

WHITEPAPER

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# TETRA AND DMR TIER III: WHICH OPEN STANDARD DIGITAL TRUNKING IS RIGHT FOR ME?

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**sepura**

Going further in critical communications



The last few decades have seen the emergence of two major open standard digital technologies for trunking radio: TETRA and DMR Tier III. The first to appear was TETRA (short for 'TERrestrial TRunked RADio') which initially targeted mission-critical communications such as public safety and defense but expanded its scope to include transport and utilities. Later on Digital Mobile Radio (DMR) was developed as a direct replacement for analog private mobile radio to provide cost-effective, low-complexity, business-critical digital radio solutions, originally for transport and utilities. DMR, too, has expanded its scope to include mission-critical and commercial communications. Both technologies offer the advantages over analog of digital audio quality, better spectral efficiency, improved data capability, enhanced portable battery life, and being open standard, interoperability across brands. The standards for both of these technologies are managed by the European Telecommunications Standards Institute (ETSI).

### WHICH TECHNOLOGY IS RIGHT FOR ME?

While both technologies support integrated voice and data, TETRA is designed to be capable of meeting the data-oriented communications requirements of the largest agencies or organizations operating in dense urban environments whereas DMR is designed to provide the most cost-effective digital voice-oriented communications solutions for smaller agencies or for organizations operating in rural and semi-rural environments. Nevertheless, the intended markets for TETRA and DMR Tier III will overlap.

To get a better understanding of this answer let's review the technical characteristics and key differences of the two technologies. We'll consider how to configure radio sites, the communications features they support, their respective coverage performance and who manufactures equipment for each technology. We can then evaluate DMR Tier III and TETRA against some practical use cases, with a recommendation for one technology or the other. But as you might expect, there are cases where both DMR Tier III and TETRA offer equally strong solutions, with multiple vendors available to support either option.

# DMR

## DMR Technical Overview

The DMR suite of standards is developed and managed by ETSI in conjunction with vendor members of the DMR Association (which also ensures multi-vendor interoperability and promotes the technology). The standards are defined in operational 'tiers':

**Tier I**, which specifies license-free low power operation in frequencies between 446.100 - 446.200MHz, mainly for personal or recreational users. Communication services are very basic with no use of repeaters, no telephone interconnect, and time-limited talk. Tier I operation lies outside the scope of this paper.

For mission-critical and business-critical communications, however, there are Tier II and Tier III.

**Tier II**, which specifies higher power digital conventional (that is, non-trunked) operation in any licensed band between 66 MHz and 960 MHz. Communication services are far more sophisticated with repeater networks, advanced call services, IP data services, telephone interconnect, dispatch connection and secure communications available.

DMR supports both voice and data services and on a trunked network, channels can be dynamically allocated to the service that is required. With DMR, priority levels will ensure that traffic with the highest priority will get through.

In trunking operation, a special computer called a 'controller' automatically allocates traffic channels from a pool of free channels. A dedicated channel (the 'control channel') enables radio users to send call requests to the controller and for the controller to assign a free channel for the calling and called parties to use. If all the channels are in use, the call can be queued until a channel becomes available. Tier III (Trunked DMR) reserves one of its time slots (typically the first in any Base Station) to act as a control channel for the site at which the base station is located. This control slot, which continually connects the system and radio users, enables users to roam throughout the entire system without any user intervention.

**Tier III**, which adds full digital trunking operation to Tier II capabilities, based upon the MPT1327 analog trunking open standard, whereby radio channels that are available can be shared amongst users more efficiently.

The DMR Tier II/Tier III air interface uses 2-slot Time Division Multiple Access (TDMA) in a 12.5kHz channel spacing, enabling easy migration from narrow band analog and providing superior spectral efficiency (since each channel can now carry two voice/data traffic paths giving the equivalent of a 6.25kHz voice/data channel). The air interface utilizes 4FSK constant envelope modulation (4-Level Frequency Shift Keying) and includes forward error correction

(FEC) as standard. Most manufacturers offer DMR utilizing the AMBE+2 dual-rate speech vocoder developed by Digital Voice Systems, Inc. (DVSI), as recommended by the DMR Association. (Equipment which uses another vocoder will not interoperate, restricting choice for the user). The result is an air interface that offers clear digital voice, can support a variety of advanced voice and data services, and is optimized for wide-area coverage.

There are two forms of trunking, both of which are supported by DMR Tier III. In **message trunking**, the same channel is held for an entire conversation, including pauses. Cellphone systems typically use this form of trunking. When a call is set up, some time is spent allocating a channel (and any other required resources) for the call to use. The channel is released to the pool only when the conversation is completed (or because a user-defined timer, called a 'hang timer', expires). The chief advantage of this form of trunking is that the channel remains allocated for the entire period of the call. The hang timer is adjustable, enabling an organization to better manage its traffic by setting the timer to limit call times to a known length.

More efficient is **transmission trunking**, in which the channel is held only for the duration of a single transmission. Consider a conversation on a police radio in which each party in the conversation presses the PTT button when they wish to speak. The channel is released when the PTT is released. As a result, the conversation occurring over multiple transmissions may involve several different radio channels since the controller can assign a new channel at each press of the PTT. Since the channel is not tied up by pauses in the conversation, it is available to other callers and thus allows the maximum number of users to share the minimum number of channels. However, if call loadings are high, then users can be forced to queue since each over requires a channel to be reallocated (with a small time penalty) rather than holding onto the original channel.

DMR trunking is highly configurable, enabling not only the best utilization of channels but supports multiple call types, fleet numbering schemes, and great flexibility in system design. Tier II (Conventional DMR), by contrast, is really just a digital version of a basic analog radio repeater system. There is no control slot as channels and slots are assigned during programming. Any DMR Tier II system that acts in a pseudo-trunked manner is therefore proprietary and will have limited interoperation with other vendors' products.

Whether Tier II or Tier III, a DMR system can support simulcast operation, although only a few manufacturers support this. While simulcast offers all-informed broadcast-style communications with one (or two) carriers, this type of operation really makes sense for organizations that have relatively few callers communicating over very wide areas. Because a DMR channel can carry at most two simultaneous calls, simulcast is inherