August 2018

TETRA Connectivity to LTE

TETRA networks are expected to be operational for many years to come; new nationwide networks are still being deployed and many are receiving mid-life upgrades. TETRA will therefore need connectivity to other bearers, particularly LTE, to facilitate long term co-existence, safe migration from TETRA to LTE or as a hybrid communications solution. It is clear now that such interworking can be achieved and that different approaches can be taken to suit various user scenarios.

Important Note

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1 Management Summary

3GPP has commenced standardisation work of the LMR/PMR/LTE interworking functions in Release 15 and we expect to have this functionality specified in Release 16, currently planned for completion by September 2019. For interworking with another technology, 3GPP can only standardise half of the solution, and work is therefore in progress in ETSI TCCE to standardise the equivalent functionality needed by TETRA to achieve a workable solution. The architecture of this solution is outlined below.

With there being a significant gap between the release of standards and the availability of the associated functionality in products for operational use, it is not expected that there will be a full range of 3GPP compliant interworking solutions deployed until 2021/2022.

User organisations that need interworking sooner will have to accept pre-standard solutions. A number of manufacturer specific solutions are on offer to meet this need. These specific solutions offer varying degrees of functionality. In adopting any of these solutions careful consideration needs to be given to the required operational functionality together with the resilience and security of the solution. The approaches are described in ways such as TETRA services over LTE, Gateways and Integrated Solutions. The main approaches are discussed further in this paper.

2 Introduction

Broadband cellular networks, services and smart mobile terminals have advanced rapidly in recent years. Public safety organisations are using commercial mobile services and smartphones today and the use is increasing as the reliability and quality of service of cellular networks improve.

This puts pressure on the mission critical users to also use their smartphones to support their mission critical voice and data applications. To address this, the LMR/PMR industry is building interworking capability between the legacy narrowband networks and broadband cellular based systems. For the users it is extremely important that the traditional PTT service evolves smoothly to the broadband mobile world. Chapter 3 discusses the end users benefits.

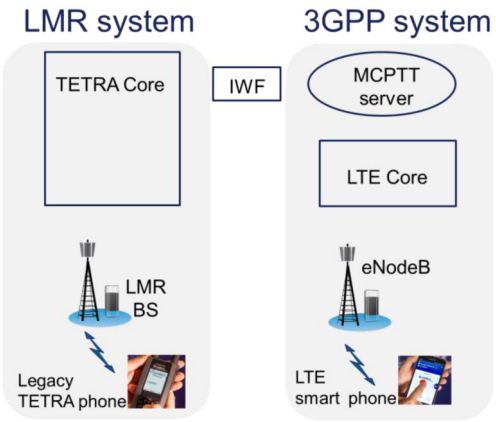


Figure 1 shows the basic elements of the functionalities in this evolution. The left side is the traditional (legacy) LMR/PMR world and the right side is the broadband world, led by 3GPP standards and currently deployed LTE systems by cellular suppliers and operators. The key issue

addressed in this white paper is the interworking between these two worlds and especially the interworking and evolution of PTT services, the group communications being the key service in the LMR/PMR networks. The interworking requirements for connection to TETRA are described in Chapter 4.

3GPP has defined Mission Critical Push-To-Talk (MCPTT) service and protocols to deliver PTT services to smartphones, defining standards for the MCPTT client software in a smartphone. In 3GPP the standardisation of an interworking function (IWF) between the MCPTT service and a non-MCPTT (LMR/PMR) service has started, as shown in Figure 2. The state and content of this standardisation is described in Chapter 5.

The MCPTT standard was tested at the Plugtests™ event organised by ETSI in June 2017 where many companies successfully connected MCPTT terminal clients to each other's MCPTT servers. A second Plugtests session took place in June 2018. The execution of more than 2000 tests, based on a test plan with more than 100 test cases, delivered a 92 per cent success rate. Further tests are scheduled for end 2018/beginning 2019, and mid 2019.

