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On the Future Architecture of Mission Critical Mobile
Broadband PPDR Networks

White Paper

**Disclaimer**

The purpose of this document is to provide information and analysis as a base for discussion about the future use of broadband technologies by public safety organizations. It does not represent an official statement of the German Government nor is it meant to provide guidance for future policies.

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Abstract

This white paper examines four possible approaches on how operators of nationwide narrowband PPDR mobile radio networks could additionally provide broadband services to their users. Three scenarios concentrate on co-operation models with commercial LTE mobile radio network operators whereas the fourth scenario describes a network with dedicated radio access. Main criteria for examining these scenarios are the readiness of the underlying network technology for mission critical communication, the timely availability of the examined scenarios and the associated costs. Furthermore, this paper also points out constraints with regard to frequency spectrum, migration of existing networks, and interoperability of terminals and control rooms.

# Introduction

In general, Public Protection and Disaster Relief (PPDR) users have access to mission critical narrowband voice plus data mobile radio networks. Most recently, PPDR users have voiced operational requirements for mission critical broadband data services. In order to evolve existing nationwide PPDR infrastructures to also support broadband data, regulatory bodies have to identify harmonised frequency spectrum for broadband PPDR communications as a prerequisite. This is further explained in Section 2.

In order to have a common understanding, mission critical communication is defined in Section 3. Furthermore, Section 4 explains that the Internet Protocol (IP) and Long Term Evolution (LTE) can – in general – provide mission critical voice and broadband data communication.

In Section 5, this white paper assesses the capabilities of four different approaches on how operators of nationwide narrowband PPDR mobile radio networks could additionally provide broadband services to their users. The first three scenarios consider co-operation models with commercial LTE mobile radio network operators. The scenario ‘Service Provider’, see Section 5.2, describes a non-mission critical interworking solution in which the commercial network operator remains in control of network and user management.

In contrast to the scenario ’Service Provider’, user management und service provisioning are under control of PPDR users in the scenario ’Mobile Virtual Network Operator (MVNO)’. According to the definition in Section 3, the scenario ‘MVNO’ can partly provide mission critical communication, see Section 5.3. Analogously to user owned narrowband PPDR networks, user owned broadband PPDR networks fully support mission critical communication, too.

The scenario ‘Radio Access Network Sharing’ is similar to a user owned broadband PPDR network, with the difference that synergies are exploited by co-operation with a commercial mobile network. Additionally, Section 5.4 explains how the scenario ‘MVNO’ could evolve to a user owned broadband PPDR networks with or without radio access network sharing. Section 5.6 compares the advantages and disadvantages of all aforementioned scenarios.

Operators of nationwide TETRA networks naturally want to protect their huge investments in these infrastructures. Section 6 points out a cost effective migration path towards broadband PPDR networks.

Besides harmonised frequency spectrum, a mission critical LTE standard and infrastructures supporting this standard, end-to-end interoperability of terminals and control rooms is a key enabler for a successful mission critical broadband PPDR technology. Section 7 proposes a way forward how interoperability testing and certification could evolve in the future.

Considering all arguments brought forward in this white paper, Section 8 concludes with a summary of recommendations.

# Broadband PPDR Frequency Spectrum

The regulatory body of the United States, the Federal Communications Commission (FCC), increased in February 2012 the already identified frequency spectrum for broadband PPDR communications to 2 · 10 MHz in the 700 MHz frequency band (758 MHz-768 MHz and 788 MHz-798 MHz). An initial study [IABG] conducted on behalf of the German Federal Ministry of the Interior in May 2010 investigated the medium-term and long-term capacity requirements of PPDR services in Germany and came to the conclusion that German PPDR services require a total bandwidth of 60 MHz (40 MHz on the uplink and 20 MHz on the downlink) for mission critical broadband mobile communications based on Long Term Evolution (LTE).

A follow-up study [WIK] conducted on behalf of the German Federal Ministry of Economics and Technology consolidated this capacity requirement to 25 MHz (15 MHz on the uplink and 10 MHz on the downlink) in December 2010. As a minimum requirement, it is agreed by operators, users, and manufacturers within the Critical Communications Broadband Group (CCBG) of the TETRA + Critical Communications Association (TCCA) and the Radio Communication Expert Group (RCEG) of the Law Enforcement Working Party (LEWP), a committee of the Council of the European Union, that 2 · 10 MHz of dedicated frequency spectrum (in total 20 MHz) below 1 GHz shall be internationally harmonised and assigned to broadband data PPDR communications. This conforms to the decisions of the FCC. Nevertheless, this minimum requirement for 20 MHz does not include frequency spectrum required for voice services, Direct Mode Operation (DMO), Air-Ground-Air (AGA) communications or ad hoc networks [ECC]. Furthermore, this minimum requirement does not consider the demand for additional frequency spectrum (5 MHz) on the uplink [WIK].

