THE VIABILITY OF TETRA FOR MANAGING ETCS SIGNALLING DATA
The three main objectives of transport operators are to improve passenger service, increase operational safety and reduce overall operating costs. Achieving these objectives involves a high degree of information management and processing, particularly in established railway signalling systems. These systems are based on radio communications networks that facilitate end-to-end transmission of the data generated, vital data, since it contains information relating to operation of the trains (position, braking distance, limit movement authority, etc.) and, therefore, to the safety of the passengers.
RAILWAY SIGNALLING APPLICATIONS USED WITHIN EUROPE

Each European country organizes its rail transport network in a particular way: signaling systems, communication systems, tracks width, power supply, etc. However, incompatibility between signalling systems that perform control and protection functions poses a serious problem for the movement of people and goods within the European Community. The Figure 1 shows the diversity of signalling systems used throughout Europe in 2003. The most of these systems are conventional systems, based on information being punctually transmitted to the train via beacons along the route, and may be inadequate and insufficient for the correct operation of current control systems.

This situation led the European Union to design a unified ERTMS (European Rail Traffic Management System) system that attempts to achieve medium-term Europe-wide homogenization of railway signalling, control functions and radio communications, via ETCS (European Train Control System) and GSM-R (Global system for Mobile communications - Railway) respectively.
THE ERTMS STANDARD

The ERTMS standard is basically divided into two main blocks. On the one hand, the ETCS (European Train Control System), which provides up to three levels of protection depending on the equipment installed.

- Level 1 involves a non-continuous communication between train and trackside (normally by means of Euro-balises). Lineside signals are necessary and train detection is performed by the trackside equipment out of the scope of ERTMS.
- Level 2 involves continuous supervision of train movement with continuous communication, which is provided by GSM-R, between both the train and trackside. Lineside signals are optional in this case, and train detection is performed by the trackside equipment out of the scope of ERTMS.
- Level 3 is also a signalling system that provides continuous train supervision with continuous communication between the train and trackside. The main difference with level 2 is that the train location and integrity is managed within the scope of the ERTMS system, i.e. there is no need for lineside signals or train detection systems on the trackside other than Euro-balises. Train integrity is supervised by the train, i.e. the train supervises being complete and not having been accidentally split.

On the other hand, GSM-R, the communication system. It is a variant of GSM cellular technology, based on circuit switching, that operates in the 800-900 MHz frequency band. This technology provides simultaneous voice and data services and incorporates functionality specifically tailored to the rail market since ASCI (Advanced Speech Call Items) features were incorporated for that purpose: Voice Group Call Service, Voice Broadcast Service, Railway Emergency Call and Shunting Emergency Call.

The GSM-R network must be considered, from a safety point of view, as an open communication system. Consequently, additional functionality is required to ensure adequate integrity. For this, ETCS has defined a secure communication protocol, called EURORADIO, based on an open communication network as GSM-R, as shown in the figure 2.

Most of the EU countries currently have Level 1 and 2 ERTMS systems deployed and running. This system is considered one of the safest and most efficient in existence hence its implementation beyond Europe, in countries such as China, India, Taiwan, Saudi Arabia and South Africa.
ERTMS DEPLOYMENT WORLD MAP. SOURCE [www.ertms.net](http://www.ertms.net) 2017
CHOICE OF GSM VERSUS TETRA

In the 1990s, it became clear that obsolete analogue radio systems would have to be replaced by a modern digital radio system. A preliminary study was conducted on the usability of either GSM (Global System for Mobile communications) or TETRA (Terrestrial Trunked Radio), the available standards for public and private communications systems. The advantages and disadvantages of both competing systems were discussed and a number of studies were undertaken to assess potential frequency needs (traffic models were established for three representative areas: London, Paris and Munich).

