition caused by interference or cell handover and can be taken as the perfect case value for this scenario. The equivalent mean value including effects of HDLC errors is quoted as 5.7s. The worst-case value is quoted as 12.5s (after the 6s position report time is deducted which is not relevant to this scenario). This worst-case value takes all normal perturbations into account (GSM-R cell handover) but excludes more serious effects such as burst errors due to electrical interference or a loss of communication. Hence, the normal case mean transmission time would be 4.5s for a 250 octet MA with a normal case maximum update time of 12.5s with a 750 octet MA. This leads to the conclusion that an MA update allowance of 12.5s maximum would ensure that all MA updates occur without operational delay (excluding effects of interference bursts and loss of communication). Note that this bottom-up analysis is included here for information purposes only. The QoS targets will be derived according to the top-down analysis described in Section 6.

A top-down analysis of the impact of QoS related delays is primarily concerned with operational delay, i.e. delayed arrival times. The relationship between delayed MA update and the consequential delay in terms of delayed arrival time needs to be determined. Transmission delays in excess of the normal case maximum transmission time will result in MA update taking place after the train has passed the Indication Point. The Indication Point represents the moment at which the driver becomes aware of the need to apply the brake. If we assume that the driver applies the brake manually on reaching the Indication Point, the train speed will have reduced by the time the updated MA is displayed on the DMI. The driver will then release the brake and apply power to return the train to the nominal line speed. This process is illustrated in Figure 9.

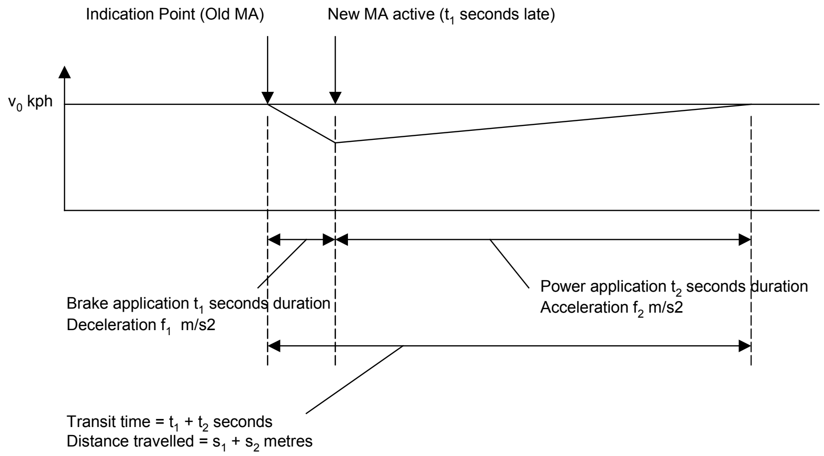


Figure 9. Late MA Update - Consequential delay

The magnitude of the operational delay is a function of the extent of the transmission delay and the train's dynamic properties. This process is described in more detail in Appendix D.

For example, assuming driver initiated deceleration and acceleration characteristics of 0.5m/s2 and 0.3m/s2 respectively, a train travelling at 200 kph, will experience no delays for an MA update delay up to 10s. An operational delay of 9s would result from an MA update delay of 30s. These figures assume that the driver will make a partial service brake application within 1s of reaching the Indication Point. Hence, it can be seen that MA update delays in the range 0-10s are likely to have little impact in terms of overall journey times. Nevertheless, updates which occur after the train has reached the Indication Point are undesirable for ergonomic reasons and the potential passenger discomfort and energy wastage resulting from an unnecessary brake application. For this reason, the scenario success criterion that MA updates should be displayed before the train reaches the Indication Point remains valid.

Figure 10 shows the relationship between the MA update time distribution function and the resultant impact on journey time. It can be seen that the potential journey time delay is strongly influenced by the magnitude of the time margin between the mean MA update time and the target update time value adopted for ETCS/GSM-R QoS. The greater the QoS update time target, the smaller the impact on journey time. There is an upper limit associated with the MA update time, this is a function of the error recovery algorithms employed within Euroradio. Failure to deliver an MA update within this time limit results in a radio link failure being declared, refer to the Loss of Communication scenario.

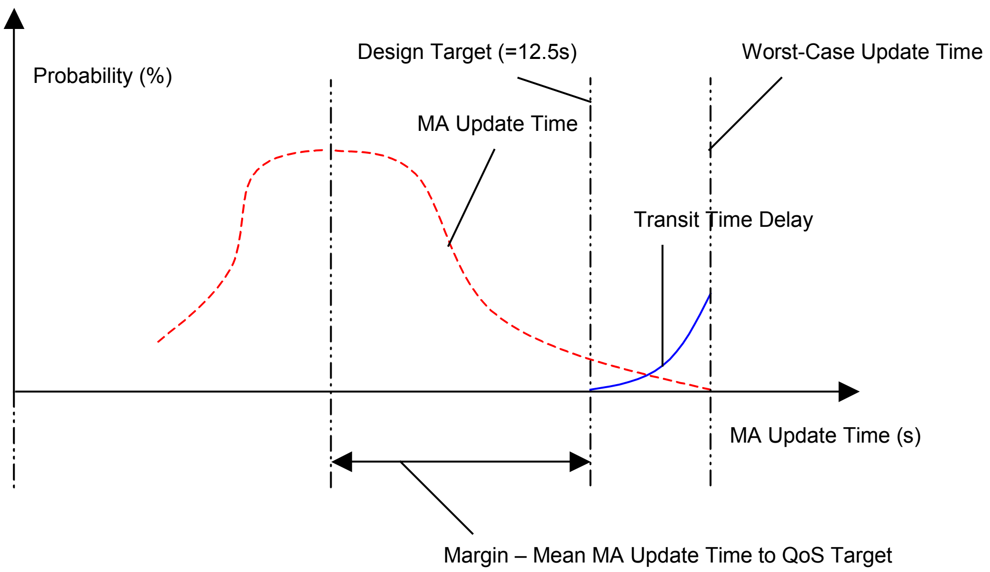


Figure 10. Relationship between MA update distribution and potential journey delay

As explained above, the resultant delay is dependent on the line speed and a particular train's dynamic characteristics at the same speed. Trains having a large deceleration to acceleration ratio will experience more delay in response to late MA update. Hence choice of an appropriate MA update allowance is dependent on the characteristics of the rolling stock using the line.

7.5 Impact of MA Extension Process on Line Capacity

The choice of the normal case maximum MA update target for this scenario has a direct impact on line capacity. The greater the MA update response time allowance, the greater the separation between following trains on the same line resulting in a reduction in theoretical line capacity. This effect is shown in Figure 11.

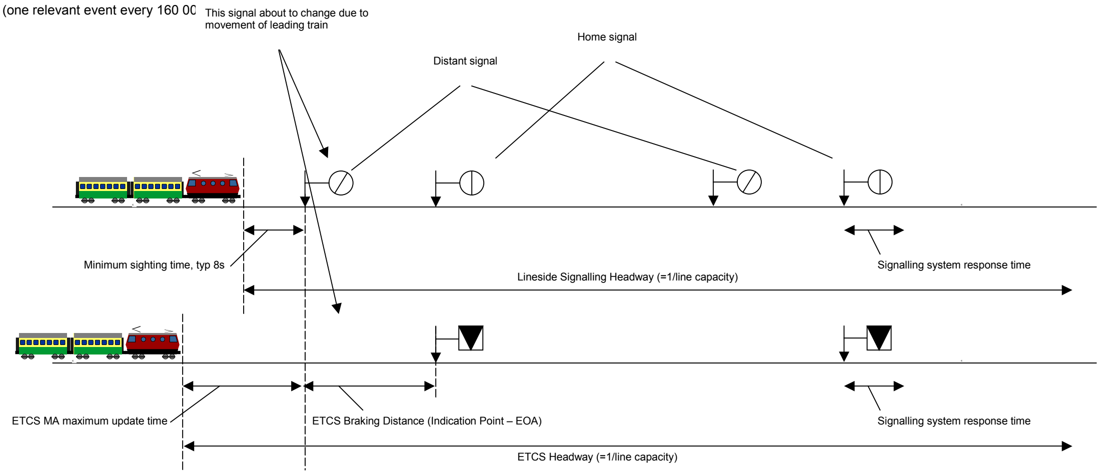


Figure 11. Impact of MA Update time on signalling headway and line capacity

Figure 11 shows a comparison between a route fitted with lineside signals and ETCS (without lineside signals). The upper portion shows how the minimum spacing between trains (headway) is governed by the signal spacing and the response time of the signalling system. The two trains are shown at their theoretical minimum spacing at the precise moment the signal aspects change. At this moment:

- The leading train has moved forward of the relevant track section boundary (axle counter or track circuit joint) by a distance corresponding to the time taken by the signalling system to update the signal aspects in response to the relevant track section becoming clear. This is the basic signalling system response time, i.e. train detection input to aspect output.

- The following train has reached the minimum allowable sighting point of the distant signal as it changes from a caution to a proceed aspect. The sighting time allowance varies from railway to railway but is typically of the order of 8s. This minimum allowance must be included as part of the theoretical headway specification, i.e. the distant signal must display a proceed aspect before the train reaches the sighting point when the line is operated at its theoretical maximum capacity.

The lineside signalling sighting constraint is not relevant to ETCS fitted routes. Normally, the MA will be displayed on the DMI at approximately the same location as the unfitted train would reach the signal sighting point, i.e. 8s before reaching the distant signal, assuming a mean MA update time of 4-5s and an MA response time design allowance of 12.5s. For the sake of simplicity, it is further assumed that the ETCS braking distance from the braking Indication Point to the EoA is directly equivalent to the distance between the distant and home signals for the non-ETCS fitted case[5]. MA updates longer than the mean update time will be invisible to the driver of the ETCS fitted train, provided the new MA is displayed before the train reaches the braking Indication Point. Note, this reduction

[5] Note the distance and time allowances between the ETCS brake indication point and the EOA are defined in EEIG document 97E881 which is in discussion between the EEIG and UNISIG.

in sighting time may be ergonomically undesirable for routes where the lineside signals are retained, e.g. certain Category 2, 3 and 4 routes used by unfitted trains.

As mentioned in the preceding paragraph, the example shown in Figure 11 assumes that the ETCS braking distance from the brake Indication Point to the EOA corresponds directly to the signal spacing (distant to home signal) for the non-ETCS case. In practice, signal spacing is normally based on worst-case assumptions regarding train performance. This means that the capacity of a line signalled with lineside signals is constrained by the performance of the worst performing trains on the network. ETCS fitted trains calculate their stopping distance on the basis of specific train data allowing greater capacity to be achieved for trains with improved braking characteristics. In other words, the ETCS Indication Point becomes the functional equivalent of the distant signal. The capacity of the line will therefore be improved in the case of ETCS fitted trains whose braking requirements (braking Indication Point to EoA) are less demanding than the normal lineside signal spacing.

7.6 Application Rules

According to UNISIG document SEL_0452, the worst-case MA update time is 12.5s, assuming an MA length of 750 octets and a GSM-R data transmission rate of 4800 bps (ignoring any position reporting or other precursor events). This worst-case response time takes account of effects such as equally distributed bit error rate (in time) at the recommended minimum EIRENE bit error rates for ETCS data transmission. Random interference effects such as burst errors are not taken into account, but, as has already been explained above, burst errors which result in a temporary transmission break are unlikely to cause any significant operational delay if they do not exceed more than 10s and occur infrequently. Hence, it can reasonably be argued that an MA update response time of the order of 12.5s should be accounted for in a practical implementation of ETCS.

