6

TERRESTRIAL TRUNKED RADIO (TETRA)

This chapter presents Terrestrial Trunked Radio (TETRA), another narrowband Land Mobile Radio (LMR) technology that provides voice and low-speed data communication capabilities for critical communication systems. The chapter discusses TETRA's technical specifications, network architecture, interfaces and protocols, and services. The standardization process and its future are also discussed. Appendix B provides a comprehensive list of related standard documents.

6.1 INTRODUCTION

TETRA is a critical communication standard developed by European Telecommunications Standards Institute (ETSI). It became widely used in many countries around the world [1–3]. Before we go further on TETRA, let's remind the reader that there is another digital LMR standard called TETRAPOL [4], which is not related to TETRA, other than the use of the acronym "TETRA," as discussed briefly in Chapters 1 and 4.

Fundamentals of Public Safety Networks and Critical Communications Systems: Technologies, Deployment, and Management, First Edition. Mehmet Ulema.

The TETRA project began in the 1980s with an objective to develop a standard for a commercial wireless mobile network. Because of this objective, initial specifications included many features like traffic maximization. While ETSI was spending many years in developing this comprehensive system, another ETSI standard, Global System for Mobile Communications (GSM), became popular and ubiquitous, dampening the TETRA effort. This setback caused significant hardship for the companies invested in TETRA development, and they identified the public safety market as a way to sell their products. With the support of several European public safety agencies, TETRA became the most popular solution for public safety in Europe and around the world.

Note that when we say "TETRA standard," we refer to a set of related standards developed by ETSI. See Appendix B for a comprehensive list of active TETRA standards. Also, note that TETRA standards have been developed in phases over time. ETSI uses the word "release" to refer to these phases—TETRA Release 1 and TETRA Release 2.

TETRA allocates channels to users on demand in both voice and data modes. Additionally, a few national and multinational networks are available and national and international roaming can be supported. The systems makes use of the available frequency allocations using Time Division Multiple Access (TDMA) technology with four user channels on one radio carrier with 25 kHz spacing between carriers.

TETRA Enhanced Data Service (TEDS), included in TETRA 2, enables more data bandwidth to TETRA data service users. The standard allows up to 691 Kbps, but limitations in spectrum availability typically give users a net throughput of around 100 Kbps. TETRA 2 also includes additional features such as enhanced cell radius for air-to-ground communications and Location Information Protocol (LIP) for advanced automatic location services.

Some of the critical features of TETRA are listed in Table 6.1. The following are some additional significant features:

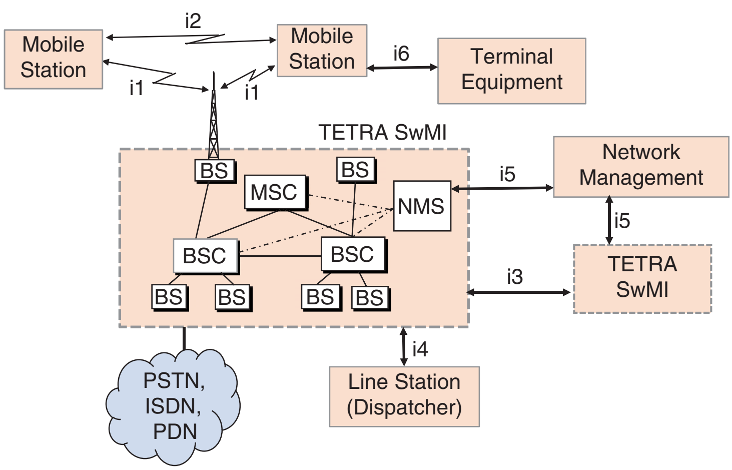
- Air interface plus end-to-end encryption
- Mutual authentication
- Integrated voice
- Multislot packet data with pre-emption
- Unlimited number of users supported

6.2 ARCHITECTURE

As shown in Figure 6.1, the TETRA architecture features a number of standardized interfaces and allows some vendor proprietary interfaces, as discussed in Section 6.3 in more detail.