The next World Radiocommunication Conference in 2015 (WRC-15), the triennial meeting of all regulatory bodies throughout the world hosted by the International Telecommunication Union (ITU), will review and revise existing radio regulations for harmonised PPDR frequency spectrum. Resolution 648 (WRC-12) [ITU] invites administrations to contribute to studies to support broadband PPDR. It will be one of the foremost tasks of LEWP/RCEG and CCBG in cooperation with ETSI TC TETRA WG4 “TETRA High Speed Data” to provide sustained operational and user requirements for 2 · 10 MHz of dedicated frequency spectrum below 1 GHz. Depending on this, WRC-15 might revise Resolution 646 (WRC-12) [ITU] in order to identify globally or regionally harmonised frequency bands for PPDR mission critical broadband mobile communications.

As part of the second digital dividend in Europe, WRC-15 might re-farm 20 MHz of frequency spectrum in the range 694 MHz-790 MHz for PPDR use. Until PPDR spectrum in the 700 MHz frequency band has been harmonised, some users and operators in Europe are looking for a broadband PPDR and LTE based (interim) solution in the 400 MHz frequency band. If such a solution is not solely intended for military use, PPDR operators and users will most probably need to cooperate with NATO which was awarded 2 · 5 MHz of frequency spectrum below 400 MHz (385 MHz-390 MHz and 395 MHz-400 MHz). Otherwise, sufficient broadband spectrum might not be available in the 400 MHz frequency band.

As shown in Table 1, peak data rates of an LTE based PPDR system with 2 · 5 MHz of frequency spectrum would not exceed 73 Mbit/s on the downlink and 18 Mbit/s on the uplink. A PPDR system with 2 · 10 MHz of frequency spectrum would not exceed 151 Mbit/s on the downlink and 37 Mbit/s on the uplink. Average achievable IP throughput will be significantly lower and definitely far away from true 4G (LTE-Advanced, LTE-A) data rates. Unlike commercial LTE networks designed for broadband download, the upload of broadband operational information in a future broadband PPDR system will be a predominant use case. It can be anticipated that the uplink will be the bottleneck of such future broadband PPDR systems.

Table 1: LTE peak data rates shared by all users in one cell

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Bandwidth** | (MHz) | 1.4 | 3 | 5 | 10 | 15 | 20 |
| **Downlink** | (Mbit/s) | 17.520 | 44.304 | 73.392 | 150.752 | 220.272 | 299.552 |
| **Uplink** | (Mbit/s) | 4.392 | 11.064 | 18.336 | 36.696 | 55.056 | 75.376 |

Due to LTE-A (Release 12) providing higher data rates on the uplink (design goal: 500 Mbit/s) and new procedures for better coverage with the help of relay nodes and for interference avoidance such as distance based frequency reuse, this uplink bottleneck will not be resolved before the successor of LTE has been adapted to mission critical communications.

# Definition of Mission Critical Communication

A mobile radio communication system must fulfil four key requirements in order to be usable for mission critical communication:

1. **The infrastructure must be resilient, redundant and highly available.**

This is normally achieved with the help of a redundant network architecture, redundant links between network elements and fail-safe network elements. Furthermore, base stations can increase the availability of their cells by operating in a fallback mode and by providing a minimum service when the connection to the infrastructure gets lost and when network wide services cannot temporarily be supported. Furthermore, main network elements need to be physically protected against intrusion and vandalism.

1. **Communication must be reliable.**

In a mission critical network, communication services have to be accessible and stable, i.e. network capacity has to be available even in case of large scale disaster scenarios. Furthermore, group and individual calls have to be setup in a predefined and extremely low time, e.g. 500 ms. Even at cell edge, speech packets, short data messages and packet data have to be reliably transferred to the end user.

1. **Communication must be secure.**

A mission critical network provides security functions in order to protect users from jamming, interception, and spoofing:

* mutual authentication of infrastructure and terminals;
* methods for temporarily and permanently disabling terminals and smart cards;
* functions to detect and compensate for jamming at the air interface;
* air interface encryption of user data and signalling data including addresses;
* end-to-end encryption of voice and data communication.
1. **Point-to-multipoint communication must be supported.**

Professional users mainly operate in groups. This is why, a mission critical network has to support point-to-multipoint communication, i.e. group calls, group addressed short data messages, and group addressed packet data.

If a mobile radio communication system does not fulfil the above four ‘mission critical’ requirements completely, then it can only be used for business critical communication. In general, commercial mobile radio networks are only capable of supporting business critical communication.

Due to the fact that TETRA complies with the four ‘mission critical’ requirements above, TETRA provides a narrowband and wideband mission critical voice plus data mobile radio technology for PMR users mainly belonging to the sectors PPDR, utilities, and transportation.

Although the LTE standard is currently enhanced to support mission critical communication as specified in [TCCA], PPDR communications will remain a niche market. Most probably, commercial LTE manufacturers and operators will only be willing to implement mission critical features in their equipment and to upgrade their networks to become mission critical if this is profitable for them.

Considering the fact, that PMR in total represents a small user group with limited budgets, commercial LTE manufacturers might not implement LTE security features although they are part of the LTE standard. Likewise, commercial LTE operators will surely avoid the huge investments associated with a resilient, redundant and highly available (> 99,999 %) network. Finally, it will be the task of PPDR manufacturers and operators to enable LTE equipment and networks for mission critical communications.

# Evolution towards a Single Network Core based on the Internet Protocol

## Explanation of the Concept and its Rationale

The concept of a single network core based on the Internet protocol was initially developed for commercial mobile networks. In commercial mobile networks, the amount of data (measured in the number of bits transported) which relates to Internet services has far exceeded the amount of data for the telephony service. Combining voice and data transmission in a single network significantly reduces cost.

In order to improve their efficiency and effectiveness, the PPDR organizations have an increasing demand for more data transmission speed and lower latency, for example to transfer video and for the remote access to data bases and applications. It is therefore foreseeable that the architecture of PPDR networks will evolve in the same direction as the architecture of commercial mobile networks.

The Voice over IP (VoIP) technology has reached a state of maturity. The speech quality is perceived by the users as similar to telephony in classical analogue telephone networks and in Integrated Services Digital Networks (ISDN). New codecs might even offer quality better than classical networks.

Thus, the reasons why voice and data were transported over different networks with different technologies have disappeared.

The evolution towards an all IP network is inevitable because the manufacturers’ maintenance support and the supply of spare parts for the switching equipment from the pre-IP era will end within a foreseeable period of time.

## Is it Suitable to Deploy Mission Critical Services over IP?

Today, the majority opinion of the public perceives the internet as a cheap network without service guarantees which should not be relied upon for mission critical communication. This public perception has valid reasons, which have to do with the current commercial reality and the implementations of Internet technology which are predominant today.

Since the Internet Protocol (IP) was originally designed for military fixed networks, there is good reason to assume that the protocol as such is suitable for mission critical communication. As pointed out by [3GPP-TR], LTE on top of this provides procedures for prioritised handling of emergency calls and multimedia priority services, an end-to-end Quality of Service (QoS) framework and broadcast of alert messages. However, it is not just the protocol which characterises a network as suitable for mission critical communication. The equipment of a mission critical network must meet higher standards in terms of reliability and security, and the resources have to be dedicated to the mission critical services.

## Separation of the Services Layer from the Network Layer

In an all IP network, the services are implemented in the higher protocol layers above the network layer, see Figure 1. The physical location of the servers becomes less important, because the network layer provides inexpensive transport to almost every location. Also, the network layer makes the services independent of access technologies (fixed or mobile, WLAN, UMTS/HSPA, or LTE) and of the operator of the access network.



Figure 1: Separation of Services from the Underlying IP Network

## Future of the Service Layer and the Subscriber Management Entities

A future mission critical mobile broadband PPDR network is based on requirements which are significantly different from those of a commercial mobile radio network:

* The most used form of voice communication is group communication.
* End-to-end encryption offers protection against eavesdropping.
* A sophisticated system exists to manage the association of users to groups.
* A PPDR network needs a higher degree of resilience and security.
* In PPDR networks, priority and pre-emption has a more important role than in commercial mobile radio networks.

Due to these requirement differences, it is not useful to combine the service layer of PPDR networks with commercial mobile radio networks. It is, therefore, recommended to use service layer equipment which is dedicated to PPDR organisations. This service layer could be an evolution of existing TETRA network elements.

# Four Scenarios for Future Mobile Broadband PPDR Network Architectures on the Network Layer

## General Preconditions for Co-Operating with Commercial Mobile Radio Networks

Three of the four scenarios described below involve co-operation models with providers of commercial mobile radio networks (LTE, UMTS/HSPA, GSM/EDGE). Such co-operation is possible under the following conditions:

* In almost all countries, there is no legal requirement which obliges the companies that operate commercial mobile radio networks to engage in any co-operation which is described in this document. Any such co-operation is voluntary and requires a commercial agreement.
* Commercial mobile radio networks offer some resilience and security, but their technical design does not take the higher needs of mission critical applications into consideration.
* Commercial mobile radio networks use frequency bands (700 MHz to 2 GHz) identified by regulators, which are much higher than those currently used for PPDR networks (mainly 400 MHz). Wave propagation characteristics depend on the frequency. Lower frequencies are more suitable for large cells and for providing indoor coverage. Higher frequencies are more suitable for small cells, in order to provide more capacity. When co-operating with commercial mobile radio networks, it needs to be considered whether the frequency bands used by these commercial networks meet PPDR wave propagation and coverage requirements and provide enough capacity for all users.
* Multi-mode terminal equipment might be required. It is not clear at this stage whether the requirements can be met using a single smart card. Therefore, it may be necessary that the terminal equipment can handle multiple smart cards.

## Service Provider Scenario: Non-Mission Critical Interworking with Commercial Mobile Radio Networks

In this scenario, the existing TETRA network is used for voice services, as long as the voice services are not migrated to voice over IP. The services based on IP are provided by means of interworking with commercial mobile radio networks, without involvement of the TETRA network. This scenario is derived from services that commercial mobile radio network operators offer for business customers. For these services, a special Access Point Name (APN) is configured in the terminal equipment.

Via this APN, the user becomes connected to the IP network of the respective company/organisation instead of the public internet. The user must have a subscription for this APN, otherwise he cannot get access. This subscription is stored in the Home Subscriber Server (HSS). Figure 2 shows the architecture in a simplified and generalized form. LTE standards leave the choice between Proxy Mobile IP and GTP. The figure assumes that GTP is used.



Figure 2: Service Provider Scenario: Non-Mission Critical Interworking with Commercial Mobile Radio Networks

The IP traffic is routed via an interface between the commercial mobile network and the IP network of the respective company/organisation without touching the public internet. For this interface, it is recommended to use dedicated resources (e.g. leased lines) instead of an IP VPN via the public internet. The internet may be congested e.g. during a disaster situation.

In this scenario, HSS and the Gateway GRPS Support Node (GGSN) are part of the commercial mobile radio network, and mobility management and authentication (including the generation and management of keys and the production of smart cards) are handled in the domain of the operator of the commercial mobile radio network, although it is not precluded that the commercial mobile radio network operator delegates the responsibility to suppliers.

Therefore, PPDR organisations might need an interface which allows PPDR control rooms to disable a subscription in case of theft or loss. It might be possible to use existing technical solutions and interfaces which commercial mobile radio network operators normally use to co-operate with their resellers and sales partners.

End-to-end encryption and services remain within the responsibility of the PPDR organisations.

These services for business customers have the following limitations and are, therefore, considered to be suitable for non-mission critical communication only.

* The usual products for business customers do not give the customer the ability to monitor the network for outages. In order to meet the requirements of PPDR organisations, a special arrangement with the operator of the commercial mobile radio network is required.
* Existing services typically do not have mechanisms which prioritise the traffic of PPDR organisations higher than the traffic of normal customers. This means that the effects of network congestion caused by unusual levels of usage by normal customers, e.g. in a disaster situation, would also apply to PPDR organisations. These services cannot be relied upon in disaster situations. In order to introduce such mechanisms, a complex solution based on IP QoS mechanisms could be used.
* When this scenario exists in parallel with an own network of a PPDR organization, it is not possible to maintain an active call when changing the network (internetwork handover).
* Generation and management of cryptographic keys (except those for end-to-end authentication and encryption) and the production of smart cards are handled by the commercial mobile radio network operator. The subscriptions of the individual users are stored in the HSS. Therefore, PPDR organisations have to trust the commercial mobile network operator, the involved suppliers, and the involved persons.

It is possible to use a service of a commercial mobile radio network operator from a neighbouring country that has a roaming agreement with all commercial mobile radio network operators in an operator’s home country. This improves resilience and coverage.

## MVNO Scenario: Partly Mission Critical Roaming with Commercial Mobile Radio Networks

This scenario is based on roaming. If PPDR organisations have an own broadband mission critical network and use this scenario to provide coverage in additional areas, then this scenario is similar to a national roaming agreement between two commercial mobile radio networks. If PPDR organisations have no broadband network, then this scenario is similar to a Mobile Virtual Network Operator (MVNO) of a commercial mobile radio network.

The IP traffic is routed via a tunnel between the commercial mobile radio network and the IP network of the PPDR organisations without touching the public internet. The tunnelling protocol can be the GPRS Tunnelling Protocol (GTP) or Proxy Mobile IP (PMIP). Figure 3 shows the architecture in a simplified and generalized form. LTE standards leave the choice between Proxy Mobile IP and GTP. The figure assumes that GTP is used.



Figure 3: MVNO Scenario: Partly Mission Critical Roaming with Commercial Mobile Radio Networks

Also, a mobility management interface exists between the commercial mobile radio network and the IP network of the PPDR organisations. The mobility management interface for roaming between LTE, UMTS/HSPA and GSM/EDGE are standardised, but there is currently no standard for roaming between the aforementioned technologies and TETRA or other PMR technologies.

