Introduction to TETRA Technology

Introduction

The TETRA Standard is a telecommunications standard for Private Mobile Radio (PMR) systems developed by ETSI as an answer, at European level, to the evolving needs of PMR Operators, which have to cope with traffic congestion and a growing demand for speech and data services.
The evolution of digital technology shows a way out of this situation allowing high spectrum efficiency and coexistence with present analogue systems.

The range of functions and services offered by *SMARTNET*, ETI's new generation digital trunked mobile radio system complying with TETRA supports applications such as:

- Secure speech/data transfer
- Automatic vehicle location
- Railway applications
- Road transport information
- File transfer & access to databases
- Fax
- Fixed image
- Slow video
- Fleet management

These applications satisfy the needs of a variety of professional users from maintenance services, taxis, delivery services, up to the emergency and security services.

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1. New European Digital Trunking Standard

The Private Mobile Radio (PMR) market lies traditionally been scattered in many dimensions in terms of technologies, frequency allocation etc. The first clear change towards international standardization was the introduction of the analogue MPT 1327 trunked radio standard that lead to a market success in most parts of the world. What has kept the MPT 1327 market partially national or regional is the lack of common Internationally harmonized frequency bands.

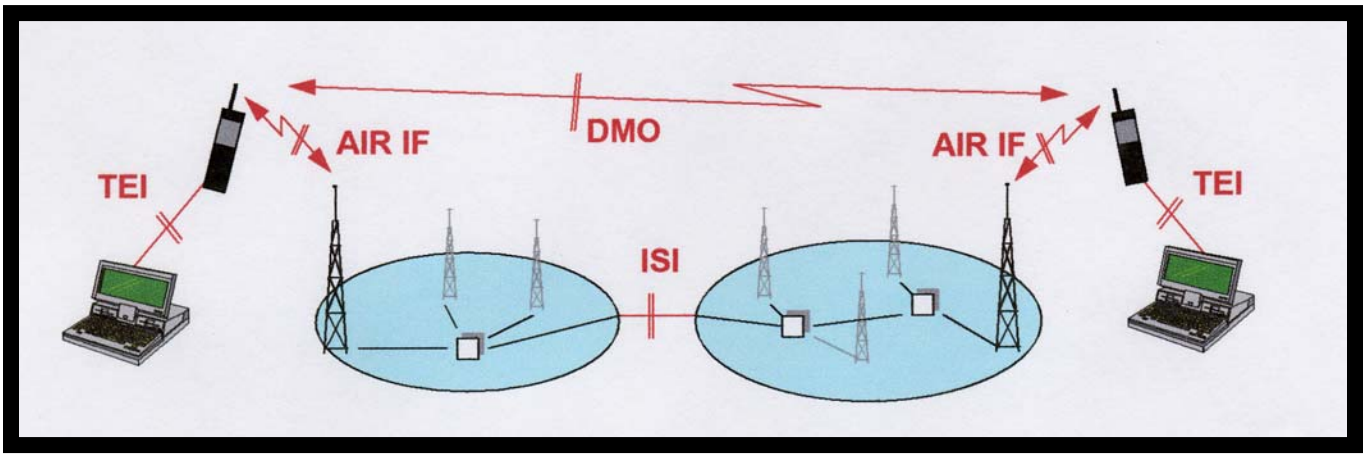
Trans-European Trunked Radio System (TETRA) is the first truly open digital private mobile radio standard. TETRA is opening an even more international PMR market with widely harmonized frequencies.
The European Telecommunications Standards Institute (ETSI) that joins the forces of network operators, national administrations, equipment manufacturers and users defines the standard. The essential parts of the TETRA standard have been approved in national voting at the end of 1995 (22 countries voted for the approval and none against it). What is notable in the status of ETSI is that it publishes telecommunications standards that are mandatory for use in Europe.

User impact can be seen clearly in the development of TETRA. Especially the emergency service users 1-iave contributed strongly in the creation of the standard. As a result, the TETRA standard contains high functionality for emergency services and is also very well suited for commercial trunked radio users. The high level of user involvement in the creation of the standard ensures that it will meet the needs of the demanding users.

The standard has gone through a thorough approval procedure with its vast number of commenting that as such ensures high quality compared with the development of proprietary solutions.

To ensure an open multivendor market, TETRA specifies the following essential interfaces:

1. Air Interface ensures the interoperability of terminal equipment from different manufacturers.
2. Terminal Equipment Interface (TEI) facilitates the independent development of mobile data applications.
3. Inter-System Interface (ISI) allows the interconnection of TETRA networks from different manufacturers.
4. Direct Mode Operation (DM0) guarantees communication between terminals also beyond network coverage.



Also a line station interface is standardized. It should be noted, that the interfaces inside the Switching and Management Infrastructure are not standardized. This provides the essential benefits of an open market, but leaves the manufacturers the freedom to implement the most cost-efficient network solutions.

All major system manufacturers, user organizations, network operators, regulators, test houses and application software developers have signed the TETRA Memorandum of Understanding (MoU), a joint effort to support and promote fast and consistent implementation of TETRA systems in the member countries. To ensure a wide open market, the TETRA MoU strives for the maximum interoperability of equipment from different manufacturers. TETRA is thus the first and only approved digital trunking standard in Europe or in any other part of the world.