TABLE 6.1. Main Parameters of TETRA [5]

Parameter	Value
Frequency bands	Several bands 380–460 MHz
Carrier spacing	25 kHz
Duplex method	FDD
Modulation	QPSK
Carrier data rate	36 Kbit/s
Access method	4-slot TDMA per 25 kHz channel
User data rate	7.2 Kbit/s per time slot (unprotected)
Voice coder rate	ACELP (4.56 Kbit/s net, 7.2 Kbit/s gross)
Power	Up to 40 watt base stationUp to 1.8 watt portable,3–10 watt mobile
Texting	Up to 1000 characters



i1: Air Interface
i2: Direct Mode Interface
i3: Intersystem Interface (ISI)
i4: Line Station (Dispatcher) Interface
i5: Network Management Interface
i6: Terminal Equipment Interface
PSTN: Public Switched Telephone Network

MSC: Mobile Switching Center
BS: Base Station
BSC: Base Station Controller
NMS: Network Management System
SwMI: Switching and Management Infrastructure
PDN: Public Data Network

Figure 6.1. TETRA network architecture.

A typical TETRA network architecture consists of one or more Switching and Management Infrastructures (SwMIs) connected by trunks, aka a backhaul transmission network. SwMIs, also called TETRA nodes in some literature, support Mobile Stations (MSs) via air (radio) interfaces, and Line Stations (LSs), commonly known as “dispatchers.” A network management center is connected to every SwMI in the network to provide operations, administration, and maintenance functions. Terminal equipment, mainly laptop and handheld computers, can be connected to mobile stations via directly wired interfaces as well.

An SwMI consists of Base Stations (BSs) supporting radio transceiver towers, Base Station Controllers (BSCs), Mobile Switching Centers (MSCs), and a Network Management System (NMS). The BS resends information from an MS to the requested receiver. Several BSs are connected to a BSC; in turn, some BSCs are connected to an MSC. These hierarchical connections and the number of entities connected vary significantly depending on the size of the network. Also, we should note that some vendors have products that combine these functionalities into a single unit. For example, the so-called Switching Control Node (SCN) combines BSC and MSC functions into one unit.

The SwMI performs switching and transmission of information (voice, data) and signaling among MSs and between MSs and gateways. An SwMI includes gateway functions to facilitate connections to a variety of external telephony (Public Switched Telephone Network [PSTN], Integrated Services Digital Data Network [ISDN], Global System for Mobile Communications [GSM], Voice over Internet Protocol [VoIP], etc.) and data (IP) networks.

The NMS is connected to all entities in an SwMI via IP interfaces to provide network management applications. An SwMI may have some other systems and servers for providing a range of functions to support, for example, roaming, authentication, and key management.

6.3 INTERFACES

As shown in Figure 6.1, the TETRA architecture includes several air interfaces and network interfaces standardized for TETRA applications, as discussed below. TETRA also has some additional interfaces, especially within the SwMI, which are left to the vendors to specify and implement.

6.3.1 Air Interfaces

TETRA specifies two types of air interfaces corresponding to the two fundamental operations involving the base stations and mobile stations:

- **Trunked Mode Operation (TMO):** The air interface in this operation refers to the radio interface between a base station and the mobile stations

TABLE 6.2. Bandwidth on Demand (Kbps)

	Number of Time Slots			
	1	2	3	4
Protection Level				
No Protection	7.2	14.4	21.6	28.8
Low Protection	4.8	9.6	14.4	19.2
High Protection	2.4	4.8	7.2	9.6

communicating through this base station. The following is a list of primary characteristics of an air interface operating in this mode:

– TDMA structure
– Four user channels
– 25 kHz channel spacing
– 36 Kbps transmission rate
– Π/4 Differential Quadrature Phase Shift Keying (DQPSK) modulation
– 7.2 Kbps speech coding (including error correction)

Effective data rate capacities that can be achieved on the air interface operating in trunk mode depend on the protection level demanded by the application, as shown in Table 6.2. The types of applications that may be using this "bandwidth on demand" future include real-time circuit mode data applications such as video and slow scan television, and those applications requiring increased throughput (or speed) in packet modes such as file transfer and database updates.

