TETRA Direct Mode and LTE Proximity Services (ProSe) compared:

Will device-to-device services in LTE be equivalent to TETRA DMO?

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1 Executive summary

This comparison has been commissioned by the TETRA and Critical Communications Association (TCCA) to provide today's users of TETRA off-network device-to-device services, known as Direct Mode Operation (DMO), with an understandable contrast to planned future LTE-based off-network services, known as Proximity Services (ProSe).

Today's Professional Mobile Radio (PMR), or "walkie-talkie" systems, for example TETRA, have two basic modes of operation:

a) **on-network**, where communication between users' radios is via the network of towers and base stations, and:

b) **off-network**, where users within radio range of one another can communicate directly, or "back-to-back".

In TETRA systems these two modes are called Trunked Mode Operation (TMO) and Direct Mode Operation (DMO).

In the future, it is planned that PMR-like capabilities will be available using commercial mobile phone technology such as 4G LTE, as used by today's smartphones. Currently, commercial mobile phones do not provide critical capabilities such as group communication, push to talk operation and Direct Mode. Work is still going on to develop the equipment that would add these PMR-like capabilities to future smartphone systems. This paper focuses on one element of that work and provides a comparison between today's TETRA Direct Mode Operation (DMO) and the so-called Proximity Services (ProSe) being planned for LTE systems of the future.

Today TETRA DMO is typically used for both local area communications and extension of network coverage. LTE ProSe has yet to be fully defined or implemented in practice, hence real life equipment is not yet on the market for evaluation.

Both the frequencies used for, and transmitted power of, DMO and ProSe are likely to be considerably different, resulting in overall reduced range for future ProSe devices by comparison with today's TETRA DMO. P3 received conflicting views from industry when investigating the current experience of TETRA DMO range. However it is commonly accepted that ProSe will have lower range and is therefore expected to require additional solutions for off-network communications, including for example drones with relay functions.

Hence this paper concludes that, whilst ProSe devices could provide equivalent, or in some cases even more functional device-to-device communications capabilities to DMO, TETRA and LTE off-network services will likely be fundamentally different in terms of the range over which they operate and the ways in which they might therefore need to be implemented.

2 Introducing Direct Mode and Proximity Services

Today's Professional Mobile Radio (PMR), or "walkie-talkie" systems, for example TETRA, have two basic modes of operation:

c) **on-network**, where communication between users' radios is via the network of towers and base stations, and:

d) **off-network**, where users within radio range of one another can communicate directly, or "back-to-back".

In TETRA systems these two modes are called Trunked Mode Operation (TMO) and Direct Mode Operation (DMO).

Users of TETRA radios have become familiar with the ability to switch between TMO and DMO in particular situations, such as using DMO in areas where network signals may not be available, or where it is desired operationally for a particular group of users working in close proximity to one another to communicate off-network.

In the future, it is planned that PMR-like capabilities will, for the first time, be available using commercial mobile phone technology such as 4G LTE, as used by today's smartphones. Currently, commercial mobile phones do not provide the critical facilities used in their everyday work by TETRA and other "walkie-talkie" users, such as group communication, push to talk operation and Direct Mode. So for example if your personal smartphone has no network signal, no "bars on the screen", it is useless and won't make or receive calls until it comes back into coverage of the network.

Work is still going on to develop the specifications and equipment that would add these PMR-like capabilities to smartphone, LTE-based systems. This paper focuses on one element of that work and provides a comparison between today's **TETRA Direct Mode Operation (DMO)** and the so-called **Proximity Services (ProSe)** being planned for LTE systems of the future.

3 Comparing TETRA DMO with LTE ProSe

In attempting a comparison it is important to appreciate that the LTE Proximity Services (ProSe) standards are still a work in progress in terms of technology specifications. Hence ProSe has yet to be fully defined or implemented in practice, and real life equipment is not yet on the market for evaluation.