Although one of the prime objectives was to use a system which was already tried and tested and for which off-the-shelf products were available, with minimal modification necessary, finally, a tight decision (1 vote) was made in favour of GSM, where some features had to be incorporated specifically tailored to the rail market. Conversely, TETRA technology provided such tailored functions but was not mature enough. A recommendation was obtained from CEPT (the European frequency allocation body) to set aside a 4 MHz spectrum within the GSM-band and allocate this for railway use only all over Europe. The frequency allocation in the 900 MHz band is shown in the following table:

<table>
<thead>
<tr>
<th>Uplink (MHz)</th>
<th>Downlink (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>876-880</td>
<td>921-925</td>
</tr>
</tbody>
</table>
PAST, PRESENT AND FUTURE OF COMMUNICATIONS FOR ETCS RAILWAY SIGNALLING

Although cellular technologies have evolved in the last years (GSM, GPRS, 3G, 4G), GSM-R remains with the same rail features incorporated in the 1990’s. Nor new inversions have been done, so that none functional growth has been seen recently and it isn’t expected in the near future. Thus, the obsolescence of GSM-R, together with the emergence of new technologies, has led to major European bodies to lead the search for a substitute, with a proposed deadline of 2022. The intention is, however, to protect any investment hitherto made in this technology.

Apart from this searching, there are currently many circumstances among national, regional, metropolitan European lines and even international lines outside Europe where the use of GSM-R is not mandatory. Here, other technologies are emerging to manage the data traffic generated by this kind of application, whilst they meet today’s safety and cost requirements. A clear example of these technologies is TETRA (Terrestrial Trunked Radio).

The TETRA standard operates in different frequency bands around 300-400 and 800 MHz and was developed to meet the communication demands of professional users (police, fire brigades, transport operators): rapid and secure communications, data transmission services, direct mode communications, quality of service, priority management, group calls, etc.

This leading critical communications technology has been extensively field tested in hundreds of transportation projects worldwide and not only in railways but also in metros and tramways networks. Next figure shows some examples of TETRA deployments around the globe.

SOME TETRA REFERENCES DEPLOYED WORLDWIDE IN TRANSPORT ENVIRONMENTS

One of the ERTMS standard targets is assure interoperability between countries of European Union. However, due to different technical and economic reasons, some initiatives have been raised to look for an alternative radio solution today. A good example of the usage of TETRA as an alternative of GSM-R can be seen with the Finnish Railways initiative, which is deeply described in the next section.
FINNISH INITIATIVE: ETCS LEVEL 1 OVER TETRA

The Finnish Transport Agency (FTA) and Finnish Railways (VR Group) were one of the first to adopt the GSM-R standard for track-to-train radio based voice communication and, although the RAILI system has worked well, now it is over 10 years. Thus, two options emerged, firstly to renew with updated GSM-R equipment or secondly to change to another type of radio network.

The decision made jointly by the Finnish Transport Agency as the infrastructure owner and VR Group, the train operating company, to prepare a plan to move to the Government’s national TETRA network (VIRVE). Of course, the European Commission derogated the existing rules making GSM-R the only option for a railway radio systems. There are main factors in reaching this decision:

• The standardisation of ERTMS (that comprises ETCS and GSM-R) is all about interoperability, allowing trains to cross borders seamlessly without multiple fitment of train-borne control and communication equipment associated with earlier national system designs. However, in Finland the question of interoperability with other European states does not arise.
• Significant savings can be made, estimated to be €10 million per year.
• In the early 1990s, when the decision to standardise on GSM-R was made, TETRA was still under development. Now, Tetra has become the de facto standard for many rail systems and it perfectly meets the service quality parameters for communication systems described by the EIRENE specifications
• The existing TETRA network has been analysed and presents sufficient capacity to have safety-related railway communication on the same network as emergency services, government agencies and the military.
• In Finland, the GSM-R operation has increasingly been subject to interference from 4G networks in adjacent frequency bands.