In this scenario, HSS, GGSN, E2EE, services, generation and management of keys and the production of smart cards belong to the domain of responsibility of PPDR organisations. Mobility management and authentication are done collaboratively, but the commercial mobile network operator does not get the permanent secret keys. The PPDR control rooms have an interface to the HSS, e. g. to disable a subscription in case of theft or loss.

This scenario could be introduced as an evolution of the existing TETRA network like this:

* One commercial mobile network operator is chosen as a partner, and a national roaming contract is agreed.
* The service platforms, the HSS and the P-GW/GGSN are chosen, installed, connected to the commercial mobile network and the existing TETRA network, and tested (initially without real users).
* Users are migrated one-by-one by moving the subscription to the HSS and giving the user a new SIM card. In order to make use of the new possibilities, users need separate dedicated terminal equipment.
* It is then possible to proceed with building an own LTE network.

This scenario has the following limitations. It is considered to be partly suitable for mission critical communication because this scenario could evolve to a fully mission critical architecture.

* The usual arrangement does not give the roaming partner the ability to monitor the network for outages. In order to meet the requirements of PPDR organisations, a special arrangement with the operator of the commercial mobile radio network is required.
* Roaming agreements normally do not include mechanisms which prioritise the traffic of PPDR organisations higher than the traffic of normal customers. This means that the effects of network congestion caused by unusual levels of usage by normal customers, e.g. in a disaster situation, would also apply to PPDR organisations. These services cannot be relied upon in disaster situations. In order to introduce such mechanisms, IP QoS mechanisms could be used. The technical solution is even more complex than the scenario ’Service Provider’, because the IP QoS mechanism would have to work across IP network boundaries in the MVNO scenario.
* When this scenario exists in parallel with an own broadband network of PPDR organisations, it may be possible to maintain an active call when changing the network (internetwork handover), but the technical solution is complex, and a co-ordination of the radio network engineering of both sides is required.
* PPDR organisations have to administer their own roaming agreements. They cannot use existing roaming agreements of the commercial mobile radio network operators. This applies to both national and international roaming.
* An Inter-System Interface (ISI) between LTE and TETRA should be defined. Having an ISI provides the advantage that all users only have a single subscription for both LTE and TETRA and a single smart card, and that group calls of both LTE and TETRA users simultaneously are possible. However, there are currently no standards for such an interface, and it is uncertain whether manufacturers will develop such an interface.

## RAN Sharing Scenario: Almost fully Mission Critical User Owned Professional Mobile Radio Network

This scenario assumes that a user owned mission critical mobile broadband PPDR core network is setup. For the radio access network, a RAN sharing agreement with a commercial mobile network operator reduces the investment and operational cost in comparison with two dedicated RANs.

The 3GPP specifications support RAN sharing, see [3GPP-TR]. The spectrum can be dedicated per operator or shared.

Initially, the user owned core network and the shared RAN exist in parallel to an existing narrowband TETRA network. The scenario allows a lot of flexibility when users are migrated from the TETRA network to the LTE network. If all users are migrated, the TETRA network can be decommissioned. The following preconditions have to be met before PPDR organisations can use RAN sharing:

* LTE has to be extended with mission critical features as mentioned in [TCCA].
* A RAN sharing contract with a commercial mobile network operator has to be agreed upon.
* This scenario is most effective if the contract partners exploit potential synergies as much as possible (e.g. choosing the same outsourcing partner for the operation and maintenance of the RAN, using shared information transmission facilities and electrical power supply, performing radio network engineering in a co-ordinated way).
* Interfaces between the core networks and the shared RAN have to be implemented.
* Manufacturers have to develop highly resilient RAN elements that can provide reliable and secure services, and which support RAN sharing.

## Dedicated RAN Scenario: Fully Mission Critical User Owned Professional Mobile Radio Network

This scenario assumes that a user owned mission critical mobile broadband PPDR radio access network based on LTE and a user owned mission critical mobile broadband PPDR core network are setup. Initially, this network exists in parallel to an existing narrowband TETRA network. The scenario allows a lot of flexibility when users are migrated from the TETRA network to the LTE network.

If all users are migrated, the TETRA network can be decommissioned. Although the limitations mentioned in the scenarios ’Service Provider’ and ‘MVNO’ no longer hold true, different limitations have to be considered before PPDR organisations can invest in a dedicated radio access network:

* Frequency spectrum for broadband PPDR communications has to be identified.
* LTE has to be extended with mission critical features as mentioned in [TCCA].
* An Inter-System Interface (ISI) between LTE and TETRA network should be defined, see scenario ’MVNO’.
* Manufacturers have to develop highly resilient LTE network elements that can provide reliable and secure services above an all-IP network, see Figure 1.

## Comparison of the Four Scenarios

The advantages and disadvantages of the three aforementioned scenarios are compared in Table 2.

Table 2: Comparison of Four Scenarios for Future Mobile Broadband PPDR Network Architectures

|  | Service Provider Scenario:Interworking with Commercial Mobile Radio Network | MVNO Scenario:Roaming with Commercial Mobile Radio Network | RAN Sharing Scenario | Dedicated RANScenario:User Owned Professional Mobile Radio Network |
| --- | --- | --- | --- | --- |
| supports mission critical communication | no | only in areas covered by the user owned network (if any) | yes, if supported by the shared RAN | yes |
| network management can be carried out by PPDR users | service layer: yes network layer: no | service layer: yes network layer: only equipment of the user owned network  | service layer and core network: yes RAN: depending on agreement | yes |
| network monitoring | service layer: yes network layer: no | service layer: yes network layer: no | service layer and core network: yes RAN: depending on agreement | yes |
| user management can be carried out by PPDR users | service layer: yes network layer: if commercially agreed, possible by means of interfaces that the commercial mobile network operator uses to co-operate with service providers | yes | yes | yes |
| Inter-System Interface between user owned network and commercial mobile network is required | no | yes | no, but an interface between the core network and the RAN is required  | no |
| control room access to commercial mobile radio network | required for a few use cases (e.g. disabling after theft/loss) | not required | not required | n/a |
| requires dedicated broadband PPDR frequency spectrum | no | only if there are areas covered by a user owned network | only if there are areas covered by a dedicated RAN or if RAN sharing with dedicated spectrum is used | yes |
| single antenna dual mode (TETRA and LTE) terminals can be used | no | no | depends (400 MHz: yes; 700 MHz: no) | depends (400 MHz: yes; 700 MHz: no) |
| availability | short term | mid term (> 2018) | long term (> 2023) | long term (> 2023) |
| costs | low to medium | medium | medium to high | medium to high |

# Migration Path for Installed TETRA Networks

Operators of nationwide TETRA networks naturally want to protect their huge investments in these infrastructures. Nevertheless, these narrowband networks need to be prepared for interworking with forthcoming broadband LTE networks. Additionally, it can be foreseen that manufacturers will discontinue supporting non-IP network elements and that E1 lines will be phased out by network providers. Thus, a medium term goal of TETRA network operators should be to transform their networks into all IP infrastructures.

As a consequence of this, the fixed access network and the circuit switched core network, both formerly E1 based, need to be re-planned completely. Under certain circumstances, some older network elements such as switching exchanges will need to be replaced, too. When migrating to an all IP infrastructure, the greatest challenge is to avoid service degradation. PPDR users expect for example short call setup times (< 500 ms) for group calls and will not accept all IP infrastructures which cannot guarantee the same quality of service the previously E1 based infrastructure did provide.

Nationwide mission critical broadband voice plus data PPDR networks will not be available before at least 2025. In the meantime, non or partly mission critical broadband data PPDR networks will be used as pointed out in Section 5. The TETRA Enhanced Data Service (TEDS) could be used in order to have access to nationwide wideband mission critical packet data (1) in areas without broadband packet data coverage and (2) as a fallback when non or partly mission critical broadband packet data is temporarily not available.

The main obstacle for the nationwide introduction of TEDS so far was the lack of harmonised frequency spectrum for wideband packet data. ETSI TC TETRA WG4 is currently working on adding voice services on QAM channels, i.e. over TEDS, to the TETRA standard. Thus, a potential scenario in the future is that existing TETRA 1 networks providing voice and narrowband packet data will at least partly migrate to TETRA 2 networks providing voice and wideband TEDS packet data without having to wait for additional harmonised frequency spectrum to be used for wideband packet data.

Nevertheless, TEDS does not provide the data rates to be used for broadband applications as specified in [IABG]. This is why, operators will continue to be reluctant to upgrade to TEDS.

PPDR operating environments include:

* day-to-day operations;
* planned public events;
* unplanned large emergencies;
* disasters.

Day-to-day operations encompass the routine operations that PPDR agencies conduct within their jurisdiction. Day-to-day operations can be either mission critical or non-mission critical. Large emergencies and/or public events are those that public protection and potentially disaster relief agencies respond to in a particular area of their jurisdiction. However, they are still required to perform their routine operations elsewhere within their jurisdiction. Large emergencies or public events are usually mission critical situations. Disasters can be caused by either natural or human activity and are always mission critical situations.

Table 3 identifies which technologies could be used to address the four different PPDR operating environments. A broadband packet data wide area network based on LTE could be used in addition to a TETRA1 network for day-to-day operations.