So whereas we can understand and experience today the capabilities and limitations of TETRA DMO, we can only assume how ProSe might work from first principles and the currently incomplete standards specifications. However, there are several fundamental principles of radio communication that we can take as a basis for assumption of how ProSe might compare with DMO. These include for example the relative radio power output and frequency bands used respectively by TETRA and LTE handsets.

The following sections briefly summarise some detailed analysis and comparisons provided in full at Appendix A, section 5 of this document.

3.1 TETRA Direct Mode

TETRA Direct Mode Operation enables communication between mobile users without the use of network infrastructure. This is a facility mandated and used by many traditional PMR user organizations for several decades.

3.1.1 Use Cases

The typical use cases for TETRA DMO comprise local area communications on the one hand and the extension of network coverage on the other hand.

The aim of TETRA network coverage extension using DMO is to provide coverage, especially for handportable communications, in areas where the TETRA network coverage isn't sufficient or at times when the network is highly loaded or fails. Equally, by operating a vehicle mounted terminal with gateway functionality a link between one or more handportable radio terminals in DMO and other users connected to the TETRA network can be established.

3.1.2 Services and Capabilities

TETRA DMO supports voice calls, Short Data Service (SDS) and circuit mode data with up to 7.2 kbps gross data rate. The voice services are based on circuit switching technology. All DMO services have point-to-point as well as point-to-multipoint addressing capabilities allowing resource efficient channel allocations.

In DMO emergency calls are supported, i.e. pre-emptive priority group calling. DMO terminals generally support only one group per direct mode radio frequency carrier, e.g. only one group is able to communicate using a specific DMO radio frequency carrier at any given time. As a consequence, a major difference between TETRA trunked and direct mode operation is that in the latter only simplex voice operation is supported for both individual and group call operation, and only single-slot circuit mode data is allowed.

TETRA DMO provides, as an option, call confidentiality against eavesdropping by means of air interface encryption. This air interface encryption implicitly provides authentication as another security feature. Additionally, end-to-end encryption is supported in DMO.

3.1.3 Frequency

DMO channels are often located in a sub-band at one end of each of the available TETRA frequency allocations, and internationally agreed common channels have been adopted in Europe. For national use, each country is free to allocate DMO channels within the base station transmit and receive bands, or in different frequency bands.

Depending on national allocations, TETRA networks are operated in parts of the frequency bands 350-370 MHz, 380-400 MHz, 406-430 MHz, 450-470 MHz and / or 870-921 MHz.

In situations where the number of DMO terminals in close proximity is high, the possibility of interference rises. Tactical measures need to be taken to coordinate the frequency usage under such circumstances. Alternatively, DMO gateways transmitting a presence signal may be used to organise channel usage. The presence signal indicates the gateway's presence on a channel and contains the gateway address as well as the individual and group addresses for which gateway service is offered. A DMO terminal within the DMO gateway's coverage will direct a group call set-up to the gateway. The Gateway will grant the DMO call as soon as the TETRA network has allocated a time slot.

3.1.4 Power and Range

All TETRA handportable terminals support power class 4 (1 Watt) and some power class 3L (1.8 Watt). Due to the limited battery capacity of handportable terminals power classes with higher transmit powers are not supported. Vehicle mounted terminals support power class 3 (3 Watt).

The maximum distance between transmitting and receiving TETRA DMO terminals does not only depend on the maximum transmit power and the frequencies being used but due to the nature of radio propagation on the properties of the area where the terminals are being used and the required link reliability.

3.2 LTE Proximity Services

Proximity Services (ProSe) in LTE was first proposed to the standards body 3GPP to satisfy the requirements of public safety and other critical users requiring the ability to communicate directly among devices when there is no sufficient network coverage or capacity.

ProSe also represents a current trend in the commercial domain to satisfy proximity-based value-added services including but not limited to advertising, automation, geo-fencing, gaming with integration of real world elements and social matching.

The basic ProSe standards were specified in LTE Release 12, enhanced in LTE Release 13 and will probably be continually added to in subsequent 3GPP releases to cater for mission critical users' requirements.