Hence, TETRA covers both present and future needs of Finnish railways: voice for current ETCS Level 1 and data when the decision to migrate to ETCS Level 2 arrives.
EUROPEAN RAILWAY AGENCY WORKSHOPS: FUTURE RAILWAY MOBILE COMMUNICATIONS SYSTEM (FRMCS)

The European Railway Agency (ERA), acting as ERTMS system authority, is leading the research of an alternative solution to GSM-R, ready by 2022. The ERA is supported and cooperates with UIC, UNISIG, CER, EIM and other groups of interest within the rail environment. The group works in the future railway mobile communication system (FRMCS) although, of course, GSM-R investments will be protected and this technology will be supported by suppliers until 2028.

Among others, the main requirements stated by this group are the following:

- The future ETCS data communication bearer should be IP based.
- The basic goal is that the onboard ETCS, EVC, is installed once (with an IP interface) and not affected by a change in the communication technology.
- Therefore, the specifications of the ETCS application should be separated from the transmission layer (bearer specifications).
- The existing ETCS functions should be guaranteed.
- The future ETCS data communication bearer should also be used by other applications.

With all these points on the table, the group will define the technology/technologies suitable for this “new” standard by complying with minimum QoS figures, capacity, availability (especially in dense areas); and look after a standardised solution (no “-R”) and the harmonious coexistence with public communication networks. At this moment, 4G Long Term Evolution (LTE) would appear the natural choice at this point.
EXAMINATION OF THE QUALITY OF SERVICE (QOS) PARAMETERS

Levels 2 and 3 of the ERTMS rely basically on radio communications: the train regularly reports its position and fixed equipment sends limit movement authorities, continuously informing how far and how fast the vehicle can move. This requires the constant exchange of small messages (generally <100 bytes, a total of <1 Kbps per train), an end-to-end delay <500 ms, call setup times <8.5s and handovers (cell changes) completed in <300 ms.

Obviously, the technology that substitutes GSM-R in certain scenarios must provide QoS parameters equivalent to those defined in the EIRENE specifications, Subset 093.

<table>
<thead>
<tr>
<th>QoS Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection establishment delay of mobile originated calls</td>
<td>&lt; 8 s (95%), ≤ 10 s (100%)</td>
</tr>
<tr>
<td>Connection establishment error ratio</td>
<td>&lt; 10⁻²</td>
</tr>
<tr>
<td>Maximum end-to-end transfer delay (30 bytes data block)</td>
<td>≤ 0.5 s (99%)</td>
</tr>
<tr>
<td>Connection loss rate</td>
<td>&lt; 10⁻²/h</td>
</tr>
<tr>
<td>Transmission interference period</td>
<td>&lt; 0.8 s (95%), &lt; 1 s (99%)</td>
</tr>
<tr>
<td>Error-free period</td>
<td>&gt; 20 s (95%), &gt; 7 s (99%)</td>
</tr>
<tr>
<td>Network registration delay</td>
<td>≤ 30 s (95%), ≤ 35 s (99%), ≤ 40 s (100%)</td>
</tr>
</tbody>
</table>

QoS REQUIREMENTS FOR GSM-R DEFINED BY SUBET 093, EIRENE SPECIFICATIONS

This study uses the Circuit Mode Data (CMD) service offered by the TETRA standard to compare the QoS offered between TETRA and GSM-R. This is the natural alternative to the circuit switching service offered by GSM-R so that the comparison is fairly.

TETRA CIRCUIT MODE DATA SERVICE

TETRA’s CMD data service allows an external application (fixed part) to establish communications with a TETRA radio (on-board unit) for simultaneous data transfer in both directions. This data is transferred transparently between the two ends via the air interface, that is, the TETRA radio does not modify the data during transmission.