Figure 6.2 shows the protocol stack used for trunk mode operations on the air interface. All services use the bottom two layers (physical and the Medium Access Control (MAC) part of the data link layer). Voice services and circuit

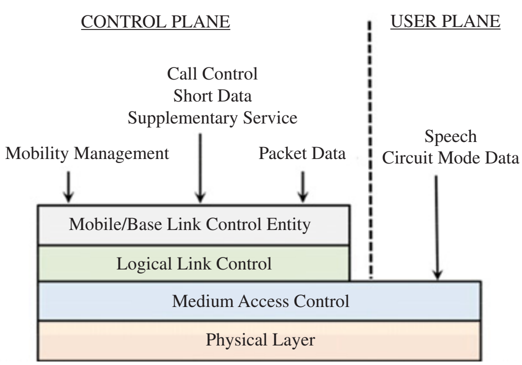


Figure 6.2. Air interface protocol stack for TM operations.

mode data services use only these two common layers. Other services use, via TETRA, defined Application Programming Interfaces (APIs), with their corresponding protocols at Layer 3.

- **Direct Mode Operation (DMO):** The air interface in this operation refers to the radio interface between any two mobile stations communicating directly without any base stations involved. TETRA identifies the following scenarios for direct mode operations:
  - *Basic Scenario*: Any individual (one-to-one) or group calls, as well as broadcast calls, are included in this scenario.
  - *Dual Watch*: While the MS is in the direct mode, the control channel of the trunk mode is monitored. Similarly, while the MS is in the TM mode, DM channels are monitored.
  - *Managed Direct Mode*: This scenario involves a managed (i.e. authorized) operation. Typically, an MS periodically broadcasts the authorization signals.
  - *Repeater*: In this scenario, the MS acts as a repeater that can support two calls simultaneously or a single call on different uplink and downlink frequencies on the same frequency for both uplink and downlink.
  - *Gateway*: In this scenario, the MS interconnects other MSs operating in the DM and TM modes.
  - *Managed Repeater, Gateway, or both Combined*: In this scenario, the MS broadcasts the authorization signals to be used in the repeater and gateway scenarios.

6.3.2 Intersystem Interface

As the name implies, this standardized Intersystem Interface (ISI) is used to interconnect all the SwMIs in a TETRA network. The ISI supports both circuit mode and packet mode information transmissions as well as cross-border roaming. As far as services are concerned, the ISI supports individual calls, group calls, supplementary services, and data services along with mobility management and security features. Some of the mobility management features include migration, deregistration, group attachment/detachment, and group linking/unlinking. TETRA authentication and Over The Air Rekeying (OTAR) for key management are two of the primary security features.

Figure 6.3 shows the ISI protocol stack. The physical layer is based on digital 64 Kbps connections.

The ISI uses Private Signalling System 1 (PSS1) at its higher layers. The PSS1, commonly known as QSIG, is a well-known signaling protocol typically used in private corporate networks mainly among Private Branch Exchanges (PBXs). For the ISI, the PSS1 includes International Organization for Standardization (ISO)/ International Electrotechnical Commission (IEC) 11582, which defines the

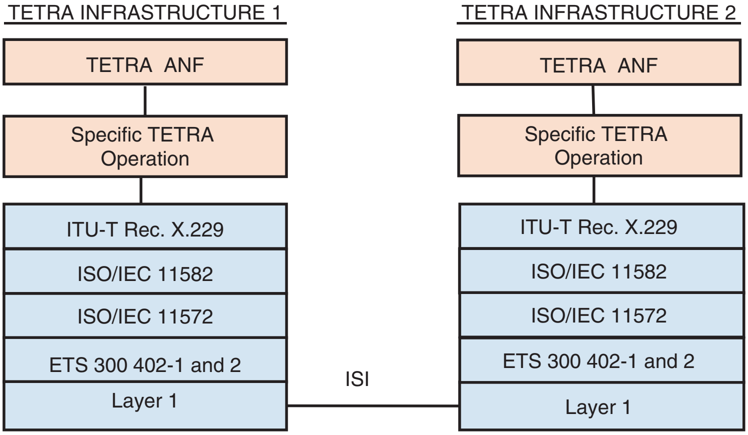


Figure 6.3. ISI protocol stack.

signaling protocol for the control of supplementary services and Additional Network Features (ANFs), with the help of International Telecommunications Union-Telecommunications sector (ITU-T) Rec. X.229 (protocol specification for remote operations), as shown in Figure 6.3. Furthermore, ISI Layer 3 is covered by the ISO/IEC 11572, which defines interexchange signaling procedures and protocol for circuit mode bearer services. At the data link layer, the ISI uses ETS 300 402-1 and 2, which are based on the ISDN.