3.2.1 Use Cases

In the off-network case, where LTE network coverage is not available, critical communications ProSe-enabled devices need to discover and communicate with each other outside the normal functionality of the network.

ProSe is intended to provide highly power-efficient, privacy-sensitive, spectrally efficient and scalable device-to-device communications. ProSe discovery identifies ProSe-enabled devices in proximity of one another using the LTE radio interface with or without using the network infrastructure - ProSe direct discovery - or using Enhanced Packet Core (EPC) - ProSe EPC-level discovery. The communication path can be established through the LTE radio interface either directly between the ProSe-enabled devices or routed via local LTE infrastructure, if available. The communication path could also be established over WLAN.

A ProSe device to network relay function is defined in LTE Release 13 and allows a device to act as a relay between the LTE network and devices not served by the network.

3.2.2 Services and Capabilities

ProSe discovery identifies that ProSe-enabled devices are in proximity. ProSe discovery is a stand-alone feature, i.e. its use is not necessarily tied to direct communication.

Network-independent direct communication does not require any network assistance to authorize the device-to-device communication, but a pre-authorisation of devices for such off-network operation is required. The communication is performed only using information and functionality available in the devices. For public safety specific usage, ProSe-enabled public safety devices can establish the communication path directly between two or more ProSe-enabled public safety devices, regardless of whether the ProSe-enabled public safety device is served by an LTE network.

Public Safety ProSe-enabled devices can automatically use ProSe when LTE network coverage is not available or the user can manually set the device to use direct discovery and direct communication even when LTE network coverage is available.

3.2.3 Frequency

ProSe in general is band specific and designed to operate in the defined LTE frequency bands. Even if public safety ProSe-enabled device can be operated in public safety as well as in commercial spectrum, only public safety spectrum is used for public safety ProSe. For example, band 14 (788-798 MHz) has been allocated in the U.S. and Canada and band 28 (703 MHz-748 MHz) in South Korea. **Thus public safety LTE services can be expected to be operated in frequency bands of almost double those generally used by TETRA today.**

ProSe is currently being analysed with regard to interference concerns. Questions of interest include adjacent band LTE interference, especially from device transmission in LTE band 13 to device-to-device communications in band 14, and conventional land mobile radio networks in neighbouring bands.

3.2.4 Power and Range

The maximum allowed transmit power of devices using ProSe is band specific. In general, for the ProSe bands described above power class 3 i.e. a maximum transmit power of 200 mW is specified. In LTE Release 11 a high-power device with 1 W (31 dBm) maximum transmit power was defined for band 14 (USA) only.

In LTE direct discovery trials held in 2014 in Bonn, Germany, discovery ranges observed were 550 m in a rural area, 350 m in an urban area with line of sight, and 170 m in an urban area with non-line of sight[1].

Due to the higher required input signal for direct communication as against discovery it can be expected that the maximum range for ProSe communication will be lower than the ranges observed for discovery during the trial.

P3 received conflicting views from industry when investigating the current experience of TETRA DMO range. However it is commonly accepted that ProSe will have lower range and is therefore expected to require additional solutions for off-network communications, including for example drones with relay functions.

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[1] see the White Paper published here

4 Conclusion: Will LTE ProSe be equivalent to TETRA DMO?

Are LTE handsets of the future using ProSe to communicate off-network with one another likely to be equivalently functional to today's TETRA radios working in Direct Mode? The short answer is no, they are not.

ProSe devices should provide equivalent, or in some cases even more functional device-to-device communications capabilities compared to DMO. However TETRA and LTE off-network services will likely be fundamentally different in terms of the range over which they operate and the ways in which they might therefore need to be implemented in practice.

5 Appendix A: Comparison of technologies and standards

5.1 TETRA Direct Mode

TETRA Direct Mode Operation enables communication between TETRA mobile users without the use of TETRA network infrastructure. This mode has been a facility mandated and used by many traditional PMR user organizations for several decades.

5.1.1 Use Cases

The typical use cases for TETRA DMO comprise local area communications on the one hand and the extension of network coverage on the other hand.