These calls can be set at different speeds with different levels of protection to overcome possible eventualities caused by the radio channel. There are three types of CMD calls supported by the TETRA standard:

- 7.2 kbps, unprotected data. This type of call offers no protection, so any data corruption is assumed by the receiver. Otherwise, a higher-level protocol must be implemented to request retransmission of information.
- Protection 4.8 kbps short interleaving depth (N=1). In these calls, bits of redundancy are used for error detection and correction, increasing security of communications meanwhile there is a reduction in bandwidth.
- Protection 2.4 kbps short interleaving depth (N=1). Like 4.8 kbps calls, these calls include additional bits for error detection and correction. These mechanisms increase the security notably, at the expense of a significant reduction in bandwidth.
PARAMETER DEFINITION FOR THE TETRA LABORATORY ENVIRONMENT

This study was carried out in a laboratory by making a CMD duplex call at 4,8 kbps between an on-board application (OBC) connected to TETRA mobile data radio equipment via RS-232 (serial interface); and an external application (RBC), connected via IP to the infrastructure (fixed part). The TETRA infrastructure has two base stations (SBS), each with a carrier to enable cell change (handover) testing.

To make conditions as realistic as possible, the laboratory set-up used a channel simulator baseband, simulating a propagation environment HT100 (mountainous environment with the train traveling at 100 km/h) at the limit of dynamic sensitivity, -99 dBm radio and -102 dBm at the carrier.

As the QoS parameters must be guaranteed regardless of the number of trains registered simultaneously in the same base station coverage area (see Subset 093), this analysis has considered the use of one dedicated data channel per train to ensure availability at all times. Thus, the measurements made in the laboratory with a single TETRA radio using one data channel (TCH) are equivalent to a real environment with several trains running simultaneously, for example, in situations of high density of users like stations or depots as well as in the whole tracks.

COMPARISON: GSM-R VERSUS TETRA

As mentioned before, the technology that substitutes GSM-R in certain scenarios must provide QoS parameters equivalent to those defined in the EIRENE specifications, being similar or superior to the ones provided by GSM-R. As follow are described the tests performed comparing the performance of each of the seven parameters specified by EIRENE are described:

Connection establishment delay of mobile originated call. This is defined as the time from the terminal’s call establishment request until indication that the call has been successfully established.
This parameter must be between <8,5 s (95%) and ≤10 s (100%). Set-up times above 10 s are evaluated as failed connection attempts.
To analyze this, 10,000 calls have been originated by the radio meanwhile, at the other end, the fixed application, connected via IP to the TETRA infrastructure, performed automatic call pick-ups once the notification was received. Once the CMD duplex call was established, both ends transmitted a message of 30 bytes, after that time the call was released from the fixed end. Six seconds after establishing the previous call, the TETRA radio repeated the process.
In the described environment, taking into account the methodology of the tests, the establishment time of a CMD call was <1 s (100%) with no failed attempts a time that exceeds the performance required by EIRENE.

Connection establishment error ratio. This value must be < 10⁻², considering as errors all failed call attempts and established calls >10 s. Therefore, considering the results above, TETRA is a competitive technology, regarding call set-up times.

Maximum end-to-end transfer delay. This is defined as the time between the first byte (of a user data block of 30 bytes) being sent by the transmitter and the last bit of the block being received by the receiver. According to EIRENE specifications, this should be ≤0.5 s (99%).
To study this, once the CMD call has been established, both ends begin to transmit packets of 30 bytes every 1 s. This makes possible to analyze the maximum end-to-end delay in both uplink and downlink.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Link</th>
<th>Maximum delay (s)</th>
<th>Average delay (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Uplink</td>
<td>0.402</td>
<td>0.218</td>
</tr>
<tr>
<td></td>
<td>Downlink</td>
<td>0.360</td>
<td>0.194</td>
</tr>
<tr>
<td>----</td>
<td>----------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>2</td>
<td>Uplink</td>
<td>0.377</td>
<td>0.219</td>
</tr>
<tr>
<td>3</td>
<td>Downlink</td>
<td>0.372</td>
<td>0.195</td>
</tr>
<tr>
<td>4</td>
<td>Uplink</td>
<td>0.449</td>
<td>0.214</td>
</tr>
<tr>
<td></td>
<td>Downlink</td>
<td>0.402</td>
<td>0.196</td>
</tr>
<tr>
<td></td>
<td>Uplink</td>
<td>0.433</td>
<td>0.215</td>
</tr>
<tr>
<td></td>
<td>Downlink</td>
<td>0.372</td>
<td>0.194</td>
</tr>
</tbody>
</table>