6.3.3 Terminal Equipment Interface (TEI)

This interface is used to exchange data between a mobile station and terminal equipment. The terminal equipment, also called peripheral in some publications, is an external device such as a laptop computer hosting one or more applications that communicate with their counterparts residing in mobile stations. These applications may be involved in controlling various parameters of mobile stations. To facilitate this, several so-called "access services" are offered on this interface. These are provided via:

- Attention (AT) commands
  - Used to access and control circuit mode data services, short data services, and radio configuration related parameters
- TETRA Network Protocol 1 (TNP1)
  - Used to access parameters related to Circuit Mode Control Entity (CMCE) and radio configurations in mobile stations

Packet data service is accessed directly via the Internet Protocol (IP) on top of the Point-to-Point Protocol (PPP).

The TEI uses ITU-T V.24/V.28 at the physical layer with speeds less than 20 Kbps. Services offered by this interface include packet data, circuit data, and short data services depending on the capabilities of the terminal equipment, as well as voice calls.

6.3.4 Line Station (Dispatcher) Interface

TETRA identifies this interface but does not specify it for standardization. This means that TETRA recognizes the need for an interface between the SwMI and line stations (mainly remote dispatcher systems). However, given the existing vendor base, TETRA also recognizes the difficulties of reaching a consensus for a common standardized interface. Therefore, this interface is left unspecified by TETRA; instead, vendor-provided interfaces are used.

6.3.5 Network Management Interface

TETRA does not specify this interface; instead, it provides a set of guidelines, incorporated into the Designer's Guide, for TETRA network administrators and vendors. The guidelines address internal and external aspects of managing TETRA networks.

Internal network management refers to the management (monitoring and controlling) of a single or multisite TETRA network. An internal network management system is assumed. The interfaces and protocols between this network management system and other components are not specified. The choices, such as Simple Network Management Protocol (SNMP) and Common Management Information Protocol (CMIP), are left to the vendors and operators.

External network management refers to the management of multiple TETRA networks connected by the ISI. One or more external management systems, mainly providing a limited set of overall management functions, such as configuration and fault management, may be involved to facilitate interoperability among various vendors and to manage roaming among multiple TETRA networks.

6.3.6 PSTN/ISDN/PDN

As discussed briefly in the architecture section, an SwMI includes several gateways to interface with external telephony and data networks. Although the interfaces and protocols between a gateway and other internal components are vendor specific, TETRA identifies standardized interfaces between a gateway and its corresponding external network.

A Public Switched Telephone Network (PSTN) gateway provides point to point or multipoint full duplex speech in clear mode with echo cancellation. However, there is no support for supplementary services on this interface. The signaling is maintained, and numbering conversion is provided across the gateway.

An ISDN gateway supports both basic and primary rates with Q.933 Digital Subscriber System no. 1 (DSS1) signaling [6]. The ISDN gateway converts TETRA signaling to DSS1 signaling and vice versa. The gateway supports rate adaptation to 64 kbit/s PCM and a small subset of supplementary services. However, this interface does not support circuit mode data services. Thanks to this interface, a user on the ISDN side can reach a TETRA user via ISDN supplementary services or by using, although not always convenient, two-stage dialing.

A Packet Data Network (PDN) gateway supports an interface, called the IP Interworking (IPI) interface, between the TETRA network and a PDN. General Packet Radio Service (GPRS) interfaces of the GSM cellular system are used on this interface, either directly or with an IP-based network in the middle. GPRS tunneling protocol is used to support roaming where the users' roaming profiles are moved through the ISI between databases.

6.4 SERVICES

Some of the critical services provided by TETRA include individual simplex and duplex calls, group calls, pre-emptive emergency and priority calls, dynamic group number assignment, call authentication, late entry, voice encryption, and packet data services. Low-speed packet data as well as circuit data modes are available, along with some form of encryption. All these services and more offered by TETRA, collectively called Voice + Data (V + D) services, can be discussed under three major categories—basic voice services, supplementary voice services, and data services, as presented in the following sections.

6.4.1 Basic Voice Services

The services in this category include individual calls, group calls, acknowledged group calls, and broadcast call services.