The aim of TETRA network coverage extension using DMO, i.e. the pure direct communication between two or more TETRA radio terminals without any network infrastructure being involved, is to provide coverage especially for handportable communications in areas where the TETRA network coverage isn't sufficient or at times when the network is highly loaded or fails. Another use case covers communications for localised activities within network coverage while a connection to the TETRA network is not needed or not wanted (private communications).

Since international roaming of devices between different national TETRA networks – in contrast to roaming in public mobile radio networks – is very restricted, TETRA DMO might be used by foreign public safety forces while operating across state borders.

By operating a vehicle mounted terminal with gateway functionality a link between one or more handportable radio terminals in DMO and other users connected to the TETRA network is established. For local area communications typically a RF coverage range of approximately 250 m is required. For scenarios with higher range requirements, a DMO repeater mode is defined in the TETRA standard. The TETRA standard explicitly allows the combination of gateway and DMO repeater functionality.

5.1.2 Services and Capabilities

TETRA DMO supports voice calls and connectionless data messaging (Short Data Service, SDS). Supported data services comprise circuit mode data with 2.4, 4.8 or 7.2 kbit/s gross data rate (depending on the channel coding scheme used) and short data service for the transmission of 16, 32, 64 or 2039 bits of user data. The voice services are based on circuit switching technology. All DMO services have point-to-point as well as point-to-multipoint addressing capabilities allowing resource efficient channel allocations.

In DMO emergency calls are supported, i.e. pre-emptive priority group calling. DMO terminals (except some DMO repeater / gateway types) support only one group per direct mode radio frequency carrier, e.g. only one group is able to communicate using a specific DMO radio frequency carrier at any given time. Two of the four time slots defined in the TETRA standard are used: one as traffic channel, another for signalling transmissions, and the remaining two time slots are kept free. As a consequence, a major difference between TETRA trunked and direct mode operation is that in the latter only simplex voice operation is supported for both individual and group call operation, and only single-slot circuit mode data is allowed.

TETRA DMO provides, as an option, call confidentiality against eavesdropping by means of air interface encryption. This air interface encryption implicitly provides authentication as another security feature. Additionally, end-to-end encryption is supported in DMO.

5.1.3 Frequency

In contrast to the trunked mode operation which makes use of duplex spacing, up- and downlink of a DMO connection are operated on the same frequency channel with 25 kHz channel spacing. Frequency separation between the allocation for DMO and TMO services is widely in place to minimize the risk of mutual interference. This can be achieved by operating DMO in a sub-band at one end of each of the available TETRA frequency allocations and has been adopted for internationally agreed common channels in Europe. For national use each country is free to allocate DMO channels within the base station transmit and receive bands, or in different frequency bands. Depending on national allocations, TETRA networks are operated in parts of the frequency bands 350-370 MHz, 380-400 MHz, 406-430 MHz, 450-470 MHz and / or 870-921 MHz.

In situations where the number of DMO terminals in close proximity is high, the possibility of interference rises. Tactical measures need to be taken to coordinate the frequency usage under such circumstances. Alternatively, DMO gateways transmitting a presence signal may be used to organise channel usage. The presence signal indicates the gateway’s presence on a channel and contains the gateway address as well as the individual and group addresses for which gateway service is offered. A DMO terminal within the DMO gateway’s coverage will direct a group call set-up to the gateway. The Gateway will grant the DMO call as soon as the TETRA network has allocated a time slot.

5.1.4 Power and Range

The nominal power classes defined for TETRA terminals in DMO range from 1 W to 30 W and are listed in Table 1 below. All handportable terminals support power class 4 and some power class 3L. Due to the limited battery capacity of handportable terminals power classes with higher transmit powers are not supported. Vehicle mounted terminals support power class 3 (3 Watt).