**TETRA END-TO-END TRANSFER DELAY**

*Transmission interference period (TTI) and error free period.* The TTI is defined as the period in which there may be loss of information or information received with errors. The maximum value of the TTI should cover all transmission errors from the train's journey, including cell changes (handovers) that are critical for communications.

Regarding Subset 093, this value must be between <0.8 s (95%) and <1 s (100%).

The cell change in GSM-R is caused by the infrastructure. This parameter assumes the worst case scenario, known as "cell radius handover with pre-emption" i.e. a lower priority call has to be disconnected before performing the handover. In this case, the TTI = time it takes to disconnect the call (about 600 ms) + time of handover in GSM-R (around 300 ms).

![GSM-R Transmission Interference Period](image)

As can be seen above, the TTI is clearly linked to the time of handover. The typical time of handover in GSM-R is about 300 ms, meanwhile in TETRA technology, this time depends on the type of handover used. Handover type 3 is the most common requiring for synchronization of the TDMA frame when moving from one cell to another. In a type 1 handover, the mobile unit engaged in a call and occupying a traffic slot informs the carrier that it has detected another cell with better coverage. Then, the carrier tells the radio which slot to occupy within the other cell.

When changing cell, the call is not interrupted and goes directly to the traffic channel of the neighbor cell. This cause a reduction of handover time compared to a type 3 handover, where the call is interrupted because the mobile unit must search for synchronization of the TDMA frame and, then, register in the new cell to establish the call again.

This analysis utilized the same set of tests as described for maximum end-to-end transfer delay. The results got in the tests with both handovers types were:

- Handover type 1: TTI <0.8 s (95%) and <1 s (100%)
- Handover type 3: TTI <1 s (95%) and <3 s (100%)

Thus, we can conclude that TETRA technology offers a performance within the limits set by EIRENE specifications when using handover type 1.
Each interference period should be followed by a called Error-Free Period (free time of error that must follow every TTI), which allows the retransmission of information that has not been received or has been received with errors, along with new information. In Subset 093, this value is specified between >20 s (95%), and >7 s (99%). Taking into account a minimum distance of 14 km between TETRA base stations and assuming a train traveling at 200 km/h, the handover will happen every 250 s approximately; for which the TETRA error free period meets EIRENE requirements. Additionally, the distance of 14 km between TETRA base stations (determined by the coverage study realized in this type of environment) is necessary to guarantee, statistically, a coverage level of 99.99% in the perimeter of the cell.

**Network registration Delay.** This is defined as the time from requested registration of the radio network to the receipt of an ACK. According to Subset 093, this must be between <30 s (95%) and ≤35 s (99%); values of >40 s are considered errors. To carry out this test, the time elapsed between power being provided to the TETRA radio and the registration command being received was measured 200 times obtaining a result of <15 s (100%), improving drastically EIRENE requirements.

All these results show that, in terms of QoS parameters, TETRA technology can be a suitable alternative to GSM-R.

**OTHER QoS PARAMETERS**

In addition to the Subset 093 QoS parameters, there are other essential aspects that reinforce TETRA usage in the signaling sector:

**Bit Error Rate (BER).** This parameter is defined as the number of erroneously received bits compared to the total number of bits sent in a given period. In this area, both TETRA and GSM-R provide figures around <10^-4.

**Maximum speed.** A maximum speed of up to 200 km/h must be guaranteed without affecting the QoS parameters. To this end, it has been empirically verified that with a more restrictive propagation model (HT300, mountainous environment with the train traveling at 300 km/h), increasing the speed results in an improvement in the error message rate (EIR) of the TETRA receiver. In addition, it has been proven that even with a 1 kHz frequency deviation between transmitter and receiver, all receivers are able to synchronize with the transmitter and receive without appreciable loss in dynamic sensitivity.

The next step is to calculate the speed at which the deviation of frequency due to the Doppler Effect is 500 Hz. This limit is given, since a mobile terminal moving from the base at ±V (V being the speed at which the Doppler shift is 500 Hz) will transmit at ±500 Hz frequency from the base, the total frequency error of the signal received by the base being ±1000 Hz.

\[
f_{\text{Doppler}} = \frac{c.f}{c+V}
\]

where \(c\) is the speed of transmission of light in a vacuum; \(f\) the operating frequency; and \(V\) the relative speed of the mobile terminal base station.

\[
|\Delta f| = |f_{\text{Doppler}} - f| = \left| \frac{c}{c+V} - 1 \right| \cdot f \leq 500Hz
\]

\[
V \leq \frac{500 \cdot c}{f - 500}
\]

For example, for \(f = 470\) MHz → \(V \leq 1148,9\) km/h; and for the maximum frequency currently used in TETRA systems.
870 MHz, \( V \leq 620.7 \text{ km/h} \).

Thus, it can be concluded that speed does not affect either symbol synchronization or the calculation of the optimum sampling time and that the algorithms used are independent of the frequency error that could cause the Doppler effect.

With the current frequencies used in TETRA, the speed limit is around 620.7 km/h at a frequency of 870 MHz. Thus, the tests performed within the HT100 simulation environment can be considered equally valid for a train traveling at 200 km/h.
ADDITIONAL ADVANTAGES OF TETRA TECHNOLOGY

Besides all the previous quality of service factors, TETRA technology provides a list of additional characteristics that make it an even more attractive proposition for the studied environment:

Operational frequency bands, TETRA is specified to operate in a wide range of frequencies within the lower part of UHF band, while GSM-R operates in the upper part of the band, concretely in 800-900 MHz. Since radio propagation loss is directly proportional to the frequency, GSM-R requires many more repeater stations than TETRA to achieve the same coverage (almost the double). This implies savings not only in terms of radio repeaters, but also in associated civil works (shelters, towers, buildings, electrical installations, antenna mounts, power systems, etc.).

\[ L_p = 32.5 + 20 \log(f) + 20 \log(D) \]

Spectrum access. Nowadays, the spectrum is a very limited resource. In fact, most of the times it is the limiting factor to choose a radio technology. GSM-R 800-900 MHz frequency bands are also used by commercial operators so that the availability of these bands and/or the interferences that can be found are the key point.

Spectral efficiency. In this respect, TETRA is four times more efficient than GSM-R, providing four channels on a bandwidth of 25 KHz, compared to GSM's eight channels of 200 KHz. Thus, in the same frequency space, TETRA can offer more channels to the user (32) supporting much higher levels of traffic and facilitating the implementation of future data applications.

IP technology. As shown in Figure 2, the interface between the fixed part and the GSM-R (IFIX) network is, in an ETCS system, a Primary Rate ISDN (PRI) type. In addition to this interface, the V.110 adaptation scheme is used in the user data channel. However, in some countries is not possible to get this type of links necessary for an ETCS signalling system over GSM-R. However, over the years, TETRA manufacturers have tended to 100% IP-based systems, providing services via an IP connection with the central node of the infrastructure. Thus, the E1 links could be replaced by IP connections, eliminating the cost and maintenance that those links require.

Profile of technology use. GSM is an ETSI standard designed for mobile telephony: frequency reuse is important, and the cost of the infrastructure is not relevant, since there are tens of millions of subscribers to support it. Clearly, this system is not efficient enough for being used in low user-density circumstances such as rail where there are hundreds of users at maximum.

Additionally, commercial networks do not guarantee a minimum quality of service to the users, but they assume that in some moments the network can be congested and no service is available. Similarly, full coverage in the territory is not assured, existing dark areas where the users cannot reach the system.

For professional users like transport operators, all these limitations imply continuous problems that affect to the operations. TETRA technology, an ETSI standard as well, solves the previous points as it is designed for a profile of usage closer to that of a rail agency.

The sizing of a TETRA system is precisely based on the number of network users. This is complemented by priorities management where, if the system is congested, the highest priority calls are able to cut on-going communications to assure their establishment. Furthermore, dedicated design of the coverage area ensures the high levels of system availability required in transportation environments in most cases, exceeding 99.9%.

Standard TETRA functionality. Some of the features natively included in the TETRA standard are particularly suited to the railway environment (group calls and emergency call priorities, group dynamics assignment, called ambient listening, direct and various data services mode, etc.). This is in contrast to GSM-R, where the basic technology GSM must be significantly adapted to meet functional requirements (ASCI features).
SIGNALLING REFERENCES OVER TETRA

KAZAHSTAN RAILWAYS: ETCS LEVEL 2 OVER TETRA

(KTZ), Kazakhstan passenger and freight rail operator company, was an essential part in the transport infrastructure development program in the country, defined for the period 2010-2014 and framed within the national strategic plan up to 2020.

The Kazakhstan geographical conditions, with vast areas without direct access to the sea, the production structure of raw materials and poorly developed road network, give rail transport an extremely important role in that strategic plan.

The company faced a major challenge of modernizing their systems, rail infrastructure, locomotives and control and operational systems, which, for sure, help to improve the competitiveness of Kazakh transport system for both passengers and freight transportation through the euro-asian international routes.

Within this program of modernization, the first two projects done by KTZ are described below:

- **Uzen – Bolashak line**: Section of 150 km between these cities in the southwest of the country. It is the beginning of a long railway line linking Kazakhstan, Turkmenistan and Iran meant to enhance trade between the countries.
- **Zhetegn – Khorgos line**: 300 km line linking two cities located close to the Chinese border. This railway is important to promote political and economic relations between the two countries and establish a new access route between China and Europe.

Given the strategic importance of both lines, it was essential to provide them with control systems that would allow security and train speeds to be increased, and thereby reduce operating costs for freight transport. These railway control systems require the support of a robust and reliable communications system, which shall be based on radio technology in order to reduce the wayside equipment, which, given the characteristics of the environment it is difficult to deploy and presents high maintenance costs.

Due to the many good references available in Europe, the railway signaling system chosen by the customer KTZ was ETCS (European Train Control System). A key aspect in the solution design was the selection of a communications system for supporting the signaling system. It was needed to find a safe, reliable, and cost-efficient system to support at least the following requirements:

- To be based on an international standard that incorporates railway related applications.
- Support for railway-specific services: Group calls, ambience listening, emergency calls, priority management, data transmission services, remote management and monitoring system, fast set-up and registration times, etc.
- Availability of equipment in UHF frequencies
- Integration of railway services into a single communications network
- High level of reliability, availability and quality of voice communications and data integrity
- Economic and technical feasibility (CAPEX)
- Low maintenance costs (OPEX)
- Capacity of the company providing the radio solution to adapt it and integrate it with the vendor of ETCS signaling system.

Competing against the current GSM-R technology mandatory in Europe, TETRA technology and specifically the TELTRONIC equipment were chosen to cover extensively the above requirements. Kazakhstan’s national railway has been the first to rely on the implementation of an ETCS (European Train Control System) railway signaling system over TETRA, being the security level implemented equivalent to that defined in the standard as ETCS Level 3. In addition, with this solution, KTZ has available through a single communications infrastructure data services to support railway signaling and voice services for communications with drivers and maintenance staff.
OTHER SIGNALLING SYSTEMS OVER TETRA: POSITIVE TRAIN CONTROL (PTC)

PTC, Positive Train Control, is an American recommendation established by the Federal Railroad Administration (FRA) in the United States. This kind of systems refers to communication-based/processor-based train control technology designed to prevent train-to-train collisions, over speed derailments, incursions into established work zone limits, and the movement of a train through a main line switch in the improper position. PTC systems vary widely in complexity and sophistication based on the level of automation and functionality being implemented, the system architecture used includes wayside systems and the degree of train control.