Table 3: Layered approach to provide communications resources depending on the operational scenario

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | day-to-day operations | planned public events | unplanned large emergencies | disasters |
| mission critical narrowband voice plus data wide area network (TETRA1, TMO) | X | X | X | X |
| non-/partly mission critical broadband packet data wide area network (LTE, scenarios ‘Service Provider’ and ‘MVNO’) | X | – | – | – |
| mission critical wideband packet data wide area network (TETRA2, TEDS) *fallback solution when LTE is not  available* | X | X | X | X |
| mission critical narrowband direct mode operation (TETRA1, DMO) *fallback solution when TMO, TEDS, and LTE are not available* | X | X | X | X |
| mission critical narrowband voice plus data local area network (TETRA1, TMO) *fallback solution when TMO, TEDS, and LTE are not available* | – | X | X | X |
| fully mission critical broadband packet voice plus data wide area network (LTE-A, scenarios ‘RAN sharing’ and ‘dedicated RAN’) | X | X | X | X |

3GPP and OMA have started standardisation work on Group Communication System Enablers for LTE, direct mode/proximity-based services, resilience, and voice services, as described in further detail in [TCCA]. The TCCA predicts that the evolution will take place in the following steps:

* narrowband dedicated PPDR network (current situation),
* co-existence of a narrowband dedicated PPDR network for voice services and a co-operation with commercial mobile network operator for non mission critical data services,
* co-existence of a narrowband dedicated PPDR network for voice services and a dedicated broadband PPDR network for mission critical data services, and
* integrated broadband PPDR network for mission critical voice and data services.

# Terminals, Interoperability Testing and Certification

Besides harmonised frequency spectrum, interoperability of terminals, control rooms and infrastructures is a key enabler for a successful mission critical broadband PPDR technology.

LEWP/RCEG has identified the following groups of PPDR applications [LEWP], which require broadband capacity:

* location data services;
* multimedia (video and photo) transfer services;
* office applications;
* download of operational information;
* upload of operational information;
* online data base enquiries;
* miscellaneous, e.g. online software updates, telemetrics, paging.

TCCA so far tested and certified TETRA features of terminals. Considering the LEWP/RCEG applications matrix, interoperability in LTE based PPDR networks needs to be tested and certified in the future not for basic features at the air interface, but on application level. Due to the vast plethora of applications of different manufacturers, it will not be possible to certify all applications.

Moreover, it seems appropriate to specify, test, and certify Application Programming Interfaces (API) for applications or groups of applications as mentioned in the LEWP/RCEG applications matrix. When, for example, a terminal uses a certified location data API, then this terminal will not harm the network and would be allowed to run any location data application, which does not need to be certified on its own.

Besides interoperability and certification, one major challenge for terminal manufacturers will be to provide dual mode terminals that support broadband LTE and narrowband PPDR networks. Due to the fact that nationwide narrowband P25 networks for mission critical voice transmission are not available in North America, manufacturers will concentrate on developing terminals that support mission critical voice and broadband data transmission over LTE in the 700 MHz frequency band for this market.

In Europe with nationwide TETRA or TETRAPOL networks operated in the 400 MHz frequency band, terminal manufacturers will most probably only be able to develop single antenna dual mode terminals for voice transmission over TETRA/TETRAPOL and broadband data transmission over LTE, if regulators provide broadband PPDR frequency spectrum for this 400 MHz frequency band, too. Otherwise, dedicated terminals for broadband data transmission over LTE would be needed.

The PMR market is a niche compared to commercial mobile radio. If Europe chose the same 700 MHz frequency band as North America for PPDR broadband communications, this would have a positive effect on competition and prices for infrastructures and terminals.

# Conclusions

The following recommendations for TETRA network operators can be derived from the arguments of this white paper:

1. Start providing broadband data services to PPDR users by becoming an MVNO, see scenario ’MVNO’.
2. Agree roaming contracts with as many LTE network providers as possible in order to mitigate service disruption.
3. As a long term solution, evolve your existing narrowband TETRA network towards a mission critical broadband voice plus data LTE network.
4. Prefer a 700 MHz based LTE solution in order to benefit from a global market for mission critical LTE infrastructures and terminals.
5. Concentrate on broadband data only in the beginning and continue using voice services of your narrowband TETRA network as long as possible since mission critical LTE networks will provide group calls and group management in the far future only as good as TETRA already does today.
6. Migrate your TETRA Switching and Management Infrastructure (SwMI) to all-IP in order to facilitate interworking with LTE networks.

# Abbreviations

3GPP Third Generation Partnership Project

AGA Air-Ground-Air

API Application Programming Interface

APN Access Point Name

BDBOS Bundesanstalt für den Digitalfunk der Behörden und Organisationen mit Sicherheitsaufgaben
*Federal Agency for Digital Radio of Security Authorities and Organizations*

The Federal Agency for Digital Radio of Security Authorities and Organizations (in German: Bundesanstalt für den Digitalfunk der Behörden und Organisationen mit Sicherheitsaufgaben, BDBOS) is owner and operator of the nationwide TETRA network “Digitalfunk BOS” for PPDR users in Germany.