The latest information on TETRA and the members of the TETRA MoU can be obtained from the TETRA MoU internet homepages at "http://www.tetramou.com".

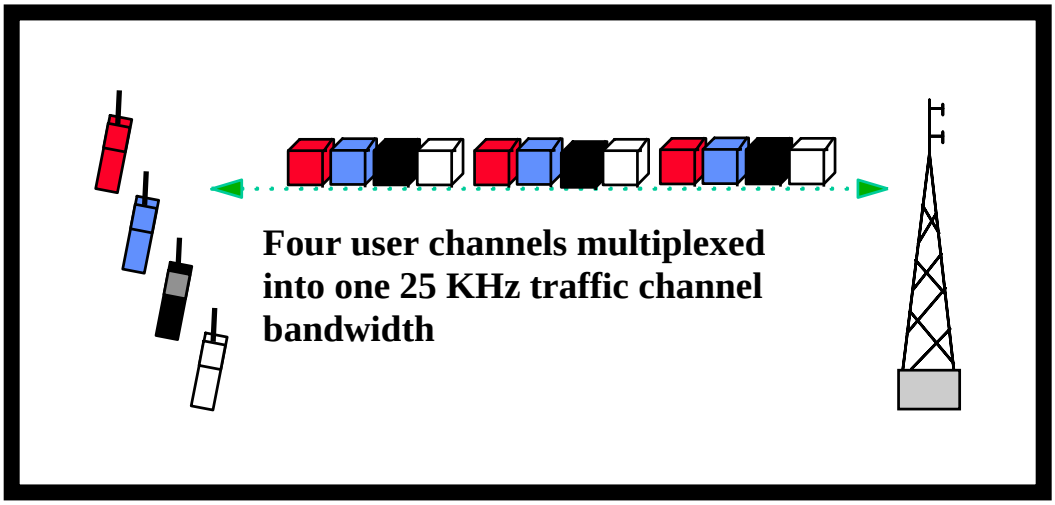
2. TETRA Sets a New Level in PMR Technology

TETRA is a highly advanced technical platform providing integrated voice and data services. This combined with outstanding connectivity possibilities set a whole new level in PMR technology.

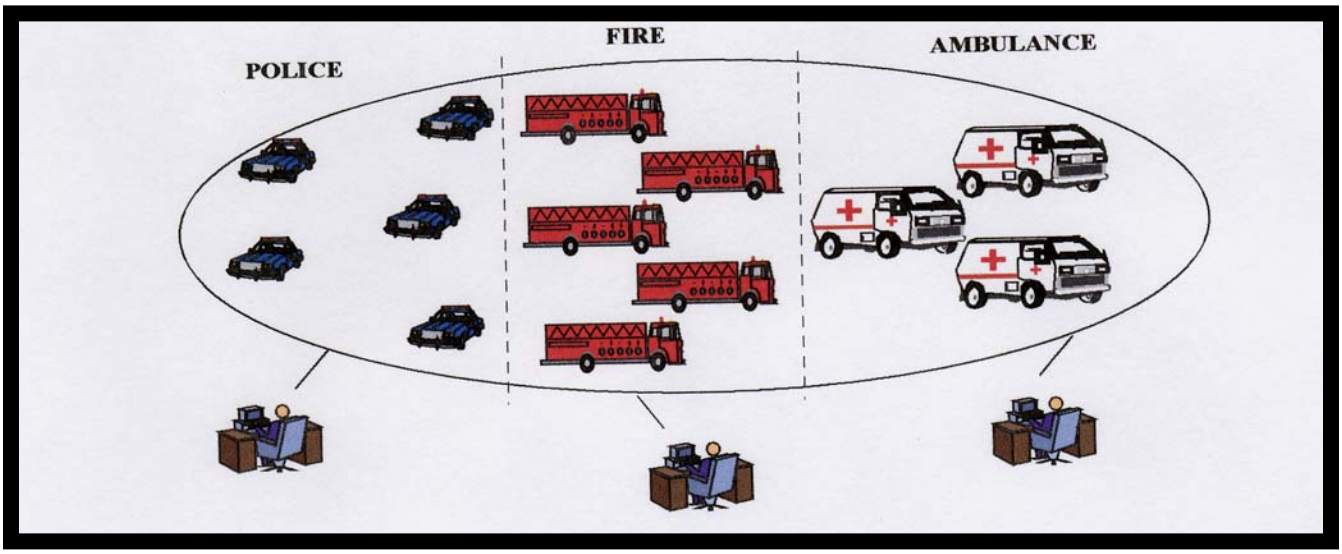
2.1 Advanced Technical Characteristics

TETRA is a fully digital system providing good voice quality and low bit error rate for data accordingly.

TETRA supports voice, circuit switched data and packet switched data services with a wide selection of data transmission rates and error protection levels. TETRA uses TDMA (Time Division Multiple Access) technology with four user channels interleaved into one carrier with 25 kHz carrier spacing. This means excellent efficiency of frequency spectrum. Cost savings are also achieved in base stations were only one radio unit is needed for every four user channels. Higher data transfer rates up to 28.8k bit/s are implemented by reserving up to four channels for the same user connection - bandwidth is allocated by demand.