The solution proved compliant with Positive Train Control (PTC) requirements established by the Federal Railroad Administration (FRA) in the United States. Generally, these systems are used for long-haul distance trains or freight and mining trains. Although currently, the communication technology used is WiFi or even proprietary solutions, TETRA may be the digital radio communications network to communicate its wayside and mobile parts and, hence, monitor and control train actions. Real project deployments of PTC over TETRA are running in the field in South Africa and South America, taking advantage of the TETRA features and costs.
TELTRONIC’S SOLUTION FOR SIGNALLING ENVIRONMENTS

Teltronic provides a complete solution for rail signaling based on TETRA technology as an alternative mean for data transmission instead of the radio systems employed to date. The proposal complies with all the technical requirements needed for the appropriate end to end performance of the signaling system and are composed of the RTP-S on-board equipment and the eNEBULA infrastructure.

- NEBULA infrastructure for TETRA mobile radio networks delivers excellent coverage, security and reliability in a platform designed for efficient implementation and cost-effective TETRA Radio Access and scalability. eNEBULA is a TETRA system fully 100% Ethernet / IP based. A secure and reliable network can be built with distributed switching, distributed intelligence, and complete fault-tolerant redundancy, as well as at lower network costs due to the use of commercial off-the-shelf equipment. Availability and reliability are kept in mind to assure that the system will still perform in spite of any unexpected circumstances. This is why the base stations count upon fallback mode controllers, redundant elements and cutting-edge components, achieving the highest availability and lending the best service possible for the complex environment of the signalling.

- RTP-S on-board equipment is mainly focused on data management in railway environments, by complying EN50155 and EN45545. It has been designed according to the strong requirements set by the railway signaling market: on the one hand, voice services are fully separated from data services. Thereby, a TETRA radio channel will be available 100% of the time for vital data transmission (location, speed restrictions, braking points or Limit Movement Authorities). On the other hand, TETRA radio acts as a modem-data providing to the external application the data services most suitable for bulk data transmission (Packet Data or Circuit Mode Data) in order to manage the vital information transmission.

The research led by the major European bodies that looks for a substitute of GSM-R, seems to point at LTE (Long Term Evolution), a broadband technology standardized by the 3GPP since it complies with the minimum statements defined in section 4.2.
In addition, LTE may support different landscape of applications used in transportation systems, as for example, real-time video transmission in mobility, remote update of Passenger Information Systems, management of scheduling and planning information or Internet for passengers, among others.

For this, and for other broadband needs detected in the recent years in other mission-critical scenarios, Teltronic includes in its portfolio an LTE solution fully integrated with the rest of products and technologies within the portfolio.
CONCLUSIONS

The variety of signalling systems within Europe leads to difficulties on railway lines that cross borders between countries. Precisely, the ERTMS standard attempts to solve this problem using ETCS and GSM-R as communication support.

However, there are currently many circumstances among national, regional, metropolitan European lines and even international lines outside Europe where the use of GSM-R is not mandatory, and other technologies, such as TETRA, can be used alternatively to meet both safety and cost requirements.

TETRA technology, compliant with EIRENE specifications, is spectrally more efficient, has a greater range of functions, and is significantly cheaper than the commonly deployed technology in this European signalling system, GSM-R.

With this study, TELTRONIC has proven TETRA technical viability to offer safe and efficient communications in the railway environment, providing ETCS signaling data. Even more, voice and operational data (location, alarm and event management) could be also delivered over the single infrastructure.

This analysis may be applicable to other transportation environments with signaling systems based on different existing protocols such as ETCS, CBTC or PTC.