Table 1: Nominal Power Classes for TETRA Terminals in DMO

Power class	Nominal power
1 (30 W)	45 dBm
1L (17.5 W)	42.5 dBm
2 (10 W)	40 dBm
2L (5.6 W)	37.5 dBm
3 (3 W)	35 dBm

Power class	Nominal power
3L (1.8 W)	32.5 dBm
4 (1 W)	30 dBm

The maximum distance between transmitting and receiving TETRA DMO terminals does not only depend on the maximum transmit power and the frequencies being used but due to the nature of radio propagation on the properties of the area where the terminals are being used and the required link reliability.

5.2 LTE Proximity Services

The delivery of applications and services based on proximity represents a current trend in the commercial domain: applications discover other instances on devices within proximity of each other and exchange application-related data. Potential proximity-triggered services include but are not limited to advertising, automation, geo-fencing, gaming with integration of real world elements and social matching. In addition to that, the interest of public safety and other critical users focusses on devices with the ability to communicate directly among themselves when there is no sufficient network coverage or capacity.

The basic ProSe standards were specified in LTE Release 12, enhanced in LTE Release 13 and will probably be continually added to in subsequent 3GPP releases to cater for mission critical users requirements.

5.2.1 Use Cases

A main characteristic of the LTE architecture is that every evolved node B (eNB), i.e. the LTE base station, strongly depends on the evolved packet core (EPC), i.e. the LTE core network, for all services provided. In case an eNB is disconnected from the EPC, communication services, even locally, are interrupted. In the off-network case (absence of LTE network coverage), public safety devices need to discover and communicate with each other by taking partial control of the functionality of the network.

ProSe is intended to provide highly power-efficient, privacy-sensitive, spectrally efficient and scalable device-to-device communications under control of the LTE network operator. ProSe discovery identifies ProSe-enabled devices in proximity of another using the LTE radio interface with or without using the network infrastructure (ProSe direct discovery) or using EPC (ProSe EPC-level discovery). ProSe communication denotes a communication between two or more ProSe-enabled devices in the proximity. The communication path can be established through the LTE radio interface either directly between the ProSe-enabled devices (ProSe direct communication) or routed via local eNBs. The communication path could also be established over WLAN.

A device to network relay function is defined in LTE Release 13 and allows a device to act as a relay between the LTE network and devices not served by the network. This will help to overcome the tight interaction between devices and the LTE network.

The major commercial driver for the introduction of ProSe is the support of discovery and direct communication between a large number of different user devices (including wearables) under the control of the mobile network operator.

5.2.2 Services and Capabilities

ProSe discovery identifies that ProSe-enabled devices are in proximity. The ProSe discovery is a stand-alone feature, i.e. its use is not necessarily tied to direct communication.

Use cases for discovery differentiate between announcing a device's presence to other devices and transmitting a request from a discovering device to other devices. In LTE Release 12 the announcing use case has been implemented.

ProSe direct communication enables the establishment of communication paths between two or more ProSe-enabled devices that are in direct communication range. The ProSe direct communication path could use the LTE network or WLAN. A network-dependent direct communication mode and a network-independent direct communication mode is considered in LTE ProSe. Network-independent direct communication does not require any network assistance to authorize the device-to-device communication, but a pre-authorisation of devices is required. The communication is performed only using information and functionality available in the devices. For public safety specific usage, ProSe-enabled public safety devices can establish the communication path directly between two or more ProSe-enabled public safety devices, regardless of whether the ProSe-enabled public safety device is served by an LTE network.

ProSe direct communication is also facilitated by the use of a ProSe device-to-network relay, which acts as a relay between the LTE network and ProSe-enabled devices.

The ProSe function consists of mechanisms on LTE radio level that enable discovery and communication between two or more devices and mechanisms in the network to control ProSe. ProSe describes an end-to-end application and has three parts:

- **ProSe application:** provides ProSe discovery and ProSe communication features on the devices.
- **ProSe application server:** manages ProSe on application level.
- **ProSe function:** provides the devices with parameters in order to use ProSe discovery and ProSe communication. This includes parameters needed for ProSe direct communication in the off-network case. The ProSe function also provides the necessary functionality to collect charging data, support network-assistant discovery and so on.