Individual call service refers to one-on-one (point-to-point) basic voice communications between two users. The connection management (i.e. call setup, call disconnect, etc.) is an essential part of this service. Both full duplex and half duplex communications in clear or encrypted modes are supported.

Group call service refers to one-to-many (point-to-multipoint) calls, typically initiated by one user to several other users in the group. The call is established immediately without waiting for an acknowledgment from the other users. This is a "Push to Talk (PTT)" type call allowing a fast, reliable way of sharing information among a group of users.

Acknowledged group call service is similar to the group call service. The difference is that the call may not be established unless a sufficient number of acknowledgments are received by the calling user.

Broadcast call service is also similar to the group call service except that the communication is unidirectional. That means that only the calling user can talk and others can only listen!

6.4.2 Supplementary Services

A supplementary service can modify or supplement a basic service. TETRA standards specify a rather rich set of mission-critical supplementary services, as briefly discussed in the following paragraphs.

Preemptive priority call (also known as an emergency call) supplementary service assigns the highest priority to a call. This means that, when needed, the lowest priority calls can be dropped to accommodate the emergency call. Typically, the calling user initiates this call by using an appropriate function (pulling a switch or pushing a button) on the end user device. Needless to say, the related dispatcher, infrastructure equipment, and other users in the group will be alerted about the priority level of this call accordingly.

Call retention supplementary service is used to protect calls against preemption, enabling users to maintain their calls when the highest priority call is guaranteed.

To ensure this, TETRA uses an internal scheme by assigning a Call Retention Value (CRV) to calls based on specific criteria such as the lifetime of the call, the type of call, and the user. When it becomes necessary, the lowest CRV valued call is dropped.

This service may be initiated either by a calling user or a called user. This may be done through the call setup by the calling user or may be requested by a called user for an incoming call.

Priority call supplementary service is used to assign to each call a priority level, which is used by the infrastructure to allocate appropriate network resources to calls based on their priority level.

TETRA allows 16 different priority levels, which can be indicated either during initial call setup by the calling user or could be determined by the network. Higher priority levels indicate the importance of the call and are typically used or given to the agents on the scene.

Dynamic Group Number Assignment (DGNA) supplementary service is used to create special user groups charged with special assignments typically related to incident-specific communications. For example, different users from different organizations could be part of a unique group handling communications to coordinate and manage an emergency situation.

DGNA service may be applied to all the users with ongoing calls or any users and groups with no active calls.

Ambiance listening supplementary service allows a terminal to act as a remote monitor during a critical situation to gather and disseminate information as an ambient (background) noise. This may be established by the calling user or by the dispatcher, who then can listen to ambient noise as well as the voice call being exchanged. Since this call may be part of a group, extreme caution concerning security must be taken when using this service.

Call authorized by dispatcher supplementary service provides a means to the dispatcher to verify a call request before the call is set up. This service may be useful in managing network congestions by allowing only the necessary calls.

Area selection supplementary service provides flexibility for users to select a geographical area for their outgoing calls. This flexibility is also available for incoming calls, which are accepted only when the calling user is situated in a predefined geographical area.

Late entry supplementary service is an air interface feature that allows latecomers to join a group call.

6.4.3 Data Services

Two different types of data services are offered by TETRA—Short Data Services (SDS) and Packet Data Services (PDS). The SDS uses TDMA time slots on the control channel to send, as the name implies, user-defined or predefined short text messages, which can be either 16, 32, 64, or 2048-bit long. On the other hand, PDS is used to send messages with any length.

Short data service, in turn, may be used for individual (point-to-point) or group (point-to-multipoint) messages. With this service, the message is transmitted immediately, making it highly valuable for low-latency applications such as transmitting status and location information. For example, TETRA Location Information Protocol (LIP) uses this service.

Packet data service may be a connection-oriented or a connectionless packet data service. The connection-oriented packet data service first establishes a virtual (logical) connection between the source and the destination and then delivers the data packets. The connectionless service begins the data transfer without establishing any virtual connection between the source and the destination. These two types of packet delivery are well-known techniques in the field of packet-switching networks. The connection-oriented service is considered more reliable and typically more suitable for point-to-point communications, whereas the connectionless service is less reliable and used for either point-to-point or point-to-multipoint communications. For example, TETRA supports IP versions 4 and 6 by using the connectionless packet data service and ITU-T X.25 protocols by using both connection-oriented and connectionless services.