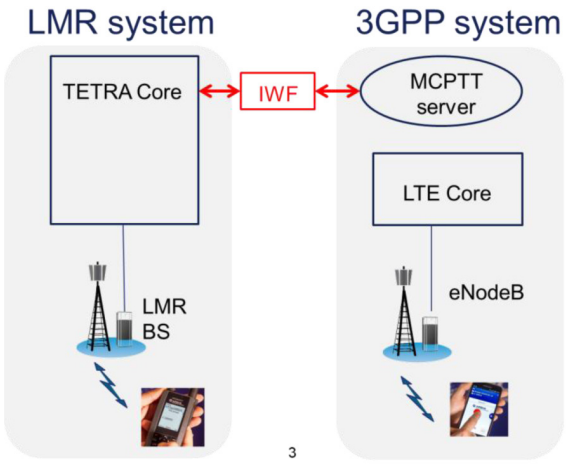


Figure 2.

As the standardisation of this interworking will take some time, and as the PMR/LMR users have different plans for evolving their current services i.e. transforming to new PTT services, the industry has developed solutions to respond to these end user needs. These include solutions to benefit from existing TETRA and 3GPP standards, existing LTE networks and off-the-shelf smartphones.

In parallel with MCPTT standards being finalised by 3GPP, this paper introduces three pre-standard (proprietary) solutions, utilising LTE infrastructures and LTE smartphones. These alternatives are company specific from suppliers, deploy current standard elements from 3GPP and TETRA in various ways, utilise cellular operator LTE services and off-the-shelf LTE smartphones in different ways. smartphones.

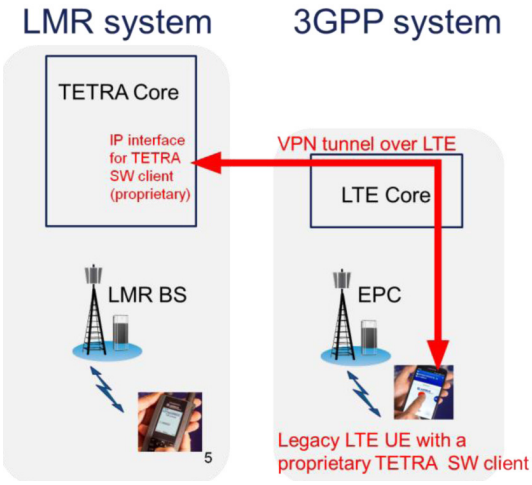


Figure 3 shows the concept of TETRA services over LTE. The concept is based on providing the existing TETRA service from the existing TETRA core network, in addition to legacy TETRA terminals over TETRA with access also over LTE access networks to LTE smartphones. The service is agnostic to the broadband access: it can be deployed over any LTE or Wi-Fi access network, commercial operator or dedicated access network. An off-the-shelf LTE smartphone can be used with its own 3GPP SIM identity and the service uses an additional TETRA identity in the TETRA SW client application in the smartphone. Therefore, the service quality and reliability depend on that of the used broadband access network. The concept is discussed in Chapter 6.2.1

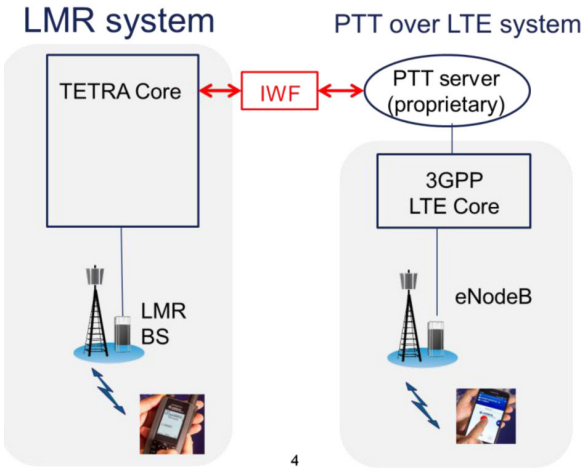


Figure 4 shows the solution, based on gateways. The concept is basically the same as that of figure 2 of interworking function (IWF) between TETRA and MCPTT, but implemented in a non-MCPTT server, providing PTT services over LTE access as of today. There are products in the market and also deployments, providing PTT services over cellular networks, currently predominantly for civilian users. Chapter 6.2.2 descries this concept in more detail.