This means that in practice, generation of a new MA should commence 12.5s before the train reaches the Indication Point of the currently-held MA. Hence, for train initiated MA update, T_MAR should be set to 12.5s plus the time taken to transmit the MA request message to the RBC and any time for the RBC to process this request. Alternatively, in cases where the RBC generates a new MA automatically in response to a change in interlocking output, the 12.5s update time allowance must be taken into account in the design of the overall signalling system to satisfy a particular combination of line speed and capacity. In conclusion, on lines which relay solely on cab signalling with no lineside signals, the 12.5s update allowance includes the sighting time allowance normally associated with lineside signals. This means that an ETCS MA update time of 12.5s is directly comparable with existing systems such as LZB. For example, within DB, LZB is normally used with a sighting time allowance of 8s and an assumed response time of 4s.

7.6.1 Requirements Summary

The following operational requirements emerge from this analysis:

- The mean MA update response time (interlocking output to DMI update) shall lie in the range 4 to 5s for a 250 octet MA.

- The MA update time for a 250 octet MA shall not exceed 12s in 99.9967% of cases (Category 1 line), 99.9964% of cases (Category 2 line), 99.9948% of cases (Category 3 line) and 98.1576% of cases (Category 4 line).
- The above requirements are based on a BER of 10E-4 and a data transmission rate of 4800 Baud.
- The signalling system shall be designed for an MA update time of 12.5s assuming a data transmission rate of 4800 Baud, BER of 10E-4 and a 750 octet MA. Where smaller values are required in time-critical locations, e.g. stations and junctions, this must be achieved by optimisation of MA size, data transmission rate and BER.

8 ENTRY INTO ETCS LEVEL 2

8.1 Description

A detailed description of the requirements applicable to the entry into Level 2 scenario can be found in the ETCS SRS v2.2.2, chapter 3.5.3 (Establishing a communication session) and chapter 5.10 (Level Transitions).

Entry into a Level 2 area amounts to a transition to Level 2 from another ETCS Application Level. Level transitions are triggered by command from trackside balise groups. A transition order balise group is located at the transition boundary, the transition takes effect as the train passes this balise group. Additionally, an announcement balise group is placed on the approach to the transition boundary to alert the driver (N.B. announcement may be given by radio if current Level is 2 or 3). Transition announcement is only mandatory for transitions to Level 2 or 3 areas. The general arrangement at a level transition boundary is shown in Figure 12.

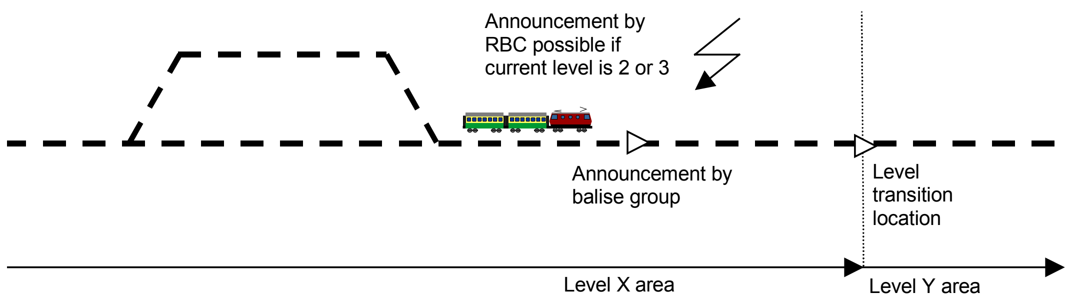


Figure 12. Transition from Level X to Level Y

This chapter will focus on the entry into level 2 from an unfitted area or an area fitted with a national system (Level 0 or Level STM respectively).

The ETCS SRS specifies the sequence of events leading up to the transition:

- *An order to connect to the RBC shall be given via balise group in rear of the border location.*

- *Train Data shall be sent to the RBC (which acknowledges the data) unless the Onboard equipment is in Sleeping mode).*

- *A level 2/3 MA and track description information shall be received from the RBC before the level transition border. If not, the train shall be tripped at passage of the border, i.e. after switching to level 2 or 3, movement is not allowed without a movement authority (refer to SRS chapter 4, transitions between modes).*

- *The driver is responsible for entering the level 2/3 area at a speed not exceeding the maximum speed of the level STM line on the approach to the transition.*

- *A position report shall be sent to the RBC when the level transition location is passed and any active STM shall be set to standby.*

Implicit in the above sequence is the precondition that GSM-R coverage must be available, and the Onboard registered with the applicable GSM-R network, prior to receipt of the initial order to contact the RBC.

The sequence of messages exchanged between the Onboard ETCS and the RBC is summarised in Figure 13.

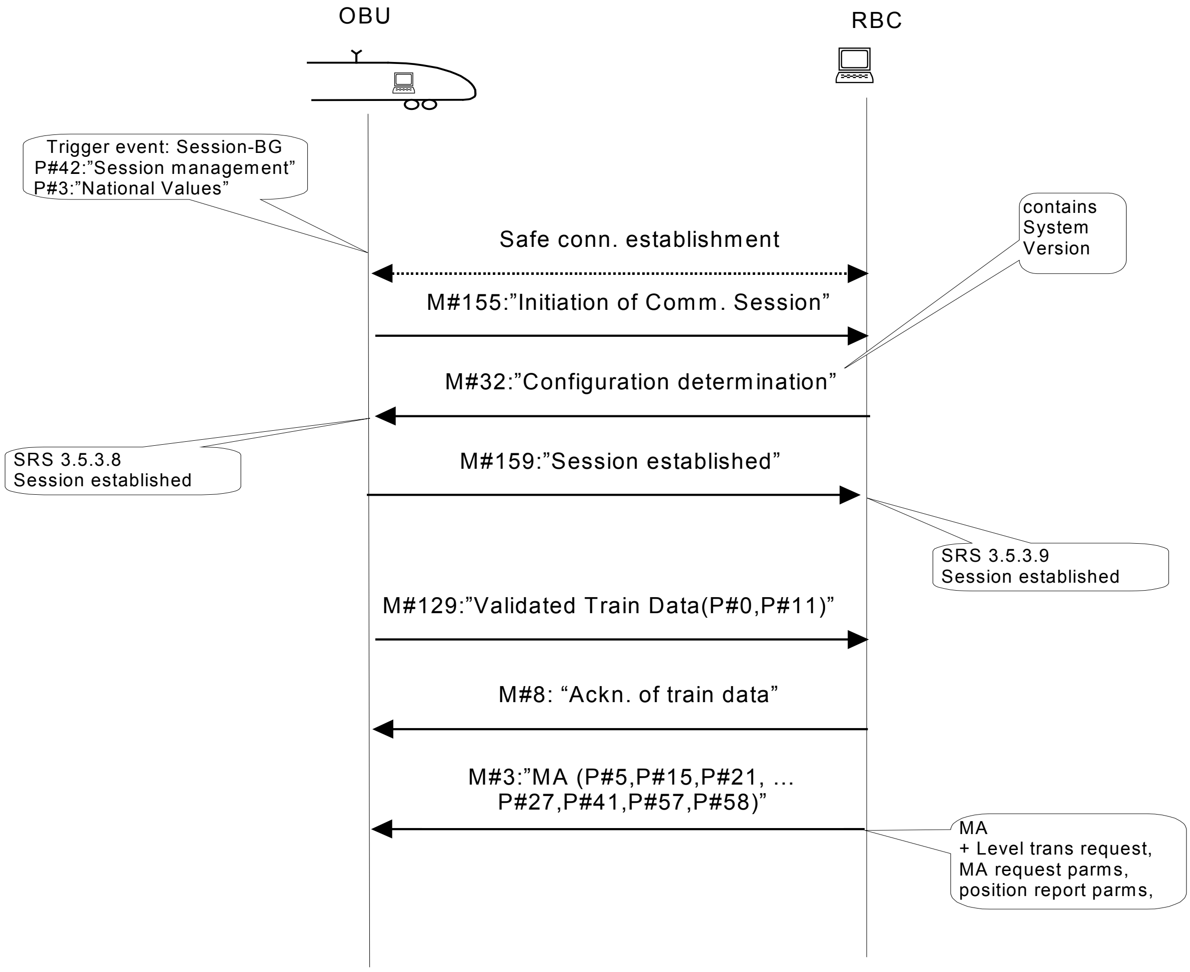


Figure 13. Message Sequence - Entry into Level 2

The precise manner in which ETCS is applied to a given track layout will vary from one installation to another according to national application standards and the specific features of a given track layout. A generic application example is shown in Figure 14. This example has been chosen to illustrate the key functional steps which can be expected to apply to the majority of practical applications. This example shows a generic track layout at the transition from an area equipped with a national train protection system, e.g. PZB, KVB, LZB, TVM, BACC, TPWS etc, to a route equipped with ETCS Level 2. An alternative route is provided for unfitted trains, or trains with unserviceable ETCS Onboard equipment, to prevent them entering the ETCS fitted line. Note, details of the national system are omitted from this diagram in the interests of clarity.

The first technical requirement to be satisfied is provision of a GSM-R service to the Onboard ETCS equipment. This requirement is fulfilled by ensuring that GSM-R radio coverage is provided consistent with GSM-R minimum quality criteria (e.g. field strength, bit error rate etc.) The GSM-R coverage must be provided sufficiently far in rear of the transition boundary to ensure a successful registration of the GSM-R Mobile Station with the network before ETCS commences the EURORADIO safe connection establishment process.

The GSM-R network registration process is not fully defined in the ETCS specifications. Note: A CR (U007) defining a new ETCS variable containing the GSMR network ID is currently in process.

As soon as the power of the Mobile Station is switched on, it initiates the network registration process according to the standard GSM specifications. This means it will first try to register with the previous network. If that is not found, then it will try to register according to the priority table in the SIM card. According to ref [2] (A11T6001) the network selection mode is set to manual. This means that the onboard ETCS can order the mobile station to register with a specific network. Note: 'manual' does not refer to any driver activity in this context. Following such a manual order from onboard ETCS, the Mobile Station shall not select any other network if the network specified in the manual registration order is not available.

When the train approaches a Level 2 transition border, we can therefore neither be sure that the Mobile Station is already registered with the correct network, nor that onboard ETCS knows the identity of the correct network. This means that the transition process has to start with a message from trackside, containing an order to register with the right network.

It is assumed that the only network selection function of onboard ETCS is to forward any network ID received from trackside as a manual network selection order to the Mobile Station. This needs to be confirmed by UNISIG in the context of CR U007. It is further assumed that the orders to select the right network and to call the RBC could be combined in one balise.

According to UNISIG in SUBSET-093 [8], a value of 40s is considered to be an appropriate limit for the time taken for the Mobile Station to complete registration with the relevant network. Following network registration, the next step in the process is the establishment of a safe connection between the Onboard and the RBC. This event is triggered by receipt of ETCS Packet 42 from a balise. The Onboard and RBC negotiate a secure connection using the data contained in Packet 42 (RBC identity information). The Onboard reports its position as soon as the session has been established (see SRS v2.2.2 3.6.6.2 h [4]).