TETRA has from the beginning been designed as a trunked system that effectively and economically supports shared usage of the network by several organizations, yet maintaining privacy and mutual security. Virtual networking inside the TETRA network enables each organization to operate independently, but still enjoy the benefits of a large, high-functionality system with efficient resource employment.

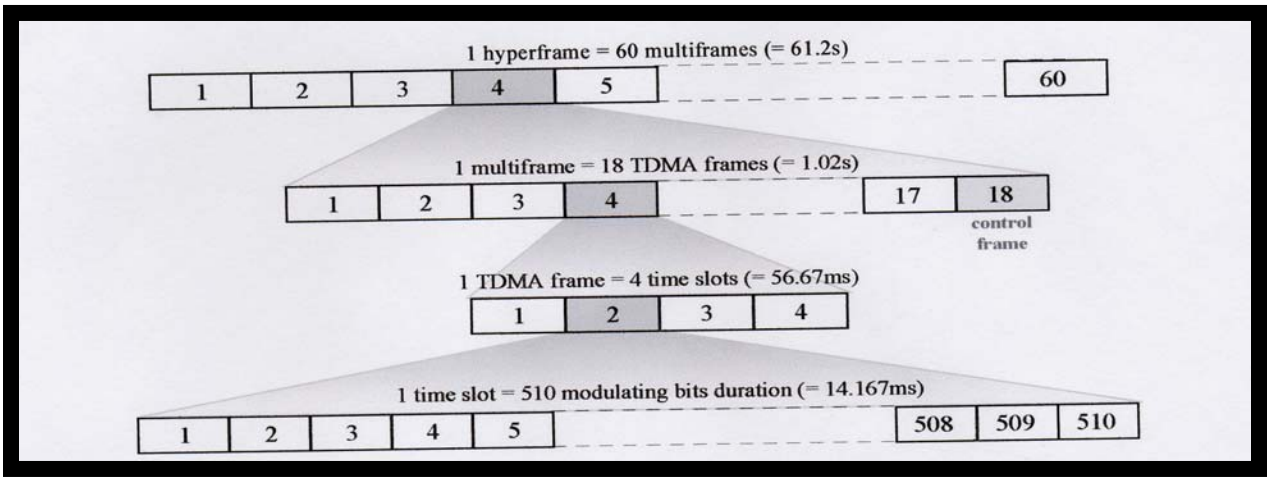


TETRA is a high security technology that inherently includes encryption of voice, data, signaling and user identities. Two encryption mechanisms are defined:

1. Air interlace encryption, which encrypts the radio path between the terminal and the base station.
2. End-to-end encryption for the most critical applications where encryption is required for the transmission throughout the system to the other terminal.

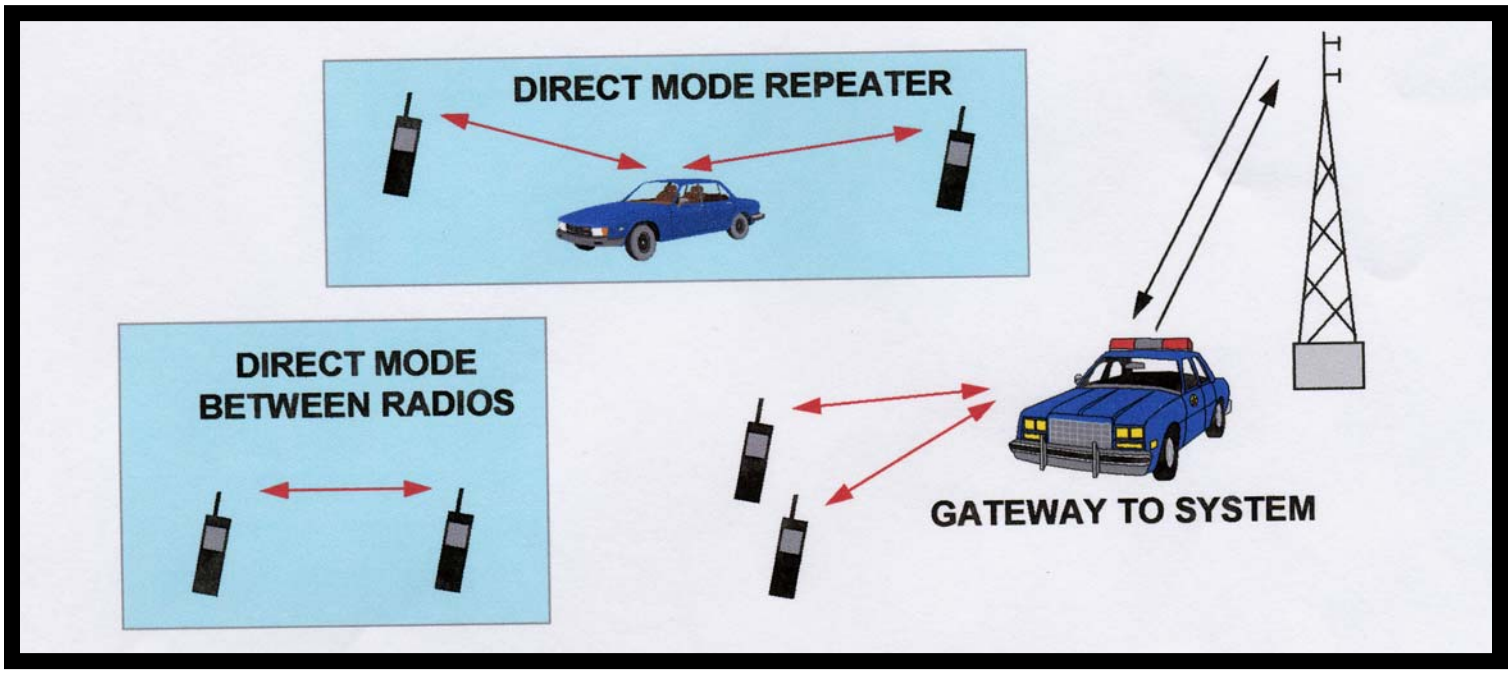
TETRA provides very fast call set-up time (300 ms), that is crucial for the public safety and emergency services. Naturally, TETRA supports both semi-duplex operations for efficient group communication and duplex operation for telephony type individual calls. The advanced group and announcement call features included in TETRA meet the needs of the most critical user applications. Multiple call priority schemes ensure effective resource allocation to the most urgent traffic in the network.

The TETRA frame structure has four time slots per TDMA frame. This is further organized as 18 TDMA frames per multiframe. In circuit mode voice and data operation traffic from an 18 frame multiframe length of time is compressed and conveyed within 17 TDMA frames, thus allowing the 18th frame to be used for control signaling without interrupting the flow of data. This 18th frame is called the control frame and provides the basis for slow associated control channel (SACCH).
The SACCH provides the background control channel signaling that is always present, even ill lumination mode when all channels are allocated to traffic, one of the most powerful features of the TETRA protocol.



The gross bit rate of one channel is 9 kbit/s, into which speech is coded with 4.8 kbit/s net bit rate using ACELP coding, which is one of the most efficient voice coding methods to date. This modulation method appearing in TETRA is n/4-QDPSK - a linear modulation.

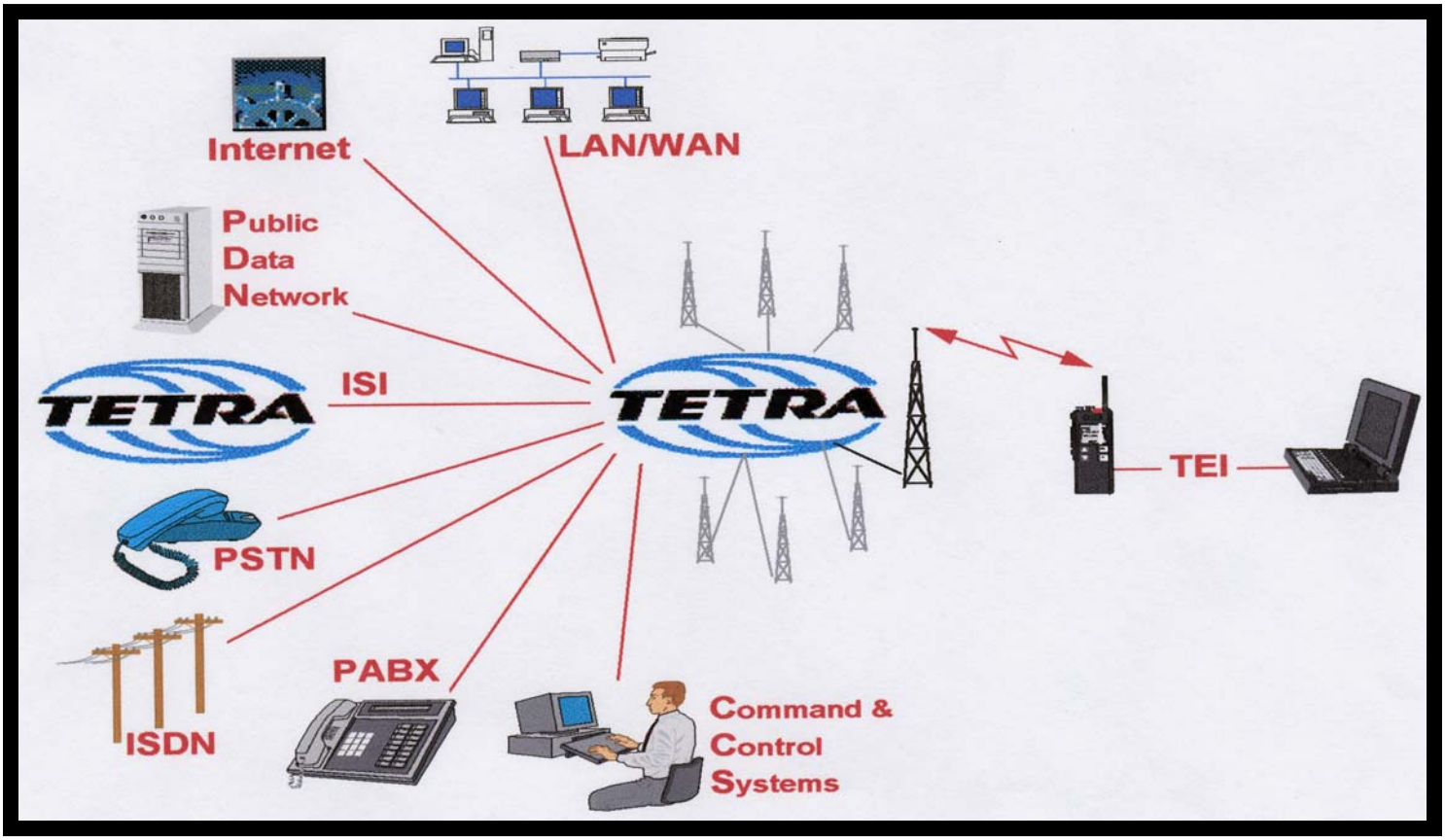
TETRA includes direct mode operation between mobile radios without the need for network iiurastnictiire. Also repeater and gateway functions are denned to extend the coverage of hand portable radios in both direct mode and network operation.



The defined power classes of TETRA radio equipment are 25 W, 10 W. 3W and 1 W.
TETRA radios can automatically adjust the output power according to the needed field strength.

2.2 Connectivity

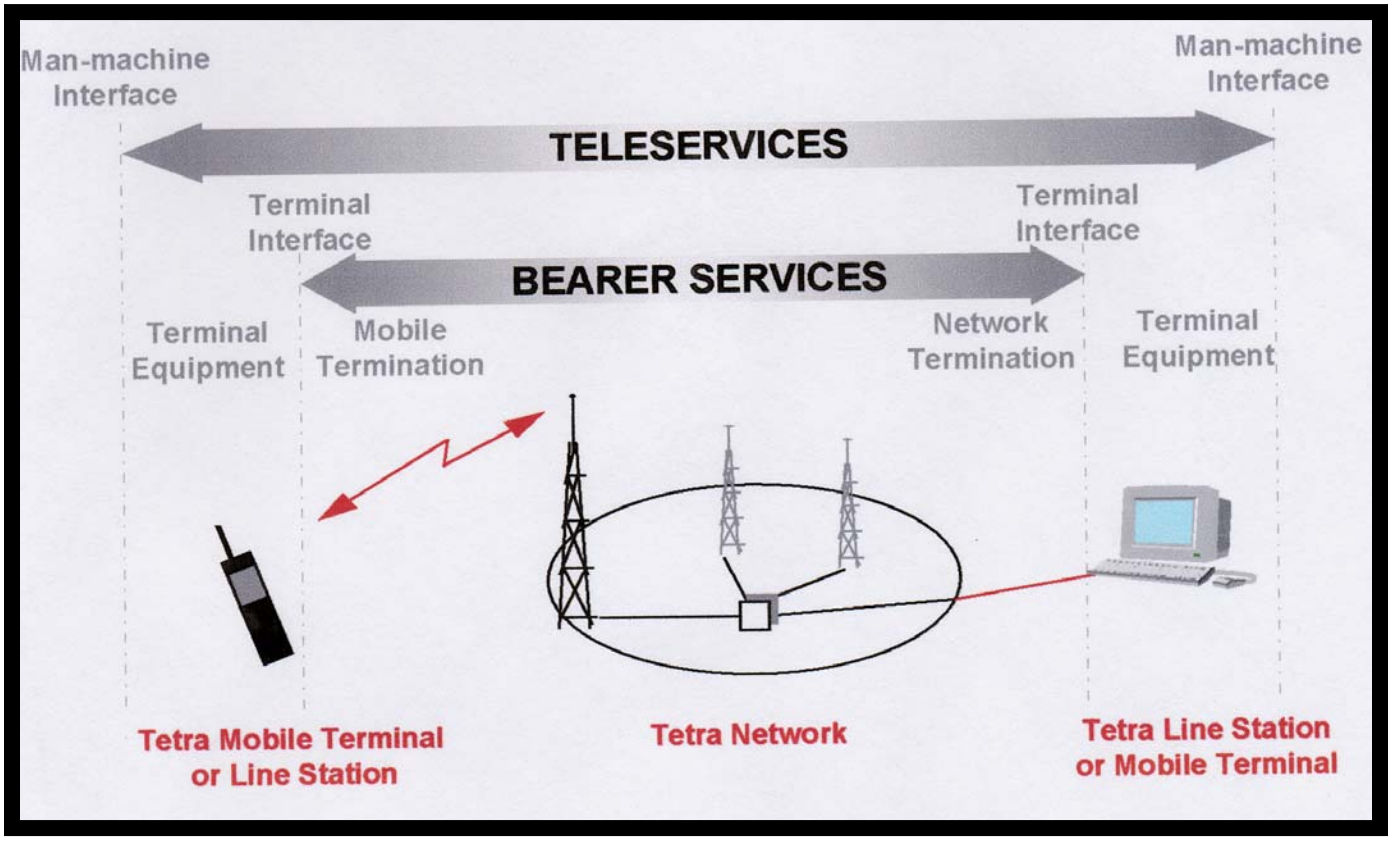
Connectivity between networks of different type is becoming increasingly important. This has been taken into account in the development of TETRA technology. TETRA networks facilitate a tide range of connections to external networks. A TETRA network can be connected to, for example, public and private telephone networks, different types of data networks as well as large command and control systems. All these networks can he accessed from the mobile terminal.



Connectivity combined with bandwidth-on-demand makes TETRA a superior platform for data application development.

2.3 TETRA Telecommunications Services

The TETRA standard defines the growing basic services for voice and data:



Teleservices provide complete communication capability for between users, including all terminal functions. In TETRA standards teleservices cover voice communications services. A bearer service provides communication capability between terminal network interfaces, excluding the functions of the terminal. TETRA bearer services are defined for data transfer.

TETRA Teleservices
Individual Call
Group Call
Acknowledged Group Call
Broadcast Call

TETRA Bearer Services
Circuit mode data 7.2/14.4/21.6/28.8 kits/s
Circuit mode protected data 4.X/9.6/14.4/19.2 kits/s
Circuit mode heavily protected data 2.4/4.8/7.2/9.6 kbits/s

Essential Supplemental Services

Call Authorized by Dispatcher	Dispatcher verifies call request before allowing call to proceed.
Area Selection	Defined areas of operation for users. Can be redefined on a call by call basis.
Access Priority	Radio Unit uplink access prioritization during congested periods.
Priority Call	Access to network resources can be prioritized.
Late Entry	Latecomers may join a call in progress.
Pre-emptive Priority Call	This call has the highest uplink priority and highest priority access to network resources. If system is busy the lowest priority communication will be dropped lo allow this call to continue. Equivalent to an "Emergency Call" in PMR terms.
Discrete Listening	Authorized RU may monitor a communication without being identified.
Ambience Listening	Dispatcher may turn on the transmitter of a RU without any indication being provided on RD. Can be used in hijack situations to listen what is happening in the car.
Dynamic Group Number Assignment	Allows the dispatcher to program new group numbers into the RUs over the air. Can also be used to group participants in an ongoing call.

Optional Supplementary Services

Calling Line Identification Present	Displays the unit ID of calling party.
Connected Line Identification Present	Displays the unit ID of the called party.
Calling/Connected Line	Either party may prevent display of unit ID.
Identification Restriction Call Report	Displays calling party ID on a busy RU.
Talking Party Identification	RU automatically identifies itself whilst in a group call.
Call Forward Unconditional	Allows an RU to forward all calls to another RU.
Call Forward on Subscriber Busy	Allows an RU to forward calls if RU busy.
Call Forward on Subscriber Not Reachable	Allows an RU to forward calls when out of service or switched off.
Call Forward on No Reply	Allows an RU to forward all unanswered calls
List Search Call	Incoming call will sequence through a user defined list until call is answered
Short Number Addressing	Short number dialing
Call Waiting	Notification of an incoming call to a busy RU
Call Hold	Allows user to interrupt existing call and re-establish when required
Call Completion Busy Subscriber	Incoming call will wait until subscriber is free before calling back
Call Completion No Reply	Incoming call will wait until subscriber has made a call before
Transfer of Control	calling back
Include Call	Initiator of a group call can transfer ownership to another party
Advice of charge	Ability to include an RU in an existing call
Call Barring	Call charge information at start, during or end of call
Call Retention	Ability to bar a call from/to a user defined list

3. TETRA Opens New Global Market

TETRA will open up a new global market. TETRA technology fulfills the requirements of a wide group of PMR users. The harmonized frequencies for TETRA in Europe will greatly contribute to the creation of a large market.

3.1 Wide User Group

The first users to implement TETRA are the European public safety and emergency services, i.e. police. & brigades, border control officials, etc. There are both technical and political reasons to encourage tills step. The existing public safety networks are coming to the end of their economic lifetime and TETRA provides the key features like encryption, direct mode and last call set-up time for these services.

TETRA is also the ideal choice for commercial PAMR networks due to superior frequency efficiency, high data transfer rate and excellent connectivity possibilities to other networks among other advanced technical characteristics.

The cumulative size of the emergency service market is more than one million users in Europe Most West-European countries already have made a political decision to implement a shared TETRA network for their emergency services. Projects for implementation of a shared public safely networks include:

- UK Home Office: 100 000 users from police & rescue
- Germany: 400 000 users from police & rescue
- Netherlands Home Office: 50 000 users from police, fire & ambulance
- Belgian Home Office: 40 000 users from police, fire & ambulance
- Finland: 50 000 users from police, fire & rescue, border guard + some other offices
- Austria, Switzerland, Spain, Portugal, Italy Greece. Sweden, Norway, Hungary, Latvia

(The indicated user quantities above are estimates made partly by the various user organizations and partly by manufacturers.)

The first implementations of TETRA will therefore be wide-area networks, typically country-wide. During the years to come, the TETRA market is foreseen to expand in two dimensions:

From the emergency service users and commercial networks. TETRA is seen to proceed to other PMR markets such as railways, utility and industrial users. Many traditional PMR network users that have previously relied only on their own network may al-o decide to join a commercial TETRA network and save in infrastructure investment costs. The virtual networking possibilities inside TETRA networks make this a very feasible option.

A similar global trend is also foreseen for TETRA as did take place for MPT trunking and GSM cellular technologies. The fast-growing Asian markets soon took up these emerging open standards and contributed to make them as global de facto standards in all parts of the world (excluding North America and Japan). Wide interest tore open standard digital trunking has also been expressed in South America.

3.2 Harmonized TETRA Facilities

The North Atlantic Treaty Organization (NATO) has given up 20 MHz of radio frequencies in Europe for emergency and public safety services. This virgin frequency band resides in between 380 - 400 MHz. National authorities have allocated two sets
5 MHz each in this 20 MHz band for Public Safety TETRA networks. Due to a common frequency, a large market for TETRA products will be created guaranteeing product supply and competitive prices.

European national authorities have also begun allocating frequencies for commercial
TETRA. Various plans exist to implement commercial TETRA networks starting at the 410-430- frequency band. The UK has already awarded two licenses to operate commercial TETRA networks in this band.

Other frequencies for these commercial TETRA applications in Europe reside in the following bands:

450-460 / 460-470 MHz
870-876/915-921 MHz.

3.3 TETRA Fulfils European Police Requirements

The ETSI Technical Sub-Committee RES 06 has conducted an extensive investigation and comparison of the TETRA standard and the requirements defined in the Schengen Telecom Group document -Draft - Digital Radio Communications Network for Security Organization (Tactical and Operational Requirements). The conclusion of this investigation was that the TETRA standard fulfils these highly demanding requirements, with the small exception of end-to-end delay, which is an insignificant 15 msec longer than desired.

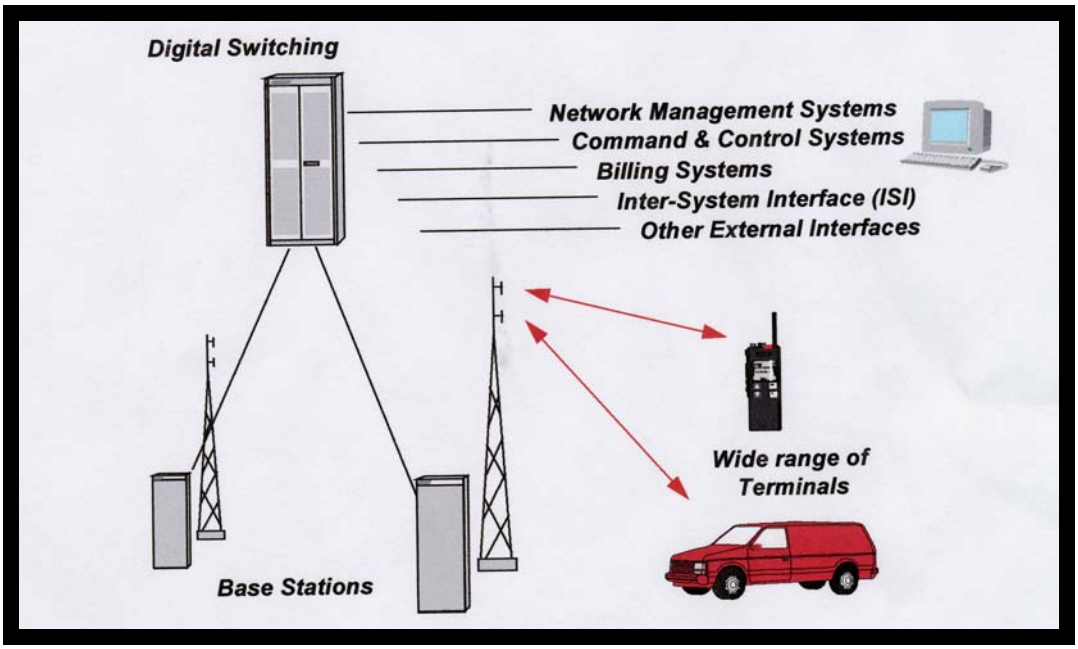
Various European authorities have also conducted their own comparisons of the technological possibilities available. The answer has consistently been that TETRA technology is superior for European police requirements.

In addition, TETRA is the only digital trunking standard approved and recommended by ETSI. The emergence of other competing standards is highly unlikely, since ETSI does not approve different standards with the same scope.

4. TETRA Products

All major manufacturers are committed to TETRA development and developing products. Most manufacturers have already presented working TETRA equipment at international telecommunications exhibitions.

Typical infrastructure network products consist of digital mobile exchanges and base stations. Some manufacturers might also use separate base station controllers. As stated earlier, the standards do not instruct the construction and architecture of the network infrastructure.



Dispatcher stations are one important group of the infrastructure products. Especially the emergency service users require sophisticated dispatching solutions, also integrated with administrative command and control systems. Network management workstations facilitate management of large networks. Billing systems are developed for commercial TETRA networks. There are several manufacturers that can offer complete turn-key solutions, including infrastructure and terminals. Some manufacturers concentrate on terminal equipment or data applications.

Most manufacturers have had their first products available during 1997. These were generic products, but especially suitable for the public safety authority networks and operate on the 380 - 400 MHz frequency band. Products for the 410 - 430 MHz frequency band followed soon afterwards.

Due to competition, the market prices of both TETRA infrastructure and terminals from the beginning were cheaper compared with proprietary digital trunking systems.

5. Validation Procedures Ensure Functional Integrity

Continual testing ensures compatibility to standards already in the development phase of the products. An essential part of the development of the TETRA standard has been the definition of conformance testing specifications. They are published as part of the standards in a formal language, that can be directly applied to control automated test systems. The publication ofcontbnnance test specifications in a formal language and as a mandatory part of the standards effectively ensures, that the test results at different test sites are consistent.

The functional consistency of the TETRA standards is verified as a set of field trials by interworking tests on equipment from different manufacturers. This is one of the most important steps in the validation of TETRA standards and they are conducted in Denmark by the Danish TETRA Co-operative during l996.

To ensure the compatibility of TETRA equipment from different sources there must be well-defined type approval procedures and rules available. Currently the TETRA Memorandum of Understanding (MoU) organization is developing these procedures and equipment. There will be one or more test houses, that are authorized to do type approval tests for TETRA equipment and it is very likely that one of these test houses will be the laboratory of Telecom Denmark, that is doing type approval tests for GSM also.

These measures taken ensure, that when TETRA products come to the market, their interoperability is already properly tested and certified, so that the customer does not need to take any risk with this respect. Strict type approval procedures are a strength of open systems compared with proprietary solutions, which are typically tested in customer systems.

One practical example of the importance of type approval procedures are the type approval tests done on MPT trunking systems, which indeed detected many errors in all the tested equipment.

6. TETRA is Complementary to GSM

TETRA is not intended to compete with GSM or any cellular technologies - they are clearly made for different purposes. TETRA is designed for professional mobile radio applications and GSM is designed for public cellular telephony. Although these applications may occasionally overlap, there is a fundamental difference in the requirements.

There have been proposals to add PMR-type functionality in the GSM standards to expand the GSM market towards professional radio users - especially for railway applications. It is likely, that GSM will some day contain some professional user oriented features. but those will be far from the PMR needs. It will not be possible to implement direct mode operation, fast call set-up or proper semi-duplex group communications features into today's GSM networks.

The modification of the GSM standards and systems to a PMR-like product has been studied by many manufacturers. The result was clearly that this son of modifications deep in the core of the current GSM architecture would be too expensive, line-consuming and risky to implement. TETRA is clearly a superior platform for digital professional mobile radio applications.

It is a common misunderstanding, that GSM professional radios would be cheaper than for example TETRA professional radios, just because GSM cellular phones are cheaper. This wishful thinking is not based on any hard facts. Both the manufacturing and operator communities are lacking interest to seriously develop professional mobile radio features into GSM. The expected market volume is far too small for the big cellular phone manufacturers, whose production capacity could manufacture the total cumulative five-year European volume within a few days.

The expected infrastructure market volumes for example on tile railway sector are likewise too small compared with the main stream GSM market volumes. The successful GSM infrastructure vendors are not interested in implementing professional mobile radio features.

It can as well be assumed that the interest of current GSM operators in the implementation of these features will significantly decrease, when the risks and costs involved in implementing these features in the existing networks is revealed.

7. ETSI References

More information concerning the TETRA standard can be found from the following European Telecommunications Standards:

TETRA Voice Plus Bata	**ETS 300 392**
Part I:	General network design
Part 2:	Air Interface
Part 3:	Inner-working
Part 4:	Gateways
Part 5:	Terminal equipment interface
Part 6:	Line connected stations
Parl 7:	Security
Part 8:	Network management services
Part 9:	Performance objectives
Part 10:	Supplementary services stage 1
Part 11:	Supplementary services stage 2
Part 12:	Supplementary services stage ?
Part 13:	SDL model for air interface
Part 14:	PICS Profoma
Part 15:	Intel-working - extended operations
Part l6:	Gateways for supplementary services

TETRA Packet Data Optimised	**ETS 300 393**
Part 1:	General network design
Part 2:	Air Interface
Part 3:	liner-working
Part 4:	Gateways
Part 5:	Terminal equipment interface
Part 6:	Line connected stations
Part 7:	Security
Part 8:	Network management yen/ices
Part 9:	Performance objectives
Part 10:	SDL model for air interface
Part 11:	PICS Proforma

TETRA Codec	**ETS300395**
Part 1:	General description of speech functions
Part 2:	Codec
Part 3:	Specific operational features
Part 4:	Codec conformance testing

TETRA Direct Mode Operation	**ETS 300 396**
Part I:	General network design
Part 2:	Direct MS - MS air interface - radio aspects
Part 3:	Repeater
Part 4:	Gateway
Part 5:	Security

Copies of ETSI standards can be obtained from national standardization authorities.