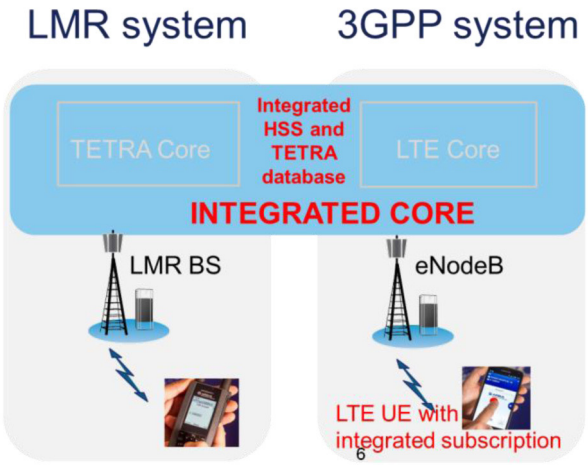


Figure 5 shows an integrated solution. The solution integrates both LTE and TETRA switching capabilities into a single core platform, providing unified TETRA and LTE core functionalities, including the subscriber and group databases, 3GPP home subscriber system (HSS) and the EPC core switching and routing elements. It unifies the LTE subscriber (SIM) and TETRA user identity (SSID). Chapter 6.2.3 describes the integrated solution in detail.

3 End User Benefits from Interworking

During the migration of services, it may be very beneficial to operate the two services alongside each other using interworking, thereby allowing connections between users on TETRA and LTE. For some users this may be a long term solution until the resilience, mission critical functionalities and security of the available public access LTE system are guaranteed.

Where coverage for LTE is still being rolled out, or where for economic or topographic reasons providing LTE coverage is not viable, the existing TETRA coverage can be used together with DMO, gateways and repeaters.

It is conceivable that some users on sensitive missions will want the extra security of TETRA along with the isolation from public access systems but who need to be able to at times connect with others on LTE.

The MCDATA standard will include interworking of SDS thus allowing operational procedures and productivity gains from using SDS to be continued.

4 Interworking Requirements

In the study made by ETSI TC-TCCE TR 103.565: "The following services are required to be carried across an interworking function between TETRA and 3GPP MC services:

a) Individual call – duplex and semi duplex
a) Group call
b) Variants of these, such as emergency calls and broadcast calls.
c) Short Data Service
d) Packet data service[1]

Users will also require the following supplementary services to be supported:

a) Late entry on either system
b) Talking party identity, carried between systems
c) Calling party identity, carried between systems
d) Restriction of calling and talking party identities carried between systems
e) Group management on both systems
f) Further supplementary services as required.

Additional service characteristics to be supported are:

a) Prioritisation schemes allowing priority requests to be resolved between systems
b) Pre-emption"

Security services such as authentication, air interface encryption and end to end encryption (e2ee) need to be maintained appropriately.

For the transport of these services to appear seamless there has to be a solution for identity/ addressing management between the systems, group affiliation, de-affiliation, group control system, late entry, private calls, vocoder reconciliation, end to end payload encryption, key management, re-grouping, group linking, floor control, SDS messaging and payload size handling. There are solutions proposed for nearly all of these. The most significant gap at this time is end to end encryption and its key management. End to end encryption requires the encryption and also voice coding to be maintained end to end over both interconnected systems, as decryption and transcoding breaks the end to end security. This also makes ACELP TETRA voice coding a critical issue to be supported in MCPTT for interworking between TETRA and MCPTT terminals and control rooms where fully end to end encryption is required.

[1] Packet data service interworking is for further study, but may simply make use of IP routing techniques outside the scope of this study.

5 Overview of the Standardised Architecture

5.1 Standardised Interworking of voice services (MCPTT – TETRA)

The following is a picture and explanation of a generic solution for interworking between LTE and non-LTE systems for Mission Critical Push To Talk taken from 3GPP TR 23.782 V15.0.0 (2017-06) "Study on mission critical communication interworking between LTE and non-LTE systems" (Subsection clause 6.1.1)

LMR/PMR system specifications define the equipment and sub-systems that constitute the network, including base stations and terminals. While in MCPTT systems, the MCPTT server provides centralised support for MCPTT services. In order to realise communication between these different systems, an interworking function (IWF) is introduced to support protocol translation, identity mapping, routing, and so on.

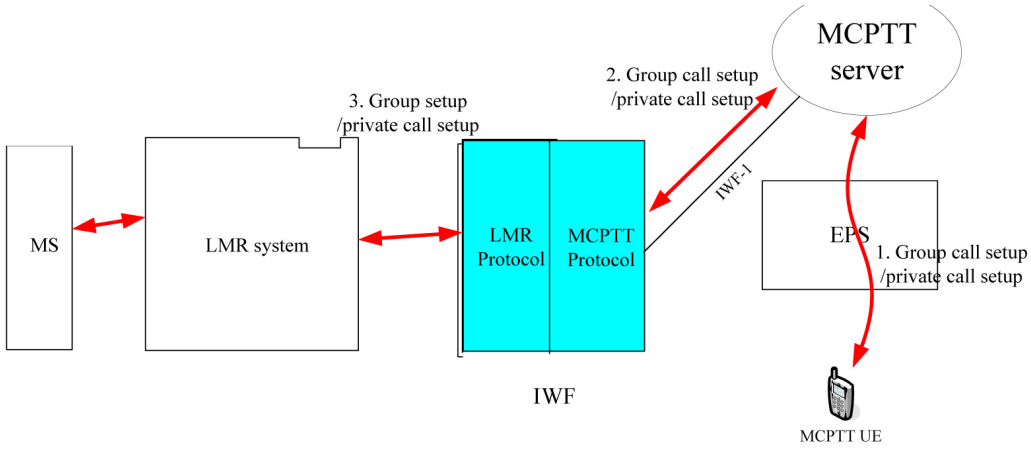


Figure 6: General Interworking architecture between MCPTT and LMR/PMR Systems

An IWF function is introduced in between the MCPTT system and the LMR/PMR system.

The IWF is composed of two parts:

1. An interface to the MCPTT system based on the current MCPTT specification 3GPP TS 23.379 [11], the IWF-1 can use a subset of existing MCPTT reference points (e.g. MCPTT-3 between one MCPTT server and another MCPTT server).

2. An interface to the LMR/PMR system based on reference point(s) defined by the LMR/PMR system.

The IWF1 interface, identified in, but not specified in 3GPP TS 23.379 [11], is the reference point through which MCPTT systems support interworking with legacy systems.

NOTE: TC-TCCE has developed ETSI TR 103 2691 [16] which defines an architecture model supporting Critical Communications Application (CCA) to operate with broadband IP networks such as 3GPP LTE (i.e. between the IWF and the LMR/PMRsystem).

The TETRA model for interworking is defined in ETSI TR 103 565 “Study into interworking between TETRA and 3GPP mission critical services”. This model is outlined below:

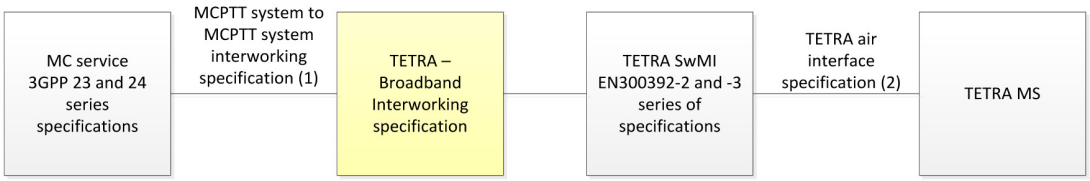


Figure 7: Concept of the interworking function

The interworking function to be specified as a result of this study will take the TETRA Inter-System Interface, specified in the ETSI EN 300 392-3 series of specifications [i.6] as a model of the functionality possible between TETRA systems, and the MCPTT interworking interface, which is expected to be specified within 3GPP Release 16, as inputs. The interface to the TETRA SwMI could make use of the TETRA ISI, or could be outside the scope of the standardisation process.

This Technical Report is intended to lead to a Technical Specification which specifies the interaction between the interface between a TETRA MS and a TETRA SwMI under the conditions of inter-system behaviour (shown as (1) in Figure 7, and the MC system interworking interface (shown as (2) in Figure 7).