The transition announcement may be given by balise or by radio. This announcement is given by means of Packet 41. The announced location is supervised by the ETCS Onboard equipment and the transition implemented at the boundary, irrespective of the subsequent receipt of the necessary ETCS control data (Movement Authority and track description). A train attempting to enter the ETCS Level 2 route without the relevant ETCS control data will be tripped as it crosses the transition boundary (i.e. detection of transition balise or passing location given in Packet 41). It is assumed for simplicity that the transition announcement, Packet 41, is contained within the same balise group used to order the connection to the RBC, Packet 42 (Separate balise groups may be used for each telegramme, if preferred). The transition announcement will be given as soon as a safe connection has been established if the system is configured to deliver the announcement by radio. The term 'announcement balise' used in this report is intended to refer to the balise used to transmit the initial order to contact the RBC. There is no intention to exclude the possibility of transmission by radio. The medium used to transmit the transition announcement, balise or radio, is not expected to have any significant influence on the QoS requirements applicable to this scenario.

Having received an initial position report following establishment of an ETCS communication session, the RBC, sensing that the train is approaching a transition to a Level 2/3 area, attempts to generate a Movement Authority on the basis of route information obtained from the trackside signalling system (i.e. the interlocking). Provided the RBC is able to determine that a route is set beyond the transition boundary, the Movement Authority is transmitted to the Onboard ETCS equipment. The RBC also transmits the applicable trackside description data (gradient, static speed profiles etc.).

The Onboard responds by acknowledging receipt of the Movement Authority. On receipt of this acknowledgement, the RBC may optionally request the trackside signalling system to clear the signal on the approach to the ETCS Level 2 transition boundary. Note that the term ‘signal’ is used here in the context of a transition from Level 0. Transitions from Level STM to Level 2 may be managed without the use of lineside signals; the equivalent signalling authority may instead be given by the national cab signalling display, in which case, the signals shown in Figure 14 and referred to in the following text would be replaced by lineside marker boards or their equivalent. If the process described fails for any reason, the train will be brought to a halt at the junction signal or maker board under the control of the national system. An operational decision can then be taken to reroute the train away from the Level 2 area. Note that this RBC function is an optional feature which may or may not be implemented according to national preferences. If this function is not implemented, failure of the RBC to deliver a valid MA will result in the train being unexpectedly tripped as it crosses the Level 2 boundary. The consequence will be a significant operational delay. The impact of late MA delivery is significantly reduced where the optional function is used, the resultant delay will be similar to the MA extension scenario in this case.

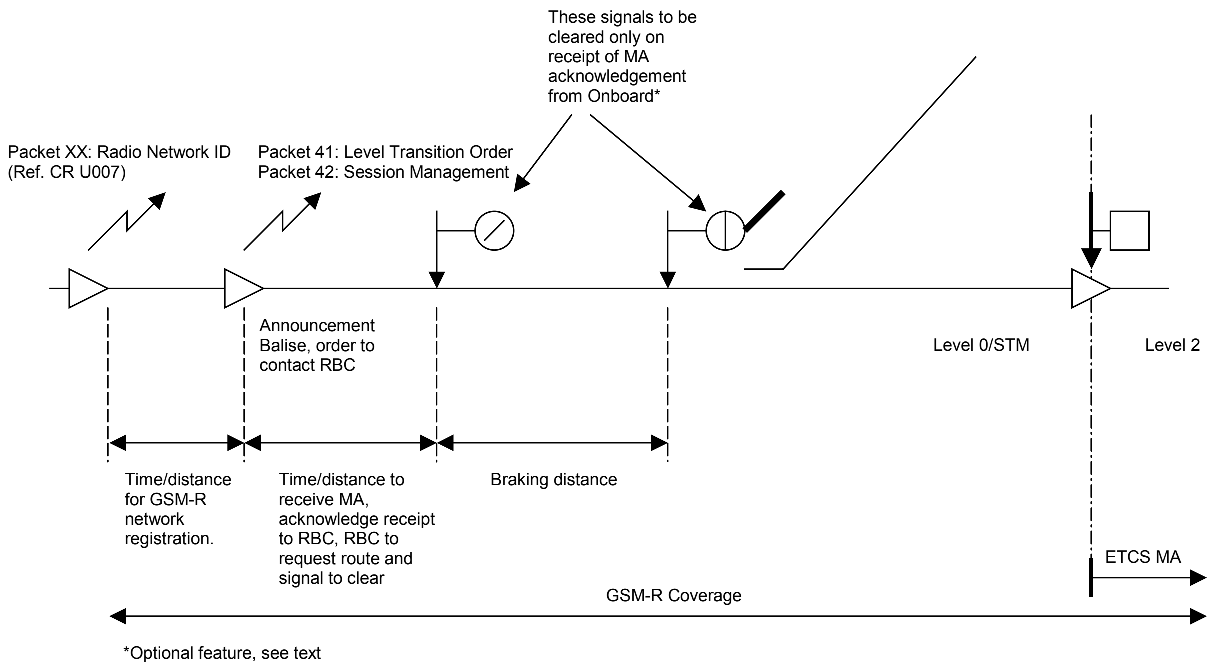


Figure 14. Entry into Level 2 – Balise Location Principles

8.2 Analysis

The relevant performance objective for this scenario is that trains should be able to enter ETCS Level 2 routes without any reduction in speed due to ETCS-related causes. Trains which comply with this simple operational objective will be considered to have made a successful entry. Trains will not always be able to meet this objective due to the statistical nature of the communications and data processing functions involved. A target must therefore be established to define an acceptable probability of success.

It can be seen from the functional analysis given in Section 8.1, that the following features have a direct impact on the statistical chances of achieving a successful entry into the Level 2 area:

8.2.1 Registration with the relevant GSM-R network

Mobile Station registration must be complete before the approaching train is ordered to contact the RBC (by the announcement balise). This system requirement leads to further requirements concerning the physical extent of the GSM-R radio coverage in relation to the speed of approaching trains and the time taken to execute the registration process.

8.2.2 Euroradio Session Establishment

Must be complete in good time to allow ETCS to be able to communicate with the RBC taking account of the subsequent actions (see below) which must be complete before the train reaches the point at which a brake application becomes necessary.

8.2.3 Generation and Delivery of Initial ETCS Movement Authority

Must be complete in good time to allow ETCS to deliver the initial ETCS Movement Authority to the approaching train taking account of the subsequent actions (see below) which must be complete before the train reaches the point at which a brake application becomes necessary.

8.2.4 Clearance of National Signals Controlling Approach to ETCS Boundary

Must be complete in good time to allow the national signalling system to clear the signal controlling the approach to the ETCS boundary before the train reaches the point at which a brake application becomes necessary. As explained above, this is an optional function,

These requirements translate into generic application engineering rules based on train speed and system response times. The formation of ETCS application rules is beyond the scope of this document. The relevant system response times are as follows:

- $T_{GSMRREG}$ - time to detect and register with the relevant network on entry to GSM-R coverage area – needed to determine geographic limits of GSM-R coverage area in rear of the announcement balise.

- $T_{SESSIONESTABLISHMENT}$ - Time required for Euroradio session establishment – contributes to the determination of the geographic location of the announcement balise in rear of the brake indication point (distant signal).

- $T_{MAUPDATE}$ - Time taken for the RBC to generate and deliver the initial ETCS Movement Authority - contributes to the determination of the geographic location of the announcement balise in rear of the brake indication point (distant signal). This allowance is identical to the normal Movement Authority update time defined in Section 7, assuming that the relevant route data is already available from the national signalling system. An additional allowance must be made for any additional delays imposed by the national signalling system.

- T_{MAACK} - Time taken for the Onboard ETCS to acknowledge receipt of the initial Movement Authority - contributes to the determination of the geographic location of the announcement balise in rear of the brake indication point (distant signal).

- $T_{SIGNALCLEAR}$ - Time taken for the national signalling system to clear approach signals in response to RBC request - contributes to the determination of the geographic location of the announcement balise in rear of the brake indication point (distant signal). This request is made in response to MA update acknowledgement from the Onboard. Signals must clear before train the distant signal to avoid need for braking. Note this parameter is only relevant where the optional MA acknowledgement function is used.

Hence, two performance constraints can be derived:

- GSM-R coverage must be available a time $T_{GSMRREG}$ before the train reaches the announcement balise.

- The announcement balise must be located a minimum travel time $T_{ANNOUNCEMENTL2/3}$ in rear of the brake indication point (distant signal) where:

  $T_{ANNOUNCEMENTL2/3} = T_{SESSIONESTABLISHMENT} + T_{MAUPDATE} + T_{MAACK} + T_{SIGNALCLEAR}$

8.3 Quality of Service Requirements

Section 8.2 concluded that there are two principal Quality of Service response time parameters applicable to the entry into Level 2 scenario, $T_{GSMRREG}$ and $T_{ANNOUNCEMENTL2/3}$. Appropriate target values for these parameters must now be considered.

A prompt response to the manual registration order received from the trackside balise (see Section 8.1) is clearly preferable since this limits the extent of GSM-R coverage which must be provided in rear of the ETCS Level 2 area. The longer the time taken to complete the registration process, the greater the extent of GSM-R radio coverage that must be provided. Determination of the absolute value of $T_{GSMRREG}$ is largely an economic matter so far as the infrastructure elements are concerned. Appropriate values can therefore be determined at national level. In conclusion, the principal interoperability requirement so far as Quality of Service is concerned is the ability of a given network to complete the registration process within the nationally specified target value. The registration process will exceed this limit in a minority of cases leading to a failure to meet the fundamental objective of allowing a train to enter onto a Level 2 area without reduction of speed. Hence, a defined confidence factor needs to be established for the probability of successfully completing the registration process within the nationally specified target value.

Likewise, the absolute value of the ETCS announcement parameter, $T_{ANNOUNCEMENTL2/3}$, is not significant in itself, provided the announcement balise is place sufficiently far in rear of the brake indication point (distant signal). As for the GSM-R registration process, the important consideration from the Quality of Service point of view is the confidence factor associated with achievement of the target value since values in excess of the target will result in failure to achieve the scenario’s fundamental performance objective. It is important to note that this parameter includes performance parameters related to ETCS, GSM-R (including associated fixed telecommunication links) and the national signalling system. The contribution of the wholly national elements, i.e. the GSM-R related fixed telecommunication links and the national signalling system should not be included within the derivation of the ETCS QoS parameters due to the wide variation in the performance attributes of individual national systems. These national systems have no impact on interoperability; nevertheless, an appropriate allowance must be made when formulating relevant national applications engineering rules governing placement of the announcement balise.

8.4 Application Rules

Balises must be placed on the approach to the Level 2 area to ensure that GSM-R registration takes place and an RBC session is established in good time to allow the necessary ETCS messages to be passed when required. The positioning of these balises must take account of the time needed to complete the registration and session establishment process at the applicable line speed.

9 AWAKENING AND START OF MISSION PROCEDURE

9.1 Description

A detailed description of the ETCS Start of Mission procedure is given in the ETCS SRS v2.2.2 SUBSET 026-5, chapter 5.4 [4]. The principal Quality of Service related performance parameter is the time taken from the driver's first interaction with the system up to the point at which authorisation to proceed is displayed. The precise steps to be followed will inevitably vary according to the way in which the Onboard equipment has been configured and specific operational circumstances. The analysis in this section is focused on missions which have the objective of starting in Full Supervision mode. This includes missions which start initially in Staff Responsible mode due to the need to verify entry conditions to Full Supervision mode (e.g. verification of train position). Missions which start in other modes, i.e. NL, SL, SH, OS and UN are excluded from this analysis as the respective ETCS initialisation process is not expected to adversely affect operational service. Missions starting under the control of an STM will be included in a future issue of this report.

9.1.1 Initial Conditions

The initial starting conditions for the ETCS equipment will inevitably vary according to operational circumstances and the manner in which the ETCS Onboard equipment is configured. For example, the Onboard assembly could be connected directly to a vehicle power bus which means that it would remain energised whilst the vehicle is parked. A load shedding arrangement is likely to be used to limit the duration for which the Onboard assembly remains powered to prevent battery discharge.

One of the following initial states will apply on entry to the Start of Mission process:

- Driving position unoccupied, Onboard in NP mode (*vehicle parked, no power to Onboard ETCS*)

  This is the typical situation applicable to a diesel-powered vehicle which has been left unattended for any significant period.

- Driving position unoccupied, Onboard in SB mode (*power to Onboard maintained whilst vehicle parked between missions*)

  This situation is typical of vehicles with electric traction where the traction supply is maintained for the purpose of float charging of vehicle batteries and maintaining power to other vehicle systems.

The variety of operational situations described above results in range of initial starting conditions on entry to the Start of Mission procedure described in the ETCS SRS. The full range of possible entry conditions is listed below:

Mode Sequence	Scenario
NP – SB	Both cabs unoccupied (with both Onboards powered down), new cab occupied (both onboards powered up), new cab opened (causing old cab to go to SL)
SB	Both cabs unoccupied (with both Onboards remaining powered up), new cab occupied, new cab opened (causing old cab to go to SL)

Note: 'old cab' refers to the cab used in the previous mission, 'new cab' is the cab to be used for the new mission.

It can be seen from the above analysis that there are two modes in which a new mission can commence, NP and SB. The ETCS Start of Mission procedure described in the ETCS SRS 5.4. considers SB mode only, NP mode isn't specifically mentioned. This is an academic point since the only condition necessary for the transition from NP to SB to occur is the application of power to the onboard ETCS. The operational differences between these two initial states is that the power-up self-test procedure is carried out on entry to SB mode from NP mode and that certain control data may need to be revalidated following transitions from NP mode, e.g. train position, ETCS level.

The driver's interaction with the system commences with the activation of the driving position, normally achieved by means of a key operated switch which activates all relevant control systems, including the ETCS Onboard equipment. This step is referred to in the ETCS SRS as 'opening the desk'. The driver is prompted to enter or revalidate his ID on opening the desk and may be required to validate or re-enter the required ETCS Level and RBC contact details.

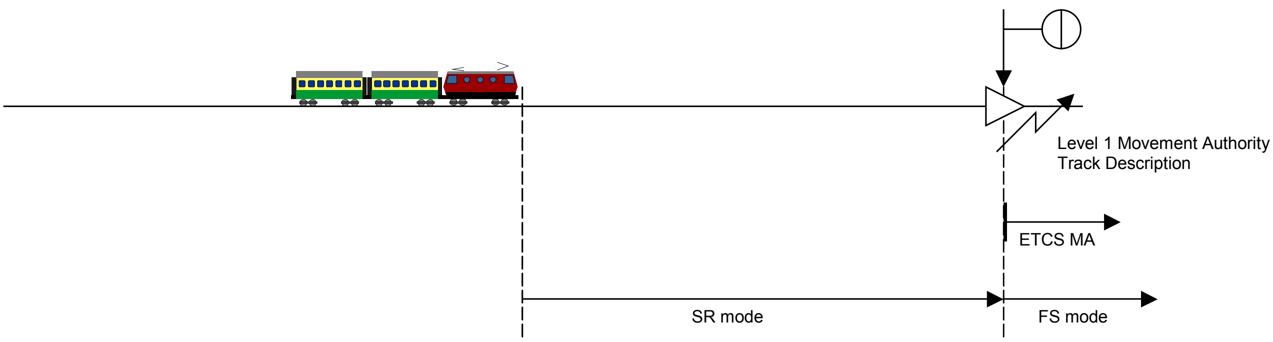
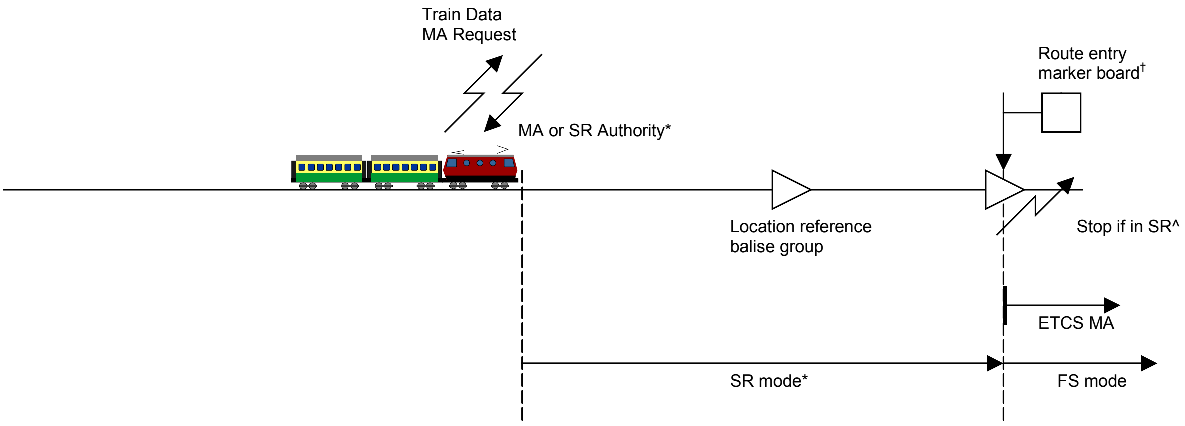


Figure 15. Starting in Level 1

A typical arrangement for the Level 1 Start of Mission procedure is shown in Figure 15. Trains cannot start directly in Full Supervision mode in Level 1 areas since there is no means of delivering an ETCS Movement Authority to the train. Hence, trains must run in

SR mode at least until reaching the first balise group capable of issuing an ETCS Movement Authority. Transition to Full Supervision mode is automatic when the ETCS Onboard has acquired a Movement Authority and has access to the relevant track description information.



*SR authority issued by RBC if conditions for Full Supervision MA cannot be satisfied, e.g. Onboard ETCS is unable to verify train's initial location.
^Stop if in SR command optional, other valid means of protecting route entry point may be used, e.g. list of permitted balise group identities or distance limit.
†May be replaced by starter signal to give initial authorisation to trains starting in SR mode.

Figure 16. Starting in Level 2

The Start of Mission procedure is more complex in Level 2 areas. In contrast with the Level 1 scenario described above, trains may start directly in Full Supervision mode, provided contact can be established with the relevant RBC and an ETCS Movement Authority and track description obtained. A typical arrangement applicable to Level 2 areas is shown in Figure 16. The procedure starts with the ETCS self-test, assuming the Onboard has been started from No Power mode, followed by the GSM-R network search and registration procedure. Euroradio session establishment follows allowing the ETCS Onboard to make contact with the RBC and transmit the train data, position report and any other relevant control data together with an initial MA request. The RBC responds by sending the track description and any relevant control data and an ETCS Movement Authority. Note, a Movement Authority will only be transmitted by the RBC in response to a valid position report, otherwise, the RBC will respond with a Staff Responsible authority. In some applications the driver may be required to operate the 'Track Ahead Free' button to confirm that the portion of the route between the front of the train and the signal or marker board at the entry to the Level 2 route is free of obstructions. Trains starting in SR mode will have their authority upgraded to a Full Supervision MA as soon as the train has passed a balise group and sent a valid position report to the RBC. Note, any train which attempts to enter the Level 2 route without a Full Supervision MA will be tripped by means of a balise group programmed with the 'Stop if in SR' command or by a list of allowable balise groups or a distance limit included in the SR authority. Some means must also be provided to inform the driver of when it is safe to proceed in the case of missions which start in SR mode. This may be implemented by providing a starter signal (instead of a route entry marker board), a text or voice message direct to the driver's cab or some form of route indicator.

Note that details of the national signalling system have been excluded from Figure 15 and Figure 16 for clarity.

9.2 Analysis

The relevant performance objective for this scenario is that trains should be able to start their mission, following initiation of the start of journey procedure by the driver, free of any undue delay caused by ETCS. Undue delay in this context means that the train should be able to depart on time without extension of existing allowances for driver pre-departure actions. The time allowed for the driver to prepare the train for departure varies according to the class of train and national procedures. The driver normally has to initialise a variety of systems following entry to the cab and can therefore the time taken by ETCS to perform its internal functions is not expected to have a significant operational impact assuming the driver is free to carry out other tasks at the same time.

The functional tasks involved in the Start of Mission procedure are summarised in flow-chart form in Figure 17, reproduced from the ETCS SRS. The normal paths followed by trains starting in both Levels 1 and 2 are highlighted. It can be seen that the tasks to be performed consist of a mixture of internal functional processes and manual actions undertaken by the driver.

A target value of 120s has been chosen as the total time allowed for the ETCS internal functions, assuming the mission is to be undertaken in Level 2 and the ETCS Onboard equipment and GSM-R mobile station have been awakened from an unpowered state. This value is considered to be broadly consistent with the range of national systems currently in service on the European high-speed rail network. This value has been chosen on the basis of train turn around at terminal stations where the subsequent mission must be driven from the cab at the opposite end of the train. Typical timetable intervals for such services can be as short as 4 minutes with the result that 120s is the maximum duration that can be tolerated for the awakening of the ETCS internal functions in the new cab. A reduced value of 60s has been chosen where the ETCS Onboard equipment remains powered and the GSM-R mobile station in the new cab remains registered with the network between missions.

Determination of the time allowance for the driver to complete his duties is a more difficult parameter to specify due to the large variation in the type and quantity of data to be entered in different circumstances. For example, fixed consist passenger trains are likely to require very little data to be entered by the driver since most of the relevant data is invariable and such data is expected to be preprogrammed in the Onboard's internal memory. In contrast, freight trains are likely to exhibit significant variations in their dynamic characteristics from one mission to another. Furthermore, the time taken for a driver to enter a given data value is likely to be influenced by factors such as the ergonomic features of the ETCS DMI and the medium used to advise the driver of the required values. These factors fall outside the scope of the mandatory ETCS specifications and for this reason no interoperable targets for the driver's contribution to the Start of Mission procedure are given in this document.

It can be seen by reference to Figure 17 that the internal functional elements of the Start of Mission procedure falling within the scope of the target ETCS response time are as follows:

- ETCS Onboard self-test (not shown in flowchart)*
- GSM-R network search and registration (not shown in flowchart)*, $T_{GSMRREG}$
- Euroradio session establishment (A31), $T_{SESSIONESTABLISHMENT}$
- Onboard reports stored position to RBC (A33)
- Onboard sends train data to RBC (S11)
- RBC acknowledges train data (E14)
- Onboard sends MA request to RBC (S21)
- RBC sends MA to Onboard (E29), $T_{MAUPDATE}$

These tasks are applicable to a mission starting in Levels 2 or 3. Missions starting in Level 1 involve a subset of these tasks hence the target values for this scenario will be derived on the basis of the more demanding Level 2/3 case. Some of these elements correspond directly with parameters specified elsewhere in this document; these are identified where applicable. Note, the first two items in the above list (marked thus *) apply only when the scenario involves awakening from No Power mode.

Two of the parameters identified in the above list, $T_{GSMRREG}$ and $T_{MAUPDATE}$, already have target values assigned to them of 40s and 12.5s respectively. The duration of the Onboard self-test is specified in the ETCS FRS (clause 4.1.1.4) as a maximum of 15s. This leaves a total of 52s available for the remaining internal functional elements of the Start of Mission procedure.

9.3 Application Rules

A target value of 120s has been chosen as the total time allowed for the ETCS internal functions, assuming the mission is to be undertaken in Level 2 and the ETCS Onboard equipment and GSM-R mobile station have been awakened from an unpowered state. A reduced value of 60s has been chosen for services characterised by short turn around times in terminal stations. This reduced value assumes that the ETCS Onboard equipment remains powered and the GSM-R mobile station remains registered with the network between missions.

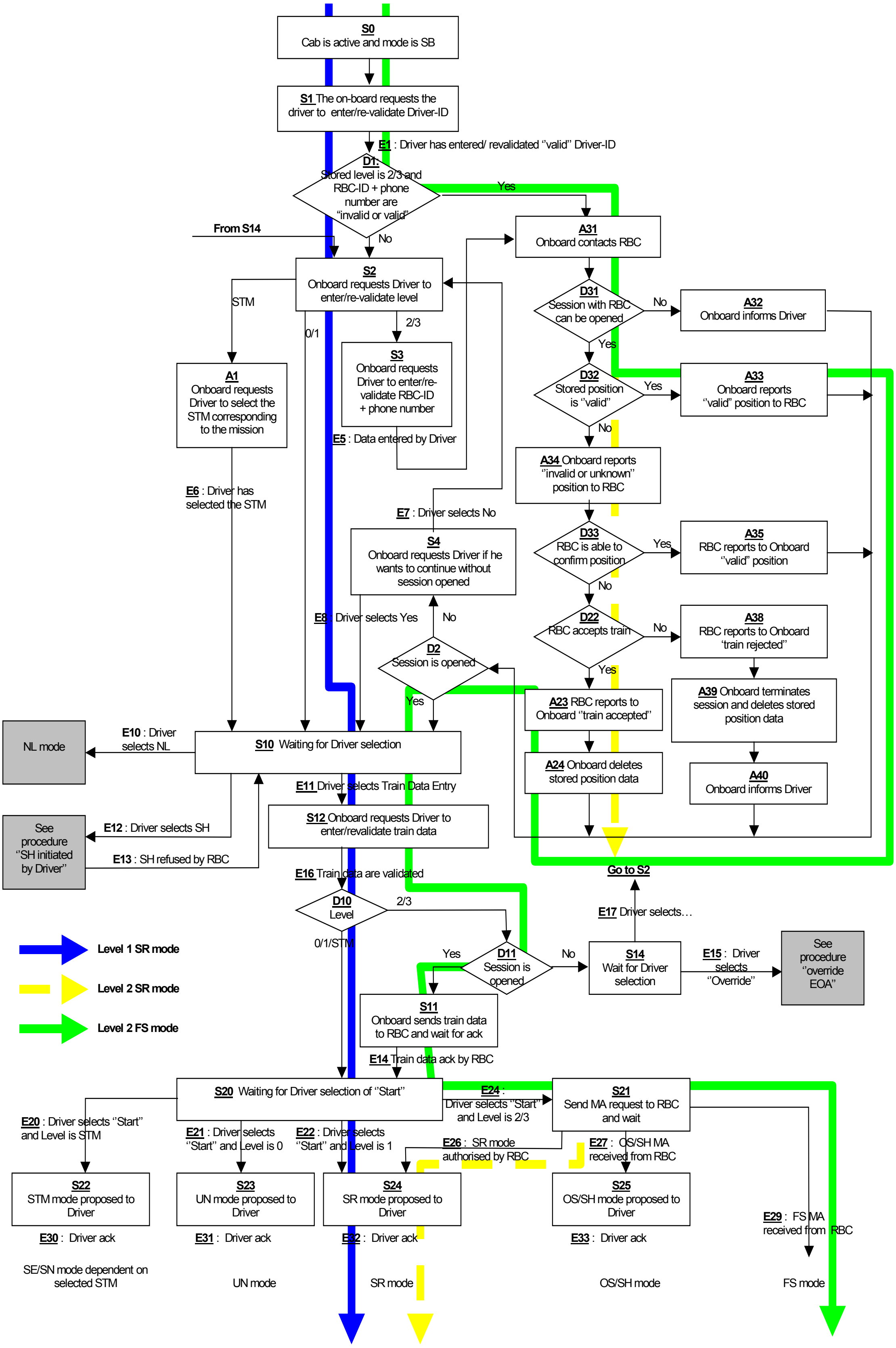


Figure 17. Start of Mission Procedure

10 RBC HANDOVER

The process of transfer of control from one RBC to another is normally invisible to the driver, provided the necessary internal ETCS and GSM-R functional processes are completed in good time. Hence, this scenario is not a valid Quality of Service scenario in its own right but a potential cause of failure to meet the Quality of Service objectives for the principal scenarios defined in Section 7. Consequently, this scenario will not be analysed any further. Note that the Quality of Service objectives applicable to the MA Update and Entry into Level 2 scenarios must take account of potential delays in the RBC handover process.

11 LOSS OF COMMUNICATION BETWEEN TRACKSIDE AND ONBOARD ETCS APPLICATIONS

ETCS relies on Euroradio and GSM-R for the transfer of data between the ETCS trackside and Onboard sub-systems as shown in Figure 18.

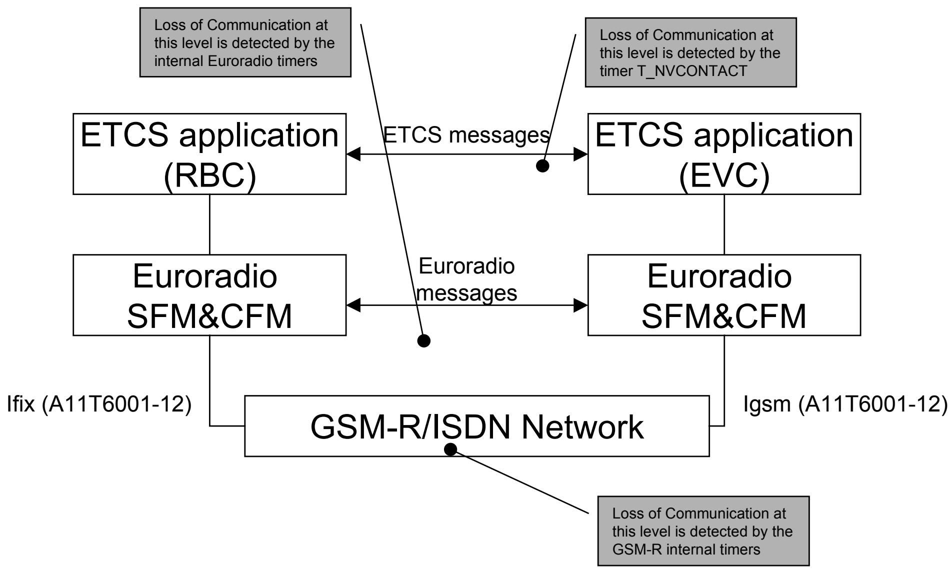


Figure 18. ETCS Track-to-Train Communications Layers

Depending on the configuration of the different parameters, the loss of communication will be detected by the different mechanisms inside the different layers that form the Euroradio protocol stack (including the GSM-R network), as well as inside the ETCS application layer.

Although the goal of each of the various mechanisms is different, it seems reasonable to expect that a good optimisation and synchronisation between the different mechanisms at each level is necessary. Any communication problem in the lower layers will be cascaded up through the protocol stack.

Loss of communication can be caused by any of following:

- Loss of communication detected by the ETCS application
- Loss of communication detected by the Euroradio Layers
- Loss of communication detected by the GSM-R equipment

These scenarios are considered in detail below.

11.1 Loss of Communication Detected by the ETCS Application

The mechanism used by the application layer for detecting the loss of transmission is the timer T_NVCONTACT. As stated in the SRS 2.2.2 [4]: " If no safe message has been received from the track for more than T_NVCONTACT seconds, an appropriate action according to M_NVCONTACT must be triggered".

The impact of the loss of communication detected by the ETCS application layer is described in Section 12.

11.2 Loss of Communication Detected by the Euroradio Layers

The current SRS 2.2.2 foresees that in case of accidental loss, the involved entities shall considered the communication session still established (at the ETCS level). The safe connection shall be setup again.

It assumed that the T_NVCONTACT does not expire.

The impact will depend on the conditions prevailing when the loss is detected. If the train has just received a MA, the impact could be nill. On the contrary, if the train is just about to receive a new MA and is approaching to the braking area of the braking curve, there will be an impact.

11.3 Loss of Communication Detected by the GSM-R Equipment

Although a confirmation is needed from the GSM-R industry, it is reasonable to assume that the detection of the loss of connection by the GSM-R equipment (or a call dropped due to the expiry of a timer in the GSM-R components) will be reported to the Euroradio layers. In this case the circumstances relating to the preceding case, 'loss of data-transmission detected by the Euroradio Layers' would apply except that the connection loss discovery time will be increased marginally by the time taken for the connection loss to be reported to the Euroradio layer.

11.4 Analysis

A sequence of events is triggered when Euroradio detects of a loss of connection with the ultimate aim of re-establishing the connection between the Onboard and the RBC. This sequence is illustrated in Figure 19.

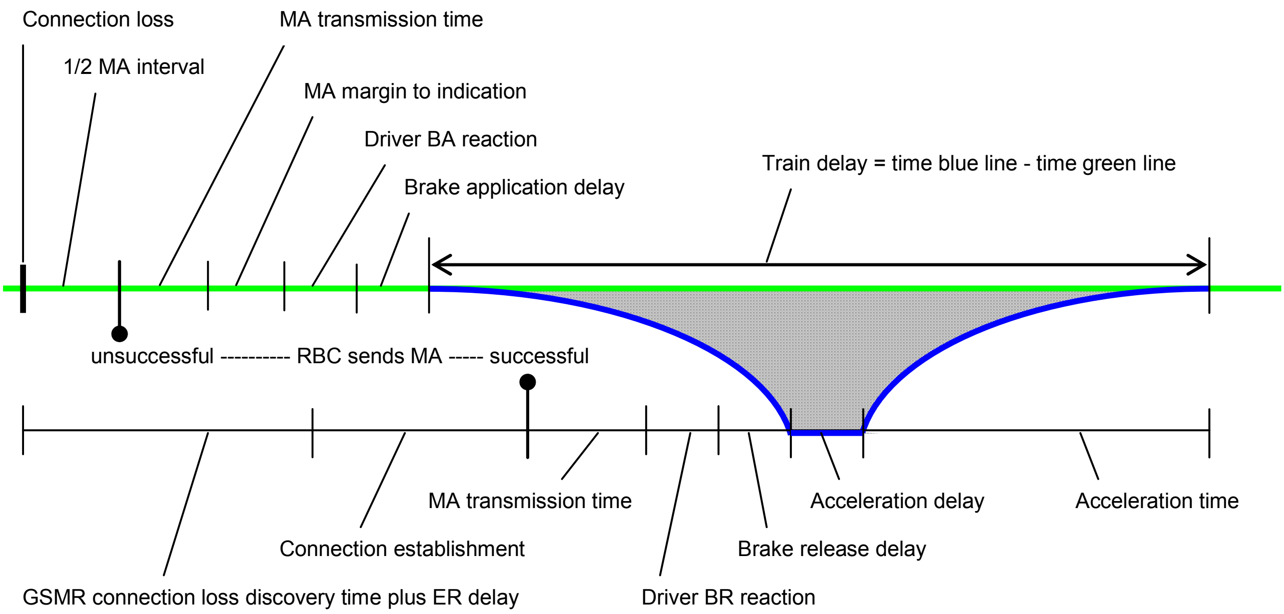


Figure 19. Loss of Connection

The scenario commences with a sudden break in communication between the Onboard and the RBC. Initially, neither party is aware that communication has been lost. Two independent processes are initiated following a break in the track to train communication link. These processes are described below:

Braking Process: Provided a valid MA is Onboard and no new MA is needed, the train will continue to run normally with the driver obeying the last transmitted MA. At some later point, a new MA would normally be received by the Onboard. Due to the fact that no communication session exists, the new MA will not be received when expected. The period of time between the break in communication occurring and the expected arrival time of a new MA could vary from zero (new MA required immediately) up to the normal MA refresh cycle (new MA just received). On average, this interval will be taken to be one-half of the normal MA refresh cycle. The new MA would normally be expected to be received and decoded with a small margin before it is actually needed, i.e. a small time prior to the Indication Point. The Indication Point represents the moment at which the driver becomes aware of the need to apply the brake to stop the train before the end of the current MA. As no new MA has been received, the driver will apply the brake in response to passing the Indication Point. The brakes will start to slow the train after a further delay corresponding to the brake system response time.

Re-establishment Process: In parallel with the braking process described above, the Euroradio layer will attempt to re-establish the connection with the RBC. A period of time is required by the GSM-R Mobile Station before the loss of connection is positively confirmed. Following detection of the loss of connection by the Mobile Station, the Euroradio layer is informed and the re-establishment process commences. The Euroradio layer will make a maximum of three reconnection attempts if necessary however for the purpose of this analysis it is assumed that a successful reconnection is made on the first attempt. It is assumed that the new MA will be transmitted as soon as the communication link is restored. Following successful receipt of the new MA by the Onboard, the DMI will be updated and the driver will release the brake control after a short reaction time. The train speed will stop reducing after a further delay corresponding to the brake system response time. The driver will now apply power and after an acceleration delay the train speed will start to increase.

After some time, the train will regain its initial speed. The resultant operational delay is equal to the difference in transit times for the delayed train to cover the distance for which the train speed was travelling below the normal line speed compared with a train traversing the same route with no delay.

Taking the case of a Category 2 line with a nominal operational line speed of 200 kph, a delay of 28s will result, assuming the following typical train characteristics and ETCS parameter values:

Line speed 200kph

Block length 1500m

Deceleration 0.5ms^2

Acceleration 0.3ms^2

MA to Indication margin 3s

Driver reaction time (apply brake) 1s

Driver reaction time (release brake) 2s

Brake response time (apply and release) 3s

MA Update time 5s

Connection loss detection time 10s

Euroradio delay (detection to re-establishment 1s

Connection establishment delay 40s

This result is typical of the delays which can be expected with high speed passenger trains operating on Category 2 lines. Other trains will be affected differently. For example, freight trains are likely to experience smaller delays due to their poorer braking capabilities.

12 T_NVCONTACT

12.1 Description

Refer to ETCS SRS 2.2.2 Subset 026, Chapters 3.16.3.4 (Supervision of Radio link), Appendix 3.2 and 7.5.1.148 for a full description of the T_NVCONTACT function.

The value of T_NVCONTACT has many different consequences according to the value assigned to this variable. The implementation of M_NVCONTACT determines the severity of the consequences ranging from that comparable to a marginally delayed MA to the more extreme case of a train trip.

12.2 Analysis

The values of T_NVCONTACT are not based principally on QoS criteria but rather are based on national safety considerations. Those considerations are beyond the scope of this document.

12.3 Target Value

The different railways propose very different values of T_NVCONTACT:

Italy: 7 s (justification on basis of value of old system)

France: 9 s (justification on basis of value of old system)

UK: normal case 80 s (based on the assumption of crossing the range of one defective BTS without any effect), infinity in case of lines with large radio holes.

Netherlands: 40 – 60 s

Spain: 6 s for high speed lines, 10 s for conventional lines

DB: 40 s (based on comparison with LZB)

The ETCS SRS does not call for harmonisation of this variable. Additionally, T_NVCONTACT would probably influence only the ETCS performance on each national network and is therefore exclusively a matter for consideration by each individual railway. For this reason, the impact of T_NVCONTACT will not be considered further and no QoS related requirements will be defined in this document.

12.4 Influences on ETCS / GSM-R QoS

Expiry of the T_NVCONTACT timer is not a valid Quality of Service scenario in its own right but a potential cause of failure to meet the Quality of Service objectives for the Loss of Communications scenario defined in Section 11. Consequently, no specific QoS targets will be derived for this scenario.

12.5 Application Constraints

As mentioned above, determination of the value of the T_NVCONTACT time and the associated M_NVCONTACT reaction is a matter for national implementation. Nevertheless, the analysis undertaken in the production of this report has revealed the following effects which should be taken into account by national infrastructure authorities when specifying the value of T_NVCONTACT:

- The T_NVCONTACT timer is reset at the end of reception of each radio message. Clearly, values of T_NVCONTACT shorter than the maximum message data transmission time will cause a false reaction since no loss of connection has occurred. According to SEL0452, a normal MA message could take up to 7s to transmit, excluding any inter-message gap caused by RBC processing time. Typical processing time in the RBC is 2 s, hence, under these circumstances, 9s could elapse between successive messages. Furthermore, an additional margin should be included to allow for burst errors which are not included in the SEL0452 worst-case transmission time values. For this reason values of T_NVCONTACT less than 12s is likely to result in unexpected interference to the normal ETCS data transmission process. Hence, an appropriate value of T_NVCONTACT needs to be specified in accordance with the expected maximum message transmission time.

- A break in the Onboard to RBC communication link is detected automatically by the GSM-R and Euroradio layers of the communications protocol, see Section 11. A loss of communication is reported to the ETCS application. Values of T_NVCONTACT less than the communication loss detection and re-establishment times will interfere with the normal re-establishment process significantly extending the time needed for re-establishment.

13 APPORTIONMENT OF TOP-LEVEL DELAY TARGETS TO SCENARIOS

The top-level ETCS QoS targets defined in Section 6 of this report need to be apportioned between the relevant scenarios according to the contribution of each scenario to the total potential delay affecting a given journey. For example, the Entry into Level 2 scenario, which occurs only infrequently on a given journey, is likely to have far less impact on potential delay than the MA Extension scenario which occurs very frequently. This relationship is shown in Figure 6

In addition to the frequency with which the scenario occurs, it is also necessary to understand the consequence in terms of the resultant operational delay should the scenario fail to meet the ‘normal case’ target.

The consequential delay is dependant on a complex combination of factors, the most significant of which include:

- Transmission delay
- Train deceleration and acceleration characteristics
- Line speed

The apportionment of the top-level ETCS QoS targets to individual scenarios is therefore a difficult matter to resolve. Nevertheless, the railway's assessment of the relevant contribution of each scenario to the overall operational delay caused by ETCS QoS effects is as follows:

- MA Extension 90%
- Entry into L2 5%
- Awakening and Start of Mission 5%

Having derived a reasonable apportionment between scenarios, it is now possible to derive QoS targets for each scenario. Taking the Category 1 (pure high-speed line) MTBD >5 minute target derived in Section 6.3.3:

Total QoS MTBD = 10 000h

This is apportioned as follows:

MA Extension (90%) MTBD = 10 000/0.9 = 11 111 hr

Awakening (5%) MTBD = 10 000/0.05 = 200 000 hr

Entry into L2 (5%) MTBD = 10 000/0.05 = 200 000 hr

Next, the probability of causing a delay of 5 minutes needs to be derived for each scenario. The first step in this process is to calculate the system response delay necessary to cause an operational delay of 5 minutes. This value can be derived from the analysis described in Appendix D.

In the case of MA Extension and a line speed of 300kph, a system response delay of 246s results in an operational delay of 300s (5 min). For convenience, the relationship between system response delay and operational delay for all categories is given in Table 6

Line Speed (kph)	**System Response Delay (s)**	**Operational Delay (s)**
300	246	300
300	90	60
300	64	30
300	30	6

Line Speed (kph)	System Response Delay (s)	Operational Delay (s)
300	11	0
200	265	300
200	74	60
200	49	30
200	25	6
200	9	0
160	272	300
160	67	60
160	48	30
160	23	6
160	9	0
120	280	300
120	58	60
120	120	42
120	120	20
120	120	8

Table 4. Typical relationship between system response delay and operational delay.

The relationship in Table 6 applies to the MA Extension scenario and to the Entry into Level 2 scenario, provided the optional RBC to interlocking MA acknowledgement function described in Section 8.2 is implemented. If this function is not implemented, the operational delay is likely always to exceed 5 minutes due to the resultant ETCS trip. The operational delay caused by a system response delay in the Awakening and Start of Mission procedure is equal to the system response delay.

Next the number of incidences of each scenario per hour needs to be assessed. Typical scenario frequencies are:

MA Extension	100 /h
Awakening	(Journey Time)/1 /h

Entry into L2 2 /hr[6]

The acceptable probability of disturbance can now be determined as follows:

Probability of disturbance = 1/(scenario MTBD x scenario frequency)

For the MA Extension scenario:

Probability of disturbance >5 min = 1/(11 111 x 100)

= 9 $x10^{-7}$

This is the QoS target for the MA Extension scenario at a line speed of 300kph, i.e. one out of every 1.1 million (1/9 $x10^{-7}$) MA updates may be delayed by more than 246s.

The QoS targets for the other scenarios and line categories for delays greater than 5 minutes and between 0 and 5 minutes can be calculated in the same way. The resultant QoS targets corresponding to the MTBD targets listed in Section 6.3 (Table 2) are given in Table 6.

The analysis in this document has been based on two operational delay targets; delays greater than 5 minutes, which correspond to the railways' punctuality targets and delays between 0 and 5 minutes. The latter range is more representative of the kind of delays attributable to QoS and has been given an apportionment weighting of 80% with the remainder (20%) apportioned to RAM effects, see Section 6.3.2. It would be reasonable to consider a further apportionment for the 0 to 5 minute target as shown in Table 5

Operational Delay (s)	Apportionment (% of 0 – 5 minute target)
0 – 6	80
6 – 60	15
60 – 300	5

Table 5. Further apportionment of 0 - 5 min delays

[6] This value includes an allowance for the RBC/RBC handover process which is considered to carry an equivalent risk of disturbance due to the need to initiate a safe connection with the accepting RBC.

Category	Operational Delay, t [min]	Journey Duration [h]	ETCS QoS related MTBD (from Table 2) [h]	MA Extension MTBD/frequency [h] ([/h])	Awakening MTBD/frequency [h]/[/h]	Entry into L2 MTBD/frequency [h]/[/h]	QoS Target per MA extension [/h]	QoS Target per Awakening [/h]	QoS Target per Entry into L2 [/h]
Pure High Speed	>5	3	10000	11111 (100)	200000 (.33)	200000 (2)	9.0E-07	1.5E-05	2.5E-06
	0<t<5		1250	1389 (100)	25000 (.33)	25000 (2)	7.2E-07	1.2E-04	2.0E-05
High Capacity Line	>5	5	16667	18519 (100)	333333 (.2)	333333 (2)	5.4E-07	1.5E-05	1.5E-06
	0<t<5		2083	2315 (100)	41667 (.2)	41667 (2)	4.3E-06	1.2E-04	1.2E-05
Low Capacity Line	>5	4	13333	14815 (100)	266667 (.25)	266667 (2)	6.8E-07	1.5E-05	1.9E-06
	0<t<5		1667	1852 (100)	33333 (.25)	33333 (2)	5.4E-06	1.2E-04	1.5E-05
Urban Railways[7]	>2	1	5555	6173 (100)	111111 (1)	111111 (2)	1.6E-07	9.0E-06	4.5E-06
	0<t<2		926	1029 (100)	18519 (1)	18519 (2)	9.7E-06	5.4E-05	2.7E-05

Table 6. QoS Targets by Scenario

[7] Due to a different punctuality target for urban railways the QoS ETCS part is estimated to have a share of 30% of delays of more than 2 minutes and 90 % for delays of less than 2 minutes.

The apportionment process described above represents one of a variety of methods by which appropriate QoS targets for ETCS can be derived. Nevertheless, the values given in Table 6 are intended to form a basis for the technical QoS requirements to be derived by ETCS and GSM-R supply industries.

Alternative apportionments can also be considered. For example, an apportionment based on the probability of a given operational delay per scenario could be proposed as follows:

- Entry into Level 2: operational delay $>$ 300s (Trip possible)
- Awakening: mean operational delay about 60s
- MA extension: typical delay as a maximum we assume 30s

Now we have to weight the scenarios according to their influence on the top-level QoS targets:

- Entry into level 2: weighting factor: $\lambda_{L2} = 1$
- Awakening: weighting factor: $\lambda_{AW} = 1/5 = 5\ \lambda_{L2}$
- MA extension: weighting factor: $\lambda_{MA} = 1/10 = 10\ \lambda_{L2}$

So, the total probability of a disturbance due to ETCS, $\lambda_{ETCS,}$ is given by

$$\lambda_{ETCS} = \lambda_{L2} + \lambda_{AW} + \lambda_{MA} = \lambda_{L2} + 5\ \lambda_{L2} + 10\ \lambda_{L2} = 16\ \lambda_{L2}$$

Taking the previous example of the Category 1 line and the >5 minute delay:

$$\lambda = \lambda_{ETCS} = 1 / MTBD = 10^{-4}\ [/h]$$

Hence:

$\boldsymbol{\lambda_{L2} = 1/16\ \lambda = 10^{-4} / 16 = 6.25 \times 10^{-6}\ h}$ [/h] (one relevant event every 160 000 h)

$\boldsymbol{\lambda_{AW} = 5/16\ \lambda = 10^{-4} * 5 / 16 = 31.25 \times 10^{-6}\ h}$ [/h] (one relevant event every 32 000 h)

$\boldsymbol{\lambda_{MA} = 10/16\ \lambda = 10^{-4} * 10 / 16 = 62.5 \times 10^{-6}\ h}$ [/h] (one relevant event every 16 000 h)

These targets are a little different to those given in Table 6. Values for the complete range of line categories and delay targets can be derived in the same way. Ultimately, any suitable apportionment can be used provided the top-level targets defined in Table 2 are respected.

13.1 Summary of ETCS/GSM-R Scenarios and Target QoS Requirements

Examples of the relevant QoS parameters and application rules are summarised in Table 7.

Scenario	QoS Parameters	Application Rules
MA extension	Transfer delay Transmission error rate	Short MA for time critical scenarios
Entry into Level 2	Registration delay Connection establishment delay Connection establishment error rate Transfer delay Transmission error rate	Radio coverage Balise group locations
Awakening/ Start of Mission	Connection establishment delay Connection establishment error rate Transfer delay	
RBC/RBC handover	Connection establishment delay Connection establishment error rate Transfer delay Transmission error rate	Balise group locations
Communication loss / T_NVCONTACT	Registration delay Connection loss rate Connection establishment delay Connection establishment error rate Transfer delay Transmission error rate	Radio coverage Number of mobile stations on-board Short MA for time critical scenarios

Table 7. QoS Scenarios & Relevant Parameters

14 DERIVATION OF TECHNICAL QOS REQUIREMENTS

As mentioned in Section 2, the derivation of technical QoS requirements is beyond the scope of this document. UNISIG document SUBSET-093 specifies requirements relating to QoS for the GSM-R data transmission system. A number of these requirements have no assigned values at present pending derivation of the operational QoS requirements. Appropriate values can now be assigned to the SUBSET-093 QoS parameters derived from the operational requirements specified in Section 13 of this report.

The analysis undertaken in the production of this report has identified a number of application engineering rules necessary to ensure that adequate margins are built into a given ETCS application to ensure reliable operation. For example, generation of a new

Movement Authority should be initiated 12s prior to the train reaching the Indication point to ensure that it is displayed on the DMI before the train enters the braking curve area. These rules should be captured within other relevant ETCS Class 1 specifications as appropriate, e.g. SUBSET-040, Engineering Rules.

Appendix A: Data Length of a MA

France:

For France, the trackside sends information to the Onboard in such a way that the train will always have resources for 9 sections. Therefore during awakening or when entering the ETCS area from national systems, a complete description for 9 sections shall be sent to the train (18000 metres because the mean block length on French high speed lines is 1500 metres, but let's take 2000 meters in case of gradients). But during the journey, only an extension for one section is sent to the train each time the train leaves the previous section.

1/ For the whole MA let's have the following:

Total length of MA (m):	18 000
Number of sections:	1
Danger Point defined:	YES
Overlap defined:	NO
Number of linked balise groups:	18
Number of steps in the gradient profile:	108
Number of steps in the SSP:	18
Number of train categories:	1

We use:

184 bits : standard packet 15 (MA authority for level 2/3) with

N_ITER = 0

79 + 18*49 : packet 5 for 18 linked balise groups

3 * (54 + 32*24) + 54 + 20*24 : 3 packets 21 with 32 gradients + 1 packet

21 with 12 gradients

53 + 18*33: packet 27 for 18 SSP

therefore, the total is 184 + 961 + 3000 + 647 = 4792 bits.

2/ For only the extension on 2000 metres, the total is 184 + 177 + 342 + 119 = 822. bits.

Prorail example:

MA example 01-Prorail.xls

RFI example:

ETCS MA extension-RFI.xls

Appendix B: Transfer Time for Typical MA

An estimate was made of the time to transfer a MA on the basis of the calculations of data length for a MA extension provided by EL (822 bit), RD (800 bit) and DC (840 bit) (see Appendix A)as follows:

Assumptions:

880 bit for a MA extension (110 Byte)

The first HDLC frame can transfer 11 Byte of information

The following HDLC frames can transfer 25 Byte of information

Together with header etc. a complete HDLC frame comprises 32 Bytes

That means: To transfer an information of 110 Byte 5 HDLC frames are required plus 1 remaining incomplete Frame. So, in total 6 HDLC frames are necessary to transmit the complete MA extension.

Hence:

(5 frames x 32 Byte/frame + 1 frame x 18 Byte/frame) x 8 bit/Byte = 1424 bit

ETCS allows data transfer rates of 2K4, 4K8 and 9K6 bit/s. Since on the Italian and German pilot lines 4K8 bit/s is used, the estimate is based on an assumed transfer rate of 4K8 bit/s:

Hence:

1424 bit / 4K8 bit/s $\approx$ 300 ms

For the whole process approximately one additional frame is required. Therefore the time required to transmit the MA extension increases to approximately 400 ms:

	400 ms	for the data
+	450 ms	transfer delay time
+	250 ms	processing delay (without cycle times!)
	1.1 – 1.2 s	for MA extension under optimum conditions such as a good coverage and without a handover.

In the case of one defective frame: an additional 1200 ms is required to identify which frame is defective and to retransmit it.

In the case of an RBC handover: an additional 2000 ms is required, (a transmission break of 1 sec and 1 sec to repeat the transmission)

Taken together, these occurrences extend the potential transmission delay by up to 4.4 sec.

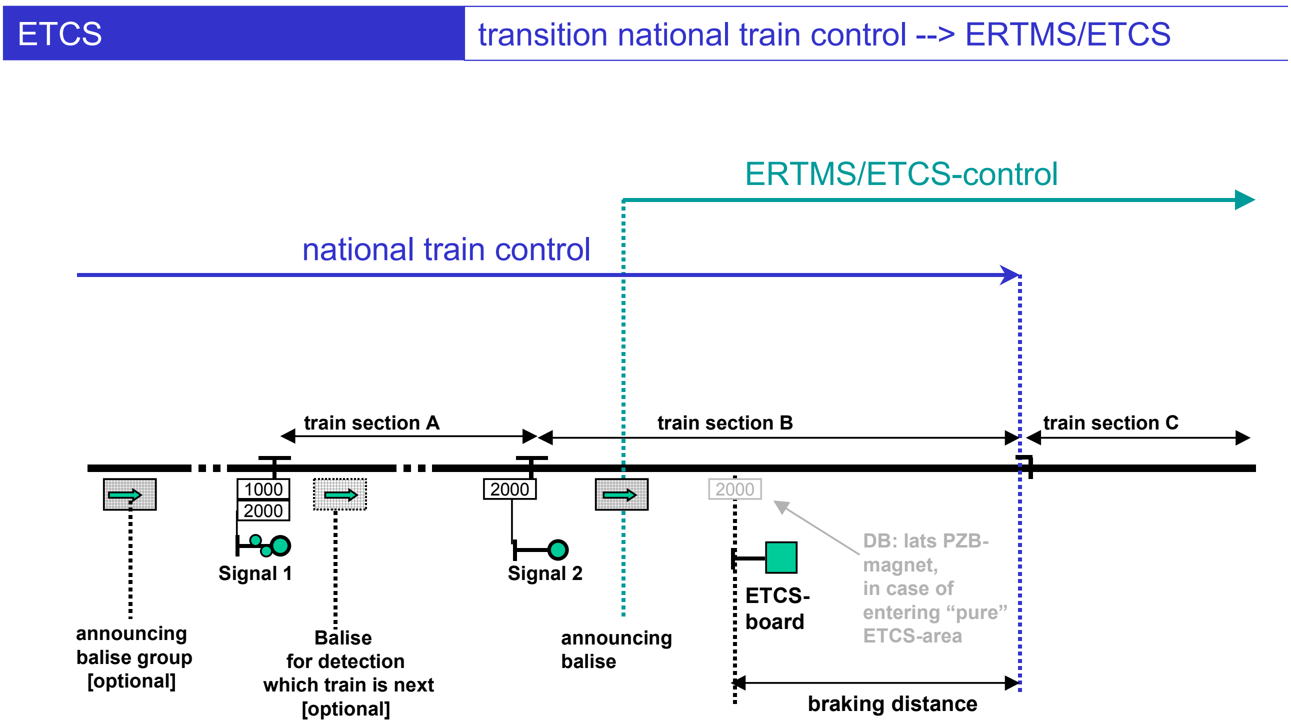
In the case of a data transfer rate of 9K6 bit/s, only the time for the data transmission portion is divided by two (200 ms), the rest stays as high as for 4K8 bit/s. Additionally, a higher data transfer rate probably does not increase the performance at all because of a higher frame error rate.

If a train runs at 300 km/h, the nominal time between handovers is 60s assuming a GSM-R handover occurs every 5 km on average. This amounts to a 2% possibility of a handover occurring in a given transmission. Hence, the average transfer time (1.2 s) increases only slightly (2% x 3 s) extending the average transmission delay time by 60 ms.

Appendix C: Transition from National Train Control

France and Italy require 2 balise groups, one to start the radio connection establishment process, contacting RBC the second to request a MA. In particular, the Italian solution with lineside signals on the approach to the L 2 area was discussed in detail. This approach has the advantage that a train will not be tripped in case of problems, e.g. call establishment. Disadvantages were seen in the larger distances of the announcement balises, which requires a more complicated interlocking logic when points are on the track. This approach relies on the presence of a national lineside signals, NB in France such an approach would be impossible.

The DB solution looks as follows:



Appendix D: Relationship Between System Response Delay and Operational Delay

The relationship between the delayed update of an MA and the consequential operational delay depends on a variety of factors. The extent of the operational delay is equal to the time difference between a train which experiences an operational delay and one which experiences no delay, over the portion of the route for which the delayed train runs at less than the intended line speed. This is illustrated diagrammatically in Figure 20.

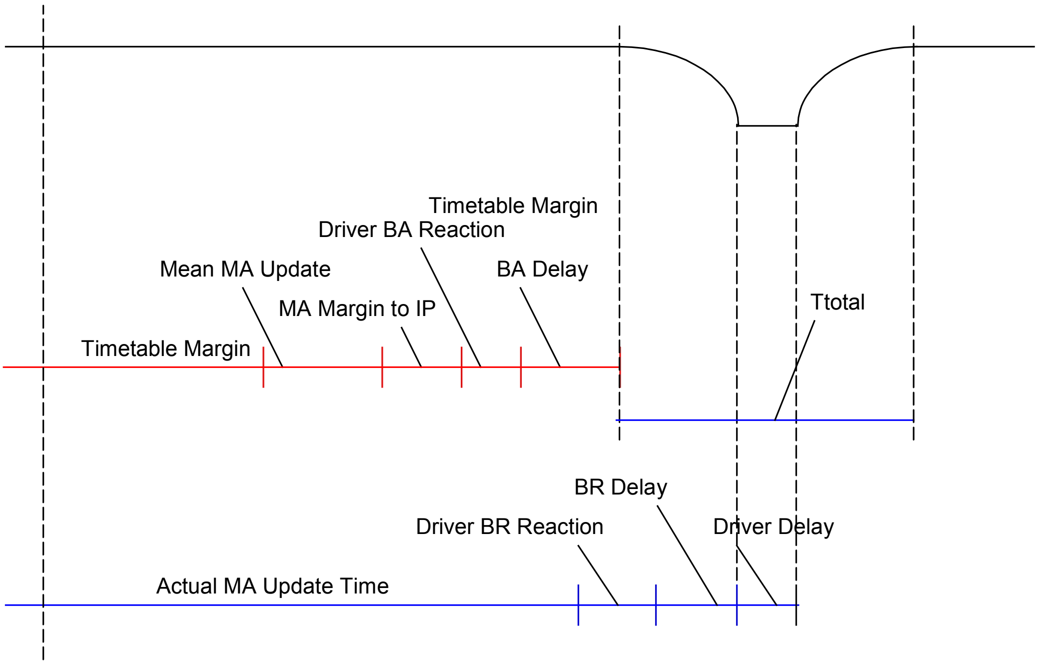


Figure 20 Effect of MA update delay.

Two parallel processes take place in this scenario as follows:

1) Normal update (new MA received before train reaches Indication Point) – red sequence

2) Delayed update (new MA received after train has passed Indication Point) – blue sequence

The following ETCS terms are used:

Permitted Speed curve – the instantaneous Permitted Speed, the braking curve which is indicated to the driver (top of the Permitted Speed arc on the DMI), calculated backwards from the End of Authority. Note; this curve is more conservative than the Service Brake Intervention curve to ensure that the driver will not inadvertently trigger an intervention due to small errors in following the Permitted Speed curve.

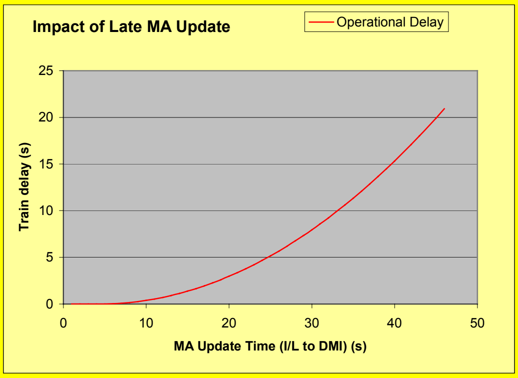
Indication Point – first indication given to the driver that he is approaching the End of Authority, needs to be given early enough for the driver to apply the brake manually and remain within the Permitted Speed curve. This indication must occur an interval at least equal to the brake system response time before the Permitted Speed starts to reduce if the driver is to stand any chance of respecting the Permitted Speed curve. The value of this interval is still under discussion within EEIG and UNISIG.

End of Authority (EoA) – the geographic limit contained within the Movement Authority beyond which the train is not authorised to travel. Any attempt to cross the EoA will result in a train trip. Note; the driver would normally bring the train to a halt a few metres before the EoA and wait for a new MA if necessary.

A spreadsheet has been created to simplify the calculation of the consequential delay and allow the effect of different train characteristics to be evaluated. An extract from this spreadsheet is shown in Figure 21.

Train delay

Line speed	200	55.56	m/s
Deceleration	0.5		m/s/s
Acceleration	0.3		m/s/s
Margin MA to Indication	0		s
Typical driver BA reaction time	1		s
Typical driver BR reaction time	2		s
Brake application delay	3		s
Brake release delay	3		s
Mean MA update time	5		s
Driver delay	2		s
Timetable Margin	0		s
Time I/L o/p - BA	9.00		s



MA Update	T BA-BR	V-BR	D BA-BR	D low	D BR-Vline	T low-Vline	Ttotal	Tnormal	Operational Delay
0	0.00	55.56	0.00	111.11	0.00	0	2.00	2.00	0
1	0.00	55.56	0.00	111.11	0.00	0	2.00	2.00	0
2	0.00	55.56	0.00	111.11	0.00	0	2.00	2.00	0
3	0.00	55.56	0.00	111.11	0.00	0	2.00	2.00	0
4	0.00	55.56	0.00	111.11	0.00	0	2.00	2.00	0
5	1.00	55.06	55.31	110.11	92.18	1.666667	4.67	4.64	0
6	2.00	54.56	110.11	109.11	183.52	3.333333	7.33	7.25	0
7	3.00	54.06	164.42	108.11	274.03	5	10.00	9.84	0
8	4.00	53.56	218.22	107.11	363.70	6.666667	12.67	12.40	0
9	5.00	53.06	271.53	106.11	452.55	8.333333	15.33	14.94	0
10	6.00	52.56	324.33	105.11	540.56	10	18.00	17.46	1
11	7.00	52.06	376.64	104.11	627.73	11.66667	20.67	19.95	1
12	8.00	51.56	428.44	103.11	714.07	13.33333	23.33	22.42	1
13	9.00	51.06	479.75	102.11	799.58	15	26.00	24.87	1
14	10.00	50.56	530.56	101.11	884.26	16.66667	28.67	27.29	1
15	11.00	50.06	580.86	100.11	968.10	18.33333	31.33	29.68	2
16	12.00	49.56	630.67	99.11	1051.11	20	34.00	32.06	2
17	13.00	49.06	679.97	98.11	1133.29	21.66667	36.67	34.40	2
18	14.00	48.56	728.78	97.11	1214.63	23.33333	39.33	36.73	3
19	15.00	48.06	777.08	96.11	1295.14	25	42.00	39.03	3
20	16.00	47.56	824.89	95.11	1374.81	26.66667	44.67	41.31	3
21	17.00	47.06	872.19	94.11	1453.66	28.33333	47.33	43.56	4
22	18.00	46.56	919.00	93.11	1531.67	30	50.00	45.79	4
23	19.00	46.06	965.31	92.11	1608.84	31.66667	52.67	47.99	5
24	20.00	45.56	1011.11	91.11	1685.19	33.33333	55.33	50.17	5
25	21.00	45.06	1056.42	90.11	1760.69	35	58.00	52.33	6
26	22.00	44.56	1101.22	89.11	1835.37	36.66667	60.67	54.46	6
27	23.00	44.06	1145.53	88.11	1909.21	38.33333	63.33	56.57	7
28	24.00	43.56	1189.33	87.11	1982.22	40	66.00	58.66	7
29	25.00	43.06	1232.64	86.11	2054.40	41.66667	68.67	60.72	8
30	26.00	42.56	1275.44	85.11	2125.74	43.33333	71.33	62.75	9
31	27.00	42.06	1317.75	84.11	2196.25	45	74.00	64.77	9
32	28.00	41.56	1359.56	83.11	2265.93	46.66667	76.67	66.75	10
33	29.00	41.06	1400.86	82.11	2334.77	48.33333	79.33	68.72	11
34	30.00	40.56	1441.67	81.11	2402.78	50	82.00	70.66	11
35	31.00	40.06	1481.97	80.11	2469.95	51.66667	84.67	72.58	12
36	32.00	39.56	1521.78	79.11	2536.30	53.33333	87.33	74.47	13
37	33.00	39.06	1561.08	78.11	2601.81	55	90.00	76.34	14

Figure 21. MA Update Delay Spreadsheet.

The terms used in this spreadsheet are described as follows:

Timetable Margin (Cell D17) – This is difference between the planned timetable service interval and the signalling headway.

MA Transmission Time (Cell D13) – This is the time interval from the change of interlocking output (aspect) to DMI update. This is the mean MA update time. Note; it is assumed that any necessary preconditions, e.g. route setting, MA request etc., are satisfied in advance.

Margin MA to Indication (Cell D8) – This is an additional margin to allow for the statistical distribution of the MA update process, i.e. it is a margin to allow for MA update times which are longer than the mean update time. The end of this time interval is the Indication Point.

Typical driver BA reaction time (Cell D9) – This is the time taken for a typical driver to respond to the Indication Point and activate the brake control.

Brake application delay (Cell D11) – This is the time taken for the train to start to reduce speed following activation of the brake control.

MA Update Time (Column A, Row 25 onwards) – The actual MA update time, from change of interlocking output to DMI update.

Typical driver BR reaction time (Cell D10) – This is the time taken for a typical driver to release the brake control in response to a new MA being displayed on the DMI.

Brake release delay (Cell D12) – This is the time taken for the train to stop reducing speed following release of the brake control.

Driver delay (Cell D14) – This is the time taken for the driver to apply power following brake release. Note; it is assumed that the train will start to accelerate as soon as the power control is activated.

T BA-BR (Column B, Row 25 onwards) – The time difference between the moment at which train speed starts to reduce (due to no new MA received) and the moment at which the speed stops reducing (due to brake release following late MA update).

V-BR (Column C, Row 25 onwards) – This is the actual speed of the train at the moment the brake is released.

D BA-BR (Column D, Row 25 onwards) – The distance travelled while the train is reducing speed due to late MA update.

D low (Column E, Row 25 onwards) – The distance travelled between the moment the train stops reducing speed (due to late MA update) and the moment the train starts to regain speed.

D BR-Vline (Column F, Row 25 onwards) – The distance travelled between the moment the train starts to regain speed (due to late MA update) and the moment at which the train reaches the original line speed.

T low-Vline (Column G, Row 25 onwards) – The time interval between the moment the train starts to regain speed (due to late MA update) and the moment at which the train reaches the original line speed.

Ttotal (Column H, Row 25 onwards) – The total time during which the train is running at a speed lower than the original line speed (due to late MA update).

Tnormal (Column I, Row 25 onwards) – This is the time taken by a train which is not delayed (MA received before Indication Point) to cover the distance over which the delayed train runs at a speed lower than the original line speed.

Operational Delay (Column J, Row 25 onwards) – This is simply Ttotal minus Tnormal.