Direct communication is also called device-to-device communication and the radio link between two devices is called sidelink.

The capabilities can be used by any application running on a ProSe-enabled device. Two types of ProSe-enabled devices with different feature sets have been defined: a public safety type and a non-public safety type. The public safety ProSe-enabled devices have to support direct communication, while direct discovery can be omitted. Outside network operation and one-to-many ProSe direct communication are limited to public safety ProSe-enabled devices only. It is up to the manufacturers of devices whether to implement the ProSe capabilities or not.

Public Safety ProSe-enabled devices can automatically use ProSe when LTE network coverage is not available or the user can manually set the device to use direct discovery and direct communication even when LTE network coverage is available.

With LTE Release 12 broadcast direct communication is supported. In addition, LTE Release 13 introduces unicast and groupcast direct communication. Regardless of the addressing direct communication the ProSe-enabled device should receive the information regardless of whether or not it has been discovered by the transmitting device.

The ProSe function in the evolved packet core (EPC), i.e. the LTE core network, is necessary for service authorization and provisioning and setting radio and security parameters. The mobile network can control resources used for ProSe and must authorize the use of ProSe direct communication. This network control is necessary because in many countries licensing terms require the operator to be in control how their licensed spectrum is used.

For commercial use cases the mobile network operator might configure whether ProSe discovery is enabled or disabled and whether being discovered is enabled or disabled. The network operator shall be able to authorise public safety devices to establish data sessions between them using ProSe.

Online and offline charging are defined for ProSe direct discovery as well as EPC-Level discovery. Online charging is not applicable for ProSe public safety one-to-many direct communication.

On bearer level, LTE ProSe uses an identity-based crypto approach. Thus the devices need to have algorithms and ProSe group keys pre-provisioned for each group they belong to. On the media plane the integrity and confidentiality is protected using Secure Real Time Protocol (SRTP) and Secure RTCP.

5.2.3 Frequency

ProSe in general is band specific and designed to operate in the frequency bands listed in Table 2. Even if public safety ProSe-enabled device can be operated in public safety as well as in commercial spectrum, only public safety spectrum is used for public safety ProSe. For example, band number 14 has been chosen in the U.S. and Canada and band number 28 in South Korea. Within the allocated spectrum, LTE defines individual RF channel bandwidth, cp. Table 2. The same channel bandwidth is specified for both the transmit and receive path. Channel bandwidths 1.4 and 3 MHz have not been defined for any ProSe band.

Table 2: ProSe Frequency bands and channel bandwidth

ProSe band	Frequency band	ProSe direct discovery channel bandwidths	ProSe direct communication channel bandwidths
2	1850-1910 MHz	5, 10, 15, 20 MHz	-
3	1710-1785 MHz	5, 10, 15, 20 MHz	10 MHz

ProSe band	Frequency band	ProSe direct discovery channel bandwidths	ProSe direct communication channel bandwidths
4	1710-1755 MHz	5, 10, 15, 20 MHz	-
7	2500-2570 MHz	5, 10, 15, 20 MHz	10 MHz
14	788-798 MHz	5, 10 MHz	10 MHz
20	832-862 MHz	5, 10, 15, 20 MHz	10 MHz
26	814 MHz-849 MHz	5, 10, 15 MHz	10 MHz
28	703 MHz-748 MHz	5, 10, 15, 20 MHz	10 MHz
31	452.5 MHz-457.5 MHz	5 MHz	5 MHz
41	2496 MHz-2690 MHz	5, 10, 15, 20 MHz	-
68	698 MHz-728 MHz	5, 10, 15, 20 MHz	-

ProSe is currently being analysed with regard to interference concerns. Questions of interest include adjacent band LTE interference (especially from device transmission in LTE band 13 to device-to-device communications in band 14) and conventional land mobile radio networks in neighbouring bands.

5.2.4 Power and Range

The maximum allowed transmit power of devices using ProSe is band specific, too. In general, for the ProSe bands described above power class 3 is allowed which equals 23 dBm maximum transmit power. In LTE Release 11 a high-power device with 31 dBm maximum transmit power was defined for band 14 (USA) only. The maximum transmit power might be reduced by one to three dB for simultaneous ProSe sidelink and LTE uplink transmissions.

The reference sensitivity for ProSe not only depends on the ProSe band and on the channel bandwidth, but it is different for direct discovery and direct communication. For direct communication an input signal with about 5.5 dB more power is needed.

In September 2014 Deutsche Telekom, Huawei, and Qualcomm jointly conducted a LTE direct discovery trial in Bonn, Germany. With this trial the discovery performance of LTE pre-standards implementation on Qualcomm prototype devices and Huawei infrastructure was tested. The discovery range observed are 550 m in a rural area, 350 m in an urban area with line of sight, and 170 m in an urban area with non-line of sight (see the White Paper published here).

Due to the higher required input signal for direct communication it can be expected that the maximum range for direct communication will be smaller than the ranges observed during the trial.

The shorter range of LTE ProSe in comparison to TETRA DMO will raise the request for additional solutions for off-network communications or managing lacks of coverage. Such solutions might include for example drones with relay functions, autonomous networks and the reuse of diverse radio or wired accesses. Due to its broadband capabilities, LTE is a promising option for future public safety mobile radio networks. As public safety forces do also require communication capabilities in the off-network scenario, multimedia support in LTE ProSe needs to be developed and implemented.

6 Comparing the technology standards: TETRA DMO vs. LTE ProSe

Both standards, TETRA DMO and LTE ProSe, provide communication mechanisms to have a fallback communication solution in case there is a network outage or congestion or the users decide to disconnect from the network and use direct communication without involving the network infrastructure.

Terrestrial Trunked Radio (TETRA) is one of a number of digital wireless communication technologies standardized by the European Telecommunications Standards Institute (ETSI). With standards successfully established now for narrowband and wideband TETRA, ETSI technical committee TETRA and Critical Communications Evolution (TCCE) is focussing on enhancing existing standards for technologies, such as LTE, by the development of interfaces and applications, to make them suitable for mission-critical applications. Active TCCE working groups are;

- WG1 TCCE User Requirements / Services,
- WG3 TCCE Air Interface and Network Protocols,
- WG4 TCCE High Speed Data,
- WG5 TCCE Voice coding,
- WG6 TCCE Security and
- WG8 TCCE Off-network services.

TETRA DMO is implemented in TETRA devices since years and still maintained by TCCE. TCCA's TETRA DMO standards documents are listed in Table 3.

Table 3: TETRA DMO standards documents

Document number	Document title
ETSI TR 102 021-12	Terrestrial Trunked Radio (TETRA), User Requirement Specification TETRA Release 2.1, Part 12: Direct Mode Operation (DMO)
ETSI TR 102 300-3	Terrestrial Trunked Radio (TETRA), Voice plus Data (V+D), Designers' guide, Part 3: Direct Mode Operation (DMO)
ETSI EN 300 396-1	Terrestrial Trunked Radio (TETRA), Technical requirements for Direct Mode Operation (DMO), Part 1: General network design
ETSI EN 300 396-2	Terrestrial Trunked Radio (TETRA), Technical requirements for Direct Mode Operation (DMO), Part 2: Radio aspects
ETSI EN 300 396-3	Terrestrial Trunked Radio (TETRA), Technical requirements for Direct Mode Operation (DMO), Part 3: Mobile Station to Mobile Station (MS-MS) Air Interface (AI) protocol
ETSI EN 300 396-4	Terrestrial Trunked Radio (TETRA), Technical requirements for Direct Mode Operation (DMO), Part 4: Type 1 repeater air interface
ETSI EN 300 396-5	Terrestrial Trunked Radio (TETRA), Technical requirements for Direct Mode Operation (DMO), Part 5: Gateway air interface
ETSI ETS 300 396-6	Terrestrial Trunked Radio (TETRA), Direct Mode Operation (DMO), Part 6: Security
ETSI EN 303 035-2	Terrestrial Trunked Radio (TETRA), Harmonized EN for TETRA equipment covering essential requirements under article 3.2 of the R&TTE Directive, Part 2: Direct Mode Operation (DMO)
ETSI TR 100 392-17	Terrestrial Trunked Radio (TETRA), Voice plus Data (V+D), Part 17: TETRA V+D and DMO specifications
ETSI TS 100 392-5	Terrestrial Trunked Radio (TETRA), Voice plus Data (V+D) and Direct Mode Operation (DMO), Part 5: Peripheral Equipment Interface (PEI)
ETSI TS 100 392-18-1	Terrestrial Trunked Radio (TETRA), Voice plus Data (V+D) and Direct Mode Operation (DMO), Part 18: Air interface optimized applications, Sub-part 1: Location Information Protocol (LIP)
ETSI TS 100 392-18-2	Terrestrial Trunked Radio (TETRA), Voice plus Data (V+D) and Direct Mode Operation (DMO), Part 18: Air interface optimized applications, Sub-part 2: Net Assist Protocol (NAP)