One or more (up to four) TDMA information channels can be used to support packet data services, resulting in between 4.8 Kbps and 19.2 Kbps data rate.

6.5 OPERATIONS

As discussed previously, TETRA offers V+D services via TMO and DMO. These operations are already discussed in some detail in Section 6.3.1. Furthermore, the operations supporting packet data services in TETRA are discussed in Section 6.4.3.

Like many other narrowband technologies used for critical communications systems, TETRA also supports both conventional and trunked operations to provide suitable and efficient configuration options to the network operators (see Chapter 4 for a brief general discussion on these options). However, keep in mind that TETRA is designed mainly to be a trunked system. After all, the extended version of the acronym TETRA is Terrestrial Trunked Radio! Although it may be possible, it may be somewhat costly and inefficient to use TETRA in a conventional operation mode.

6.6 SECURITY

TETRA standards specify a relatively comprehensive set of features related to the user and network security, as discussed briefly here.

- **Mutual authentication** refers to the fact that the TETRA network and the terminal authenticate each other by using a TETRA Authentication Algorithm called TAA1, fully specified in TETRA standards.
- **Encryption** in TETRA can be used on the air interface between the terminal and the network and between two terminals (end-to-end).
  - *Air interface encryption* is used to encrypt the radio signals transmitted on the air by using one of the four TETRA Encryption Algorithms (TEAs). Alternatively, a country-specific encryption algorithm may also be used for this purpose.

    TETRA defines the following three security classes: Class 1—no encryption, Class 2—static cipher key encryption, and Class 3—dynamic cipher key encryption (with individual, common, or group cipher keys). Authentication in Classes 1 and 2 is optional but is required in Class 3.
  - *End-to-end encryption* enables two end-user devices to communicate by using an encryption algorithm. Encrypted signals are then transported by the network. The encryption algorithm used must be in compliance with the Security and Fraud Prevention Group (SFPG) of the TETRA Association. A well-known algorithm called the Advanced Encryption Standard (AES) is freely available, and therefore many suppliers include it in their terminals.
- **Secure enabling and disabling of terminals remotely** is a valuable feature. This way, missing terminals and compromised terminals can be disabled.

6.7 SPECTRUM

Theoretically, TETRA can be used in any frequency band from 100 to 1000 MHz (as per the current standard). However, the actual frequency used in a TETRA-based

TABLE 6.3. TETRA-Specified Spectrum Options

Frequency Band	Duplex Space
350–370 MHz	10 MHz
380–400 MHz	10 MHz
410–430 MHz	10 MHz
450–470 MHz	10 MHz
806–824 and 851–869 MHz	45 MHz
870–876 and 915–921 MHz	45 MHz

network depends on the frequency allocated to that region by the regulatory authorities and the availability of equipment supporting that frequency range. TETRA standard specifies in detail the frequency bands, as shown in Table 6.3. Others are not specified in detail.

6.8 STANDARDIZATION

TETRA standards development began in the 1980s by a group of radio manufacturers in Europe under ETSI. To keep up with user requirements, the TETRA work in ETSI went through an evolutionary path. There are two releases of the TETRA standard so far:

- TETRA Release 1—the initial set of specifications
- TETRA Release 2—this 2005 release introduced some new features:
  - Integrated TEDS for high-speed data services
  - Mixed Excitation Liner Predictive, enhanced (MELPe) voice codec
  - Adaptive Multiple Rate (AMR) voice codec
  - MO range extension
  - Enhanced cell radius for air–ground–air
  - Location Information Protocol (LIP) for advanced automatic location services

TETRA in ETSI is expected to continue to evolve beyond Release 1 and Release 2 to provide enhancements only. In other words, ETSI has no plans to develop new technology in this area. The TETRA community has been active in moving toward Long Term Evolution (LTE) based public safety networks as well. Some projects are underway to achieve seamless interoperability between TETRA and LTE-based public safety networks [7].