5.2 Standardised Interworking of data services (MCData – TETRA)

The 3GPP generic solution for Data follows a similar approach to the generic solution for MCPTT and is outlined in sub clause 6.1.2 of 3GPP TR 23.782 V15.0.0 from which the following is taken:

“LMR system specifications define the equipment and sub-systems that constitute the LMR network, including base stations and terminals, whilst in MCData systems, the MCData server provides centralised support for MCData services and in particular standalone MCData SDS services. In order to realise communication between these different systems, a logical interworking function (IWF) is introduced to support protocol translation, identity mapping, routing, and so on.

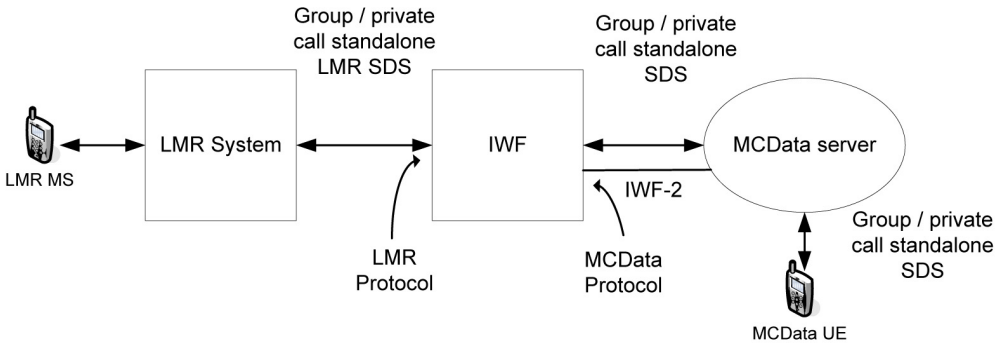


Figure 8: General interworking architecture for standalone SDS between MCData and LMR/PMR Systems

The IWF is composed of two parts:

1. An interface to the MCData system based on the current MCData specifications 3GPP TS 23.282 [18]. The IWF-2 reference point can use a subset of existing MCData reference points (e.g. MCData-3 between one MCData server and another MCData server)

2. An interface to the LMR/PMR system based on the reference point(s) defined by that system.

To ensure that standalone SDS data can be exchanged between MCData and LMR/PMR systems, the functionalities of the IWF that are supported for interworking with the MCData system and the IWF-2 will be identified in the MCData specification."

6 Discussion of Early Solutions

6.1 Technical approaches

All proprietary solutions have three components:

- A PTT application running on an LTE smartphone
- A PTT protocol operating between the smartphone application and a network server
- A network server, which interfaces to the smartphone application, receives requests, sends commands and handles user audio and data, and interfaces to the TETRA system.

In some implementations, the network server may be in control of the PTT application and may be processing call requests, setting up the calls etc, and in some implementations it may be deferring to a TETRA control server which is performing the control application.

These are described further in the following sub-sections of this paper.

6.1.1. PTT application

The proprietary PTT application is designed to be installed on the chosen smartphone operating system(s) supported by the supplier, e.g. Android or iOS. The deployment option may decide whether the end user can install this, whether it must be done by the supplier, and whether it can be modified, configured or updated over the air.

The PTT application will provide the user interface for the smartphone. Depending on the smartphone platform, controls may be 'soft' buttons on the screen, or may make use of dedicated hardware (if available). The application also controls audio capture and playback in calls, and any security mechanisms applied to user speech and data.

The PTT application can be designed to run entirely in device software, or may make use of standardised or custom hardware of the smartphone and any peripheral components such as SD cards, local or connected accessories and so on.

If the end user organisation ever intends to migrate from the proprietary approach to a 3GPP standard compliant approach, the means to upgrade or replace the application needs to be considered.

6.1.2. PTT protocol

The proprietary PTT protocol runs between the PTT application and the network server. How it operates is entirely up to the supplier – and how efficient it is as a solution. It uses the Internet Protocol (IP) across data bearers provided by the underlying LTE system. It may be based on an existing or evolving standard, e.g. OMA Push To Talk Over Cellular (POC), which is the basis for MCPTT or the MCPTT specifications directly, or may build on an existing LMR/PMR protocol such as TETRA, or since it is proprietary may follow some different choice of the supplier.

The protocol can also be considered to include the speech coding used to carry user speech in calls. This could be an off the shelf speech codec such as AMR, as used in some 3GPP applications, or ACELP, used in TETRA, or some other proprietary approach could be taken. Similarly, the security applied to the user traffic could follow and existing open standard (e.g. taken from the IP world) or could reuse another approach such as TETRA speech encryption.