Document number	Document title
ETSI TS 100 392-18-3	Terrestrial Trunked Radio (TETRA), Voice plus Data (V+D) and Direct Mode Operation (DMO), Part 18: Air interface optimized applications, Sub-part 3: Direct mode Over The Air Management protocol (DOTAM)
ETSI TS 100 392-18-4	Terrestrial Trunked Radio (TETRA), Voice plus Data (V+D) and Direct Mode Operation (DMO), Part 18: Air interface optimized applications, Sub-part 4: Net Assist Protocol 2 (NAP2)

The 3rd Generation Partnership Project (3GPP) covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities - including work on codecs, security and quality of service. The specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks. The four Technical Specification Groups (TSG) in 3GPP are;

- Radio Access Networks (RAN),
- Service & Systems Aspects (SA),
- Core Network & Terminals (CT) and
- GSM EDGE Radio Access Networks (GERAN).

The TSG Service and System Aspects (TSG-SA) works on technical specification for the overall architecture and service capabilities of systems based on 3GPP specifications. First specifications of LTE ProSe have been included in LTE Release 12. ProSe enhancements have been added to LTE Release 13, whose stage 1 recently has been frozen. Meanwhile 3GPP has started working on the evolution of LTE specifications in Release 14. The most relevant LTE ProSe standards documents are listed in Table 4.

Table 4: LTE ProSe standards documents

Document number	Document title
3GPP 22.115	Service aspects; Charging and billing
3GPP 22.278	Service requirements for the Evolved Packet System (EPS)
3GPP 22.803	Feasibility study for Proximity Services (ProSe)
3GPP 23.303	Proximity-based services (ProSe); Stage 2
3GPP 23.703	Study on architecture enhancements to support Proximity-based Services (ProSe)
3GPP 24.333	Proximity-services (ProSe) Management Objects (MO)

Document number	Document title
3GPP 24.334	Proximity-services (ProSe) User Equipment (UE) to ProSe function protocol aspects; Stage 3
3GPP 29.343	Proximity-services (ProSe) function to ProSe application server aspects (PC2); Stage 3
3GPP 29.344	Proximity-services (ProSe) function to Home Subscriber Server (HSS) aspects; Stage 3
3GPP 29.345	Inter-Proximity-services (Prose) function signalling aspects; Stage 3
3GPP 32.277	Telecommunication management; Charging management; Proximity-based Services (ProSe) charging
3GPP 32.844	Study of charging support of Proximity-based Services (ProSe) direct communication for public safety use
3GPP 33.303	Proximity-based Services (ProSe); Security aspects
3GPP 33.833	Study on security issues to support Proximity Services
3GPP 36.843	Study on LTE device to device proximity services; Radio aspects
3GPP 36.877	LTE Device to Device Proximity Services; User Equipment (UE) radio transmission and reception