*See also*: [www.bdbos.bund.de](http://www.bdbos.bund.de).

BOS Behörden und Organisationen mit Sicherheitsaufgaben
*public safety services*

CCBG Critical Communications Broadband Group

DMO Direct Mode Operation

E2EE End-to-End Encryption

ECC Electronic Communications Committee

EDGE Enhanced Data Rates for GSM Evolution

ETSI European Telecommunications Standards Institute

FCC Federal Communications Commission

GGSN Gateway GPRS Support Node

GPRS General Packet Radio Service

GSM Global System for Mobile Communications

GTP GPRS Tunnelling Protocol

HSPA High Speed Packet Access

HSS Home Subscriber Server

IABG Industrieanlagen-Betriebsgesellschaft mbH

IP Internet Protocol

ISDN Integrated Services Digital Network

ISI Inter-System Interface

ITU International Telecommunication Union

LEWP Law Enforcement Working Party

LTE Long Term Evolution

LTE-A Long Term Evolution – Advanced

MVNO Mobile Virtual Network Operator

NATO North Atlantic Treaty Organization

P-GW Packet Data Network Gateway

PMIP Proxy Mobile IP

PMR Professional Mobile Radio

PPDR Public Protection and Disaster Relief

S-GW Serving Gateway

QAM Quadrature Amplitude Modulation

QoS Quality of Service

RAN Radio Access Network

RCEG Radio Communication Expert Group

SGSN Serving GPRS Support Node

SIM Subscriber Identity Module

SwMI Switching and Management Infrastructure

TC Technical Committee

TCCA TETRA + Critical Communications Association

TETRA Terrestrial Trunked Radio

TMO Trunked Mode Operation

UMTS Universal Mobile Telecommunications System

VoIP Voice over IP

VPN Virtual Private Network

WIK Wissenschaftliches Institut für Infrastruktur und Kommunikationsdienste

WG Working Group

WLAN Wireless Local Area Network

WRC World Radiocommunication Conference

# References

[3GPP-TR] 3rd Generation Partnership Project. *TS 23.251 Technical Specification Group Services and System Aspects; Network Sharing; Architecture and functional description;* Release 11, March 2013.

*See also*: http://www.3gpp.org/ftp/Specs/archive/23\_series/23.251/23251-b50.zip.

[ALU-QC] Tewfik Doumi, Mike F. Dolan, Said Tatesh, and Alessio Casati – Alcatel-Lucent, George Tsirtsis, Kiran Anchan, and Dino Flore – Qualcomm. *LTE for Public Safety Networks. In IEEE Communications Magazine*, vol. 51, no. 2, pp. 106-112, February 2013.

*See also*: <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6461193>.

[ECC] Electronic Communications Committee (ECC). *User requirements and spectrum needs for the future European broadband PPDR system (Wide Area Network)*. Draft ECC Report 199, 2013.

*See also*: [http://www.tandcca.com/Library/Documents/Broadband/Draft%20 ECCRep199%20on%20PPDR%20requirements%20for%20ECC%20for%20 PC.DOCX](http://www.tandcca.com/Library/Documents/Broadband/Draft%20ECCRep199%20on%20PPDR%20requirements%20for%20ECC%20for%20PC.DOCX).

[IABG] Industrieanlagen-Betriebsgesellschaft mbH (IABG). *Study on Medium-Term and Long-Term Capacity Requirements of PPDR Services in Wireless Communications.* Study on behalf of the German Federal Ministry of Economics and Technology (BMWi). 20th May 2010.

[ITU] International Telecommunication Union (ITU). *World Radiocommunication Conference 2015 (WRC-15).* Agenda and Relevant Resolutions, November 2012.

*See also*:<http://www.itu.int/go/wrc-15>.

[LEWP] Law Enforcement Working Party (LEWP) – Radio Communication Expert Group (RCEG). *Public safety applications matrix*. Excel table. 2012.

*See also*: <http://www.tandcca.com/Library/Documents/Broadband/LEWP-RCEG%20Matrix.xls>.

[TCCA] TETRA + Critical Communications Association (TCCA) – Critical Communications Broadband Group (CCBG). *Mission Critical Mobile Broadband: Practical standardisation & roadmap considerations.* White Paper, February 2013.

*See also*:[http://www.tandcca.com/Library/Documents/ CCBGMissionCriticalMobileBroadbandwhitepaper2013.pdf](http://www.tandcca.com/Library/Documents/%20CCBGMissionCriticalMobileBroadbandwhitepaper2013.pdf).

[WIK] WIK-Consult. *PPDR Spectrum Harmonisation in Germany, Europe and Globally.* Study on behalf of the German Federal Ministry of Economics and Technology (BMWi). 6th December 2010.

*See also*: <http://www.wik.org/uploads/media/PPDR_Harmonisation_en_public_final_01.pdf>.