If the end user organisation ever intends to migrate from the proprietary approach to a 3GPP standard compliant approach, the means to interoperate between users with the proprietary protocol speech coding and 3GPP speech coding needs to be considered.

6.1.3. Network server

The network server provides the fixed network interface for the proprietary PTT system. It communicates with the PTT application in the smartphone using the PTT protocol over IP data bearers provided by the LTE system.

The network server may connect to the LTE server as a separate over the top (OTT) data application, making use of the quality of service (QoS) offered by the LTE system. It may be connected in a way that allows improved QoS over commercial users of the same system. Ideally, it may have connection to the Policy Control and Charging Function (PCRF) in the LTE system to allow it to set up data bearers of appropriate priority when needed.

The network server may directly control calls sent over the LTE network, and interface to the companion TETRA network, with some chosen mechanism between the two for arbitrating control of calls where members of the calls are present in both systems. Alternatively, it may simply be acting as a gateway into the TETRA system allowing the TETRA system to control all calls, even those on the LTE system.

6.2. Solutions of TETRA Connectivity to LTE

Overview of Solutions

The following sub-sections of this paper provide an overview of the different approaches to interworking with LTE. As they emphasise different aspects of the solution there can be overlap, and any solution on the market may contain aspects of more than one of these.

6.2.1. TETRA Services over LTE

TETRA over LTE is using a secured VPN tunnel over LTE data service. It is a means to connect an LTE smartphone application to an interface in TETRA service network core. From dispatcher and TETRA radio user's perspective, the smartphone user is similar to a TETRA subscriber user: using the same TETRA services and joining the same TETRA groups. LTE data access can be a commercial LTE data subscription from a cellular operator or may be a dedicated LTE access, providing public safety specific security, availability (through hardening) and priority (Release 12, where QCI's were introduced) which then provides a mission critical solution. Needless to say, the smartphone user will only have the coverage, resilience and security his or her LTE network provides.

The solution can enable a TETRA operator to increase the number of users incrementally and extend their user scope to new critical infrastructure user organisations (utilities, transport) and also to other public services segments (health care, social segment), while making use of the existing TETRA switching and service core. This can lead to reduced incremental investment to provide TETRA service to LTE smartphone (SW-App) clients. The existing control room TETRA services including dispatchers and AVL[2] systems etc. support LTE smartphone users in a similar way to TETRA radio users. The existing TETRA user and application management systems can be extended to serve also LTE phones with TETRA SW-App clients.

Service expansion to include LTE phone users can be made seamless without affecting current traditional TETRA radio users. The same (PTT, group) services could be shared between TETRA radio users and LTE smart phone users. As TETRA addressing is reused in this approach, smartphone users can take part in TETRA individual and group calls, receive PSTN calls via their TETRA service and prioritisation between TETRA services can be implemented similar to its implementation for TETRA radios.

[2] Automatic Vehicle Location

6.2.2. Gateways

A gateway approach could be considered to be one where the PTT protocol does not reuse TETRA protocol but is based on some other approach (OMA PoC, 3GPP MCPTT or fully proprietary). In this case, the gateway has to adapt the PTT protocol to the requirements of the TETRA network. The TETRA interface may be proprietary, or could be based on a standard such as the TETRA Inter System Interface.

A gateway is a broad term, and depending on the technical approach, may allow connection to mobile devices from any network. Gateway approaches could allow separate call processing on each side with the gateway also performing arbitration between TETRA and PTT users, or a single call processing server. The extent of the TETRA services supported varies but most support group and individual calls although there may be restrictions on how the group calls are configured. The robustness of the solution will depend largely on the properties of the LTE network being used as well as the particular gateway solution chosen.

The gateway solution will need to include a mechanism to adapt addresses from one network to the other, to allow identification of users and groups between networks. It may need to adapt speech coding mechanisms (although transparent relay of TETRA's ACELP codec is one option).

A security approach is needed, and is likely to provide separate security between the network server and the application clients on the LTE side from that on the TETRA network, although if the TETRA ACELP codec is used end to end, the TETRA end to end encryption approach can also be followed.

