WHITEPAPER

TETRA: THE TECHNOLOGY OF CHOICE FOR THE URBAN TRANSPORT MARKET

WHY TETRA HAS BECOME THE DE FACTO RADIO TECHNOLOGY FOR PUBLIC TRANSPORTATION, FROM BUS AND TRAM NETWORKS TO METRO SYSTEMS & RAILWAYS
The rapid adoption of TETRA technology by the public safety sector has catalysed its use in a growing range of markets: TETRA is now the de facto radio technology for public transportation, from bus and tram networks to metro systems and railways.

But why is TETRA so suited to the urban public transport market? What are the factors that have driven its success and led to such exponential growth in its use?

In looking at any new or replacement radio communications network, today’s transport operators need to consider a fully operational end-to-end system, with easy integration and secure features.

Any communications network deployed as part of a transport system has to be reliable: failure to route buses or control tramways can be catastrophic, not just for the transport operators but to the local economy. Secure, reliable, feature-rich communications are therefore of paramount importance: the solution has to work, and it has to work 24 hours a day, 365 days a year.

Aside from economic viability in its construction and operation, key considerations for a transport communications system include:

- High-quality communications (voice and data)
- A high level of reliability and availability
- Flexibility to adapt to special rail requirements and to allow integration of transportation services within a single network
- Support for radio transmission systems currently in operation
- Easy integration of future services

This document aims to establish why TETRA’s highly resilient, functionality-rich, mission-critical voice and data networks are the best choice for transport operators, now and in the future. It will also provide a brief overview of the future of mission critical technologies within the transportation sector.
WHY TETRA?

TETRA offers a complete, resilient and totally secure, service-rich communications solution.

Currently in operation in thousands of communications systems worldwide, it is a proven technology and, as an open, international standard – defined by ETSI, the European Telecommunications Standards Institute, in 1995 – it gives users access to a multi-vendor market.

Its reliability, availability and security are determining factors in its success. Additionally, TETRA’s interoperability in the event of a major incident means that public safety agencies such as police, fire and ambulance services can instantly communicate with transport staff.

Specifically designed for use by government agencies and emergency services, it has become the worldwide standard of choice for an increasing range of sectors seeking the best critical communications technology available.

Although large-scale public safety projects drove TETRA’s initial development, demand from the transportation sector has increased significantly over the last decade, with TETRA being adopted as the de facto technology for voice and data communications. Together, these two sectors now form the core of the addressable TETRA market.

**SOURCE:** TETRA + CRITICAL COMMUNICATIONS ASSOCIATION (TCCA) TRANSPORTATION GROUP
Communication scenarios for transportation environments tend to fall into two distinct areas:

- **Voice and data communication, typical of passenger service networks**, where voice is used for communication between the drivers and their passengers or the control centre, while data is used for monitoring vehicle status, real-time passenger information (RTPI), exchanging train-to-ground messages and displaying arrival and departure information for passengers. Intelligent Transportation Systems (ITS) use real-time location and capacity information to help with traffic regulation and passenger fluidity.

  This is the most common environment in which TETRA is the de facto technology worldwide.

- **Data communication, typical of mainline and suburban networks** that require a communications network to support a signalling system. Voice is still required, but these vital data communications have the highest priority in the network.

  In European mainline railways, GSM-R has traditionally been mandated according to the ERTMS standard, but many mainline train markets outside Europe have enthusiastically adopted TETRA on the basis of its features and facilities for critical applications – in Africa and South America, for example, where TETRA dominates railway and mining communications.

TETRA is the optimal choice for transport operators, as it is able to provide a complete multiservice and unified system (voice and critical data) meeting their communications needs, whilst providing high levels of availability and reliability.
INTEGRATION WITH THIRD-PARTY SUBSYSTEMS

FIXED NETWORK

The diagram below shows a typical TETRA solution for transportation, centred around a System Control Node (SCN), the main controller of the network that manages any number of Site Base Stations (SBS), providing RF transmitters and giving near-complete coverage to the required areas. The infrastructure can be monitored and controlled from a Network Management System (NMS) to ensure that proper maintenance actions are taken immediately the need arises.

This fixed system can interface with other networks, such as PSTN, PABX or even cellular networks, allowing integration with other agencies in emergency scenarios e.g. integration with local public safety and/or fire brigades services to guarantee a fully coordinated service in critical situations such as natural disasters, instances of terrorism or technical breakdown.

Control centre applications are available for managing communications, as well as specific protocols that allow users to develop fully customised applications. The control centre is also essential for smooth integration of TETRA systems with existing analogue networks, allowing seamless intercommunication amongst different technologies.

EXAMPLE OF AN INTEGRATED NETWORK IN A TRANSPORTATION ENVIRONMENT
ONBOARD

Onboard, a set of third-party systems ensure smooth end-to-end performance of the whole system. Interaction between the onboard radio terminal and the Public Address and Intercom System, for example, facilitates communication with passengers by extending the operation of the subsystem through the radio network.

The connection between the radio and the Train Control & Management System (TCMS) allows the exchange of operating and control information with the other train sub-systems, both locally and with the control centre. Thus, the status of numerous systems – such as the public address, intercom, emergency alarm, fire detection, door opening, air conditioning and braking systems – can be remotely monitored for the whole fleet. This connection can also be utilised for passenger updates, such as next station information, next vehicle arrival and operational messages.

In tramway and bus systems, integration between the radio and the Intelligent Transportation System (ITS) application is essential for the correction regulation of traffic, and smooth operation of the public transport system.

TOUGH TERMINALS FOR TOUGH CONDITIONS

Electronic equipment installed in rail vehicles must withstand extremely harsh conditions such as shock, vibration, temperature, humidity, electromagnetic compatibility, smoke and fire. Thus, electronic equipment compliant with rail regulations – such as EN 50155, EN 61373, EN 50121, ENS0125, EN 60950 and EN 45545 – is essential to assure reliability and the proper behaviour of terminals.

- EN 50155: railway applications – electronic equipment used on rolling stock
- EN 61373: railway applications – rolling stock equipment, shock and vibration tests
- EN 50121: railway applications – electromagnetic compatibility
- ENS0125: railway applications – environmental conditions for equipment part 1: rolling stock and onboard equipment
- EN 60950: information technology equipment – safety
- EN 45545: railway applications – fire protection on railway vehicles

![Diagram of onboard systems and connections]
THE BENEFITS OF TETRA IN TRANSPORTATION ENVIRONMENTS

TETRA offers high-quality voice and data communications for train speeds up to 500 km/h; a predominantly IP-based infrastructure; a wide range of fixed units, mobile and portable devices; large and small-scale control centre functionality, with tailor-made applications; and rail-certified onboard equipment to be installed in vehicles and locomotives.

Additionally, TETRA provides an interface for seamless integration with other communication technologies and subsystems, allowing the creation of a fully integrated communications solution.

Furthermore, TETRA provides two significant benefits when compared with cellular technologies such as GSM, or its rail version GSM-R:

1. **Frequency band and spectrum efficiency**
   TETRA operates in frequency bands at 300 MHz and above. GSM-R operates in the 900 MHz and 1800 MHz bands. Since radio propagation losses are directly proportional to the square of the frequency, other radio technologies allocated in higher frequencies bands require many more base station repeaters than TETRA to obtain the same level of coverage. Thus, TETRA provides savings not only in terms of radio equipment, but also in civil engineering costs (buildings/shelters, towers, etc.).

   TETRA’s spectrum use is **four times more efficient** than GSM-R, providing four channels in a bandwidth of 25KHz, compared to GSM’s eight channels in 200 KHz.

2. **Technology usage profile**
   GSM is a standard developed by ETSI for mobile telephony. One of its key features is frequency reuse; the infrastructure cost is considered insignificant by network operators since there are millions of subscribers to support it.

   GSM-R – an adaptation of GSM which includes group call and some protection for data transmission – works on the same principal, but is clearly not cost-efficient for low-density user systems.

   By contrast, TETRA technology was initially created to serve user profiles with requirements significantly closer to those of the transportation sector:

   - Mission critical features not available in commercial networks: DMO, group calls, priorities, emergency calls, etc.
   - A relatively low number of users, compared to the millions typical of a commercial, cellular network

Finally, it should not be forgotten that consumer-focused networks are developed to achieve maximum profit, not maximum resilience; they cannot offer the levels of availability required by mission critical organisations.
TETRA FUNCTIONALITIES

A range of functionality included in the TETRA standard has direct application in the transport sector. This clearly differentiates TETRA from other wireless technologies.

The following services are included within the basic features of a standard TETRA communication system:

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fleet and group management</td>
<td>Definition of fleet and group configuration tailored to operational groups, e.g. groups for lines, depots, events, emergency, stations, etc.</td>
</tr>
<tr>
<td>Group calls</td>
<td>Calls between two or more users. All parties may participate; the talking party is indicated throughout</td>
</tr>
<tr>
<td>Broadcast calls</td>
<td>Unidirectional calls between two or more users (i.e. call initiator transmits, other parties receive only)</td>
</tr>
<tr>
<td>Call setup</td>
<td>Call set-up times for individual or group calls are around 300ms</td>
</tr>
<tr>
<td>Priority management</td>
<td>Up to 15 priority levels that can be assigned to different services</td>
</tr>
<tr>
<td>Emergency calls</td>
<td>Maximum priority level calls can interrupt ongoing calls where sufficient network resources are not available</td>
</tr>
</tbody>
</table>
| Data services                | • Packet data service  
                                  | • Circuit mode data  
                                  | • Short data service  
                                  | • Status messages                                      |
| Dialling and addressing services | TETRA provides different numbering and dialling methods for accessing TETRA systems and external networks such as PABX/PSTN, ISDN. These can be complemented with other procedures to log the user in |
| Dynamic Group Number Assignment (DGNA) | Supplementary service that enables the swift creation of separate user groups e.g. for coordinated major incident response |
| Ambience listening           | Supplementary service that allows the radio to transmit without any action from, or indication to, the user |
| Duplex calls                 | ‘Telephone-style’ calls, operable by drivers in hands-free mode              |
| Direct mode                  | Direct communications between radios out of network range – especially useful for shunting operations |

FOR MORE INFORMATION, SEE APPENDIX: DETAIL OF TETRA FUNCTIONALITIES
THE FUTURE OF TETRA IN TRANSPORTATION

Within the transportation sector, the demand for TETRA voice and data services has increased significantly over the last decade, but there are still many analogue systems supporting transport operations.

The majority of these analogue systems will, in the near future, migrate to a digital technology that improves operational efficiency and, thus, the service provided to its users. Through mature digital technologies like TETRA, the sector's current voice and data needs are adequately met, in a network that offers a high degree of security and availability.

However, the growing demand for applications and services, consuming large volumes of data, makes it necessary to invest in the expansion and extension of existing digital TETRA systems to meet these new requirements for wireless broadband access.

In fact, real-time video streaming in emergency situations is the main driver for broadband capacity and the reason for LTE being promoted as the broadband standard for mission-critical users – particularly by vendors from the telecommunications market, who are keen to discourage the use of professional narrowband technologies like TETRA.

The specification for the TETRA standard is underpinned by a number of fundamental requirements that are highly relevant to the transportation sector today:

- Prioritisation and pre-emption, allowing the most important calls to be connected at times of congestion
- Emergency calls, prioritised above other traffic, which get through even if the network is busy and automatically alert controllers
- Wide-area, fast call set-up, ‘all-informed net’ group calls
- Direct Mode Operation (DMO) allowing back-to-back communication between radio terminals, independent of the network
- High-level voice encryption to meet the security needs of critical organisations
- Full-duplex voice for PABX and PSTN telephony communications

Additionally, the number of TETRA systems already deployed in buses, tramways, metros and rail systems worldwide point to TETRA and private LTE hybrid systems as the optimal communications solution for the transport sector in the near future.

This multiplatform approach will deliver a full suite of applications, from voice and position information to real-time video, with the same level of security and quality of service.

- Video-surveillance: CCTV in trains and stations
- Internet for passengers
- Data communications for signalling systems:
  - ETCS: evolution of current GSM-R radio systems
  - CBTC: improvements to overcome Wi-Fi systems
- Download of operational files: ticketing or passenger counting information, statistics and reports, etc.
- Upload of operational files: update of onboard Passenger Information Systems (PIS), multimedia systems or even planning and scheduling files at the beginning/end of the day

TETRA can expect an enduring market for the foreseeable future, coexisting and integrating with LTE. The critical LTE market is expected to grow when standard specifications are completed and adopted by product manufacturers and the industry.

In conclusion, LTE is complementary to the highly secure and resilient TETRA networks that have already proven their industry-leading qualities, delivering critical communications to the urban transport sector worldwide.
APPENDIX: DETAIL OF TETRA FUNCTIONALITIES

Here are some examples of how TETRA features are used in transport operations:

ROUTING BY LOCATION

TETRA provides several services specially designed to meet this operational requirement:

- DGNA (dynamic group number assignment): a supplementary service that allows the creation of separate user groups which may be integrated as required e.g. for major incident response. This function can be used, for example, each time a radio terminal is registered in a location area, or whenever a message is received from the terminal indicating its location
- Call forwarding

In combination, these services allow easy communication between operators and drivers: regardless of location, the driver need only dial a short code to contact the controller. The system then checks the vehicle’s location and redirects the call to the controller in charge of the relevant area.

AUTOMATIC COMMUNICATION GROUP CHANGE

Using GPS/beacon positioning, onboard equipment automatically selects the appropriate communications group as the vehicle passes through each defined section of its journey.

GROUP AND FLEET MANAGEMENT

During registration, the radio terminal requests to be attached to a number of groups. Group services are not limited to group calls, but can also be applied to short data services. Executed via the Network Management System (NMS), they allow the independent assignment of groups and permissions to each user, and the coexistence of any number of differing profiles.

Efficient configuration could even permit a number of separate entities – police, a transport operator and a fire brigade, for example – to each utilise the same network without impinging on the communications of the others.

This feature includes two concepts:

- Selected group: active group in the terminal to establish and receive calls
- Scanned groups: set of listening groups in which the terminal can receive calls (in addition to the selected group)

These groups can be configured, either to be editable by the user or to be hidden and always active, allowing special configurations. For example, a general group communication can be defined, allowing the system operator to communicate with a specific user group, or all users in emergency situations.
Groups may be enabled to work only in certain zones or across the whole network; there is no limit to the number of users in each group. Small groups or general groups may be defined according to operational requirements.

GROUP CALLS
Group call is one of the main functions of a TETRA system. It allows point-to-multi-point connections to be established for carrying voice and data traffic.

This service can be useful in several circumstances within transport operations:

- Communication with shunting groups
- Emergency communication
- Communication with different groups of vehicles along the route

Call permissions of the different usage profiles – such as who can initiate a group call, who belongs to which group, etc. – will be defined in the Network Management System.

Standard group calls are:

- Half-duplex, using the PTT (push-to-talk) button
- Direct calls, automatically connected, without any user action

The user who initiates the call has the initial permission to transmit (if the system allows it). During a call, the speaker can change; the calling user (Calling Party Type Identifier) and speaker (Talking Party Type Identifier) is indicated to users at all times.

There are also special group calls: broadcast calls or TETRA group calls from a telephone (PABX or PSTN) that allow users to extend the radio coverage throughout telephone networks, creating a fully integrated communications solution.

For any type of group call there is a configurable time of inactivity, after which the call is terminated in order to save network resources.

Another supplementary service, known as ‘Late Entry’, provides continuous call-in-progress updates to allow latecomers to join a communication channel. If the user has been outside radio coverage, for example, the control channel will divert the user’s terminal to a talk group call that is already in progress.

BROADCAST CALLS
This is a special ‘unidirectional’ group call: only the calling user has permission to transmit; other users may only listen.

Broadcast calls can be made to specific groups or the entire network. In the latter case, the TETRA standard defines a special address which has to be attached by default in every terminal.

Broadcast calls can be used to transmit railway emergency calls; both mobile and fixed terminals may use the service and the communication will have higher priority than any other.

PRIVATE CALLS
A private/individual call allows point-to-point calls to be established for voice and data. A call can be made between two radio terminals; a radio terminal and a dispatcher; two dispatchers; or a radio terminal and a telephone (PABX or PSTN).

This has a number of applications within transport operations, such as communication amongst drivers or between drivers and controllers.
Call permissions of the different usage profiles – such as who can initiate an individual call, who can call to telephones, etc. – are defined in the Network Management System and by programming the radio terminals. An individual call could be:

- half-duplex, using the PTT (push-to-talk) button
- full-duplex: it is possible to speak and listen without use of the PTT button
- direct signalling: the call is connected automatically, without any user action
- hook signalling: call is only connected when the called party accepts the call

Special individual calls can be made to a PABX/PSTN telephone. Due to the nature of the receiving device, these calls will always be full-duplex with hook signalling, routed via a telephone gateway.

“TETRA’s call set-up time is always less than a second, regardless of network structure or other external parameters”

AMBIENCE LISTENING CALLS
This remote-controlled action allows the dispatcher to listen to background noises and conversations within range of the radio terminal’s microphone without any indication being provided to the radio terminal user.

This is an important service for public service vehicles where the health and safety of staff or passengers is paramount. The control console within the driver’s cabin has an emergency panic button which, when pressed, sends a status message informing the control room of an emergency situation. The dispatcher can then initiate an ambience listening call to gain an understanding of the circumstances.

The Network Management System can enable or disable this service for the whole system, or selected fleets or terminals.

PUBLIC ADDRESS AND INTERCOM CALLS
Onboard radio equipment can be connected to vehicle sub-systems, such as the public address and intercom systems, to extend their operation throughout the radio network and support several functionalities:

- PA connection from driver to passengers
- PA interconnection from the control centre to passengers
- PA connection between cabins
- Connection between driver and alarm intercom
- Interconnection between control centre and alarm intercom

PRIORITY MANAGEMENT
TETRA technology defines 15 priority levels. The priority of each user and service can be defined in the Network Management System (NMS). Shunting and maintenance, for example, may need different priority levels, according to the type of communication.
Priority management is not limited to the set-up of priority calls:

- **Group priorities**
  Communications groups have a priority of scan assigned. This priority helps to define the different levels and usage profiles. For example, emergency groups will have a higher priority than the general line group.

- **Speech item priorities**
  In a half-duplex call, if user A asks to transmit while user B is talking and user A has pre-emptive priority assigned, B is interrupted, allowing A to talk.

**PRE-EMPTIVE PRIORITY CALL**

Emergency calls need a fast set-up, regardless of the available network resources. This call service provides highest priority access; if the network is busy, the lowest priority communication is dropped to handle the emergency call.

Typically, line dispatchers or controllers have pre-emptive priority assigned (both call and transmission), allowing them to communicate even when the network is busy.

**DYNAMIC GROUP NUMBER ASSIGNMENT (DGNA)**

This supplementary service allows authorised users to create, modify, delete and consult groups dynamically. If a route is divided into zones, DGNA can be used to change the zone group as the vehicle runs along the line. In emergency situations, various groups can be temporarily brought together to enable efficient communication and swift interaction of groups that may not typically interact in normal daily operations.

The service has the following features:

- **Group assignment to individual users**
  Temporary grouping of individual users

- **Group assignment to group users**
  Temporary union of communication groups

- **Group deletion**
  Deletion of dynamic groups at the end of special operations

**DIRECT MODE**

This special communication mode enables radios to communicate directly without using TETRA infrastructure.

This mode is typically used for controlling certain communications activities, such as maintenance and shunting communications, where a small number of users in a reduced area need to make individual or group calls giving precise instructions on handling the vehicle or changing the track. Direct mode avoids conflict of resources in the system and ensures reliable communication for the duration of the process – even where network coverage may be limited.

**STATUS MESSAGES AND SDS**

Both status messaging and Short Data Service (SDS) messaging provide very efficient methods for sharing information with little impact on voice traffic or IP data, for example, between a train and the control centre:

- free text or pre-defined messages
- remote control and alarm messages
TRAIN ID MANAGEMENT
The train ID is a code that identifies certain operational characteristics of the vehicle, such as the route name, type of train, combination of driving cabs, type of service and direction of travel.

This number is used by the control centre for management and organisation purposes and can be dynamically assigned or modified at any time, using the TETRA system.

VEHICLE MONITORING
Using TETRA data services such as SDS, operational and control information is relayed from onboard radio equipment to the control centre, allowing operatives to monitor the status of the vehicle’s subsystems, including alarms and events.

PACKET DATA AND CIRCUIT MODE DATA
Circuit Mode Data service (CMD) is based on circuit switching, similar to cellular technologies like GSM or GSM-R, and provides gross data rates of up to 7.2kbps.

The Packet Data service (PDP) is based on IP technology and allows the exchange of data between two IP addresses. The net rate provided depends on different factors such as type of traffic, size of packets, infrastructure characteristics or the protocol used (TCP or UDP).

In railway operations, both services are typically used by applications which require continuous data transmission, such as signalling.

ABOUT TELTRONIC
Part of the Sepura Group, Teltronic offers a broad portfolio of critical communication solutions for the transportation, public safety, utilities and industrial sectors based on TETRA, P25, and LTE technologies.

The portfolio also covers end-user applications and systems for integrated command and control centres and custom surveillance. Teltronic has deployed over 400 systems in more than 60 countries.
TRANSPORT REFERENCES

ALGERIA
Algers Metro
Constantine Tramway
Oran Tramway

AUSTRIA
Vienna Light Railway AG

AUSTRALIA
Sydney North West Rail Link

BRAZIL
Brasilia DF Metro
Cuiaba Tramway
Salvador Metro, Bahia
Supervia Rio de Janeiro
VLT Rio
VLT Santos

CANADA
Toronto Transit Commission

CHILE
Santiago Metro

COLOMBIA
Autobuses de Pasto
Transmilenio BRT
Northern Railways of Colombia (FENOCO)

ECUADOR
Cuenca Tramway

FRANCE
SNCF

GERMANY
KOR-Busse
Nuremberg U-Bahn

KAZAKHSTAN
Kazakhstan Railways

MALAYSIA
Ampang Light Rail

MEXICO
Buenavista-Cuauhtitlan Train
Mexico DF Light Train
Mexico DF Metro
Monterrey Metro
Puebla Tramway

MOZAMBIQUE
Moatize-Nacala Corridor

NORWAY
Bergen Tramway

PERU
Lima Light Train

POLAND
Warsaw Metro

QATAR
QEC Doha Tramway

RUSSIA
Moscow-St. Petersburg railway

SOUTH KOREA
Daegu Metro
Seoul Metro

SPAIN
Barcelona Metro
Barcelona Tramway
Bilbao Metro
Catalonia Railways FGC
Euskotren Railways
Madrid Metro
Palma de Mallorca Metro
TMB Buses, Barcelona
Valencia Railways
Zaragoza Tramway

TAIWAN
Khaosiung Light Rail

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NEXUS Tyne & Wear Metro
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New Jersey Transit buses and tramways

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