6.9 DEPLOYMENT

TETRA is in use all around the world, serving more than 2 million public safety officials as well as commercial users. Annual TETRA equipment market value is around 1 billion Euros. It has been adopted for national public safety systems in most countries in the European Union, including Austria, Belgium, Denmark, Estonia, Finland, Germany, Greece, Hungary, Italy, Ireland, Lithuania, Netherlands, Norway, Portugal, Sweden, England, and more.

The TETRA and Critical Communications Association (TCCA) estimates that more than 250 TETRA networks in more than 120 countries are currently deployed by government agencies for public safety, military, and other public services, as well as by other sectors such as utilities and transportation, around the globe.

TETRA is a mature technology. Many companies are involved in this standard. Therefore, there is a wide range of TETRA products available at the current time. These include infrastructure products, which range from small systems to scalable systems that can provide full coverage for a country. There are also many suppliers making terminals. Current terminals are now smaller, with built-in GPS and color screens, and longer battery life.

Major manufacturers have been involved in the standardized and made interoperable radio platforms, so it is easy for a customer to select the best supplier (the European Aeronautic Defense and Space (EADS) Company and Motorola have been the market leaders). Hundreds of successful installations provide confidence about the stability of the TETRA solution. There are also some Asia Pacific manufacturers who develop TETRA products (Table 6.4).

6.9.1 Cost Factors Impacting TETRA Wireless Systems

TETRA was initially designed to cover the commercial wireless mobile market. Consequently, it is a somewhat comprehensive and sophisticated technology. Therefore, the complexity is reflected in development costs; thus, the final product cost.

Another factor that impacts the cost is the trunking approach, which requires high capacity and performance switch nodes in the core network to run the full protocol. It requires high capacity transmission lines connecting base stations and the nodes to avoid excessive signaling delays.

Compared to analog systems, TETRA requires twice the number (or more) of sites to cover the same area covered by the existing analog technology. This means that higher initial investment, as well as recurring periodic costs, is required to handle maintenance, site rent, frequency licenses, and backbone links.

Also, a linear modulation used in TETRA requires more expensive hardware and implies higher energy consumption and dissipation.

Despite all these seemingly negative factors, TETRA is often a cost-effective choice for medium-to-high capacity trunked networks with high traffic volumes and small coverage areas.

TABLE 6.4. Vendors Offering TETRA Products and Services [8]

Organization	Core Products	Peripheral/ Components	Application Provider	Complete Solutions	Integrator	Testing	Consultants
Artevea	X				x		
Abiom Group	X	X					
Aeroflex						x	
Agurre				x			
Airbus Defence & Space	x	X		x	x		
Air-Lynx	x						
Airwave Solutions Ltd.					x		
Alcatel-Lucent	x				x		
Anritsu Company						x	
APD Communications			x		x		
APSI	x	x					
Arico Technologies							x
Arpeggio Ltd.							
Atos AG					x		
Briscoe Technologies							x
CLEARTONE Telecoms Ltd.	x						
CML Microcircuits		x					
Combilent A/S		x					
DAMM	x						
Eastern Comm. Co. Ltd.	x						
Entropia Digital		x			x		

(continued)

TABLE 6.4. (*Continued*)

Organization	Core Products	Peripheral/ Components	Application Provider	Complete Solutions	Integrator	Testing	Consultants
ETELM	x						
Etherstack Limited			x				
Eurofunk Kappacher			x	x			
FREQUENTIS AG	x						x
Funk-Electronic Piciorgros	x						
Huawei Technologies	x	x					
Hytera Mobilfunk GmbH	x		x				
Insta DefSec			x				
Kenwood Electronics	x						
KPN Critical Communications			x		x		
Mentura Group Oy			x				x
Motorola Solutions	x	x					
National Instruments						x	
NEC Corporation	x						
Nokia Networks	x	x					
Orbion Consulting Oy							x
P3 communications							x
Panorama Antennas Ltd.		x					
PMR-R&D GmbH	x						
Portalify Ltd.			x				
Prescom			x				
RCS Telecommunications					x		