6.2.3. Integrated Solutions

An integrated solution approach is one where the TETRA and LTE interworking is not limited to the application layer. In order to obtain optimum performances and maintainability, base stations from both technologies are connected to a single core and a single database. All the switching intelligence is centralised and both technologies appear at the radio level only (e.g. TETRA and LTE cells connected to a central core).

For the application layer, there is one single server, and common call processing is applied. LTE users have an application on their smartphones and TETRA users use their standard terminals.

The TETRA network is then directly integrated with a standard LTE network and as it uses a common subscriber data base there is no need for arbitration between two different servers, as one server is setting up the calls.

Whereas the eNodeB has a standardised interface, TETRA does not.

Mission critical applications are thereby directly tied to the LTE network through MCPTT and MC DATA interfaces and don't need to worry about the terminal technology (TETRA, LTE) for basic services; as result, a control and command centre may perform selective or group call, selective or group SDS without knowledge of the terminal type.

In most cases, users of an existing TETRA network want to preserve the TETRA numbering plan which may not be compatible with another numbering plan used by a connected network – typically, most of the existing TETRA numbering plans are not compatible with standard NMI as used by public operators. The problem is solved with a central subscriber data base: all terminals have a standard NMI and a local address (TETRA address) recorded in the unique data base. Address conversion is automatically provided.

7 Pros and Cons of the Various Approaches

The TETRA over LTE, Gateways and Integrated approaches include commitments from some of the suppliers to evolve in line with the standards. All of the approaches allow various degrees of interworking and freedom to choose the suppliers of the LTE terminals used subject to security considerations.

The extent of the functionality offered for interworking is varying and in choosing a solution there is a need to carefully check that it can meet operational needs.

7.1. TETRA over LTE

The advantages are that it is a route to enhance existing users' LTE smartphones to be able to access TETRA services thereby extending effectively the TETRA network and getting interworking started in order to develop operating procedures with public safety broadband data applications, already in use.

The real connection to TETRA is a pipe from the LTE smartphone to a TETRA system as well as control possibility of the LTE bearer QoS, whereby there is an integrated or dedicated server/ gateway to manage the interconnect/translation (traffic and signalling).

The solution assumes that for security reasons, commercial LTE users will be given a VPN tunnel from smartphone to the TETRA system and also specific priority, if supported by the commercial LTE operator (QCI parameters).

TETRA e2ee requires security key storage in the LTE terminal and TETRA e2ee key exchange (re-keying) over LTE. When using commercial LTE smart phones, a separate smart card based solution would need to be used. It also requires ACELP TETRA voice coding to be supported in the MCPTT standard for interworking between TETRA and MCPTT.

7.2. Gateways

The concept of having a gateway between TETRA and public networks is well established and PSTN gateways were an early feature in TETRA. The extension to LTE then is quite logical.

The LTE side of the network will be standard meaning that different suppliers can be used for this. The proprietary part will be the mapping of services between TETRA and LTE.

Solutions proposed by vendors have to have security approaches thought through to ensure that the security of the TETRA network is not compromised. A separate gateway cannot handle TETRA e2ee without support in both TETRA and LTE terminals. Also here, when using commercial LTE smartphones, a separate smart card based solution would need to be used.

7.3. Integrated Solutions

Whereas TETRA over IP and Gateway solutions probably are expansions of existing TETRA networks, the Integrated Solution is based on a single core and a single database and is probably best suited for new installations. An Integrated Solution uses a common database for any connected type of network; the numbering plan is then supported by a central subscriber database. The user information is then centralised and routing of PTT or other communication types is facilitated.

8 Conclusion

Several methods for Interworking of TETRA to LTE have been described in this paper. There will be a standard for interworking between TETRA and LTE that will meet the needs of critical communications users in the 2019 timeframe – the standard will then need to be converted to products and implemented in LTE networks. Through using standards-based approaches users will have the benefit of open competitive markets for their solutions and the ability to use products from different suppliers.

For those that need solutions now there is a range of company specific solutions that will give various level of interworking. These solutions may in time conform to new standards.

The deployed commercial LTE systems deliver very good, but best effort, service until hardened, updated to the latest 3GPP Release and potentially having their area coverage expanded.