Rheinmetall Defence Electron			x				
Rohde & Schwarz						x	x
Rohill Technologies B.V.	x						
Rolta India Ltd.							x
SAAB AB					x		x
SatCom IRL					x		x
Sectra Communications		x					
SELECTRIC Nachrichten-Syst.							x
Selex ES S.p.A.	x						
Sepura plc	x						
Siemens Schweiz AG	x						
Simoco EMEA Ltd .	x		x				
SITA SC					x		
ST Electronics Pte Ltd.					x		x
Swissphone Wireless AG			x		x		
Teltronic S.A.U.	x		x	x			
Testing Technologies			x	x			
TETRAsim (Beaconsim Oy)					x	x	
THALES COMM & SECURITY	x				x		
Unimo Technology Co., Ltd.	x						
Warren Systems						x	x
XPro Oy						x	x
Zetron Inc			x				
ZTE	x						

Also, TETRA is a mature time-tested standard; many products by many different vendors, applications developers, and expertise are readily available. It is a highly competitive market, which reflects in the cost of products as well as flexibility in the acquisition process. Compared to Project 25 based devices and equipment, TETRA-based devices and equipment seem to be more cost-effective.

6.10 FUTURE

The TETRA community believes that basic Private Mobile Radio (PMR) requirements will remain the same. Therefore, they can be applied to commercially available LTE technology. This implies that TETRA applications and functionalities will be running on top of the LTE telecommunications layer. In other words, LTE technology has been selected as the basis for the next step of TETRA [4, 9–12]. Obviously, new standardization effort is required to provide specifications for end-to-end functionalities and interoperability. LTE technology will enable broadband data applications. The vision also includes support for migration from existing narrowband PMR technologies such as TETRA and Project 25. The TETRA community is concerned that the standardization of the next step is somewhat challenging since it requires a global standard migrating many existing PMR technologies, requiring the collaboration of many standard bodies and stakeholders. Some other concerns include frequency allocation, LTE communities' seriousness about incorporating mission-critical voice services, new business models, and financial aspects.

TETRA community believes that the evolution from narrowband TETRA to LTE-based Broadband PMR is a long process, and narrowband TETRA is expected to remain in operational use until 2025–2030 [11, 13]. In addition to the technical standards development in ETSI, there is an industry association called the TCCA, which is charged to "develop, promote and protect" TETRA technology [8]. Mobile broadband data is their current focus; their aim is to create a single common standard that can be used for mission-critical mobile broadband solutions. TCCA's Critical Communications Broadband Group (CCBG) is tasked with driving the development of common, mobile broadband standards and solutions for critical mobile broadband users worldwide based upon LTE. They have been collaborating with user groups, ETSI, and 3GPP [13, 14].

The National Public Safety Telecommunications Council (NPSTC) and other organizations in the USA recognized this and decided in 2009 on LTE as their platform for their future national public safety network. The USA has reserved a spectrum band in the 700 MHz area for an LTE-based public safety network and, in early 2012, committed $7 billion in funding.

In addition to the further enhancement and "tune-up" work going on in these areas, there is now a clear global consensus that LTE is the technology for next-generation broadband public safety networks.

In Europe, TETRA with its TEDS extension already supports relatively higher data rates up to 100 Kbps, but it is recognized that it is not enough and therefore a new technology is needed to add real mobile broadband capabilities. The TCCA established an objective of "driving the development of mobile broadband solutions, possibly LTE based, for the users of mission critical and business critical mobile communications."

Both the TCCA and NPSTC have publicly stated that they would work with 3GPP to include the functionality necessary within the LTE standard to meet public safety needs. With NPSTC, TCCA, ETSI Technical Committee TETRA, and other organizations backing LTE, there is now a clear global consensus about the use of LTE technology to build next generation broadband public safety networks.

6.11 SUMMARY AND CONCLUSIONS

This chapter provided a relatively extensive coverage of TETRA technology, related standards, architecture, interfaces and protocols, and services.

TETRA developed by ETSI became widely used in Europe and many countries around the world. Additionally, a few national and multinational networks are available and national and international roaming can be supported.

TETRA allocates channels to users on demand in both voice and data modes. TEDS, included in TETRA 2, enables more data bandwidth for TETRA data service users. TETRA 2 also includes additional features such as enhanced cell radius for air-to-ground communications and advanced automatic location services.

TETRA network architecture consists of one or more TETRA nodes, which support mobile stations and dispatchers. A network management center is connected to every TETRA node in the network to provide operations, administration, and maintenance functions.

TETRA is expected to continue to evolve to provide enhancements only. Several projects are underway to achieve seamless interoperability between TETRA and LTE-based public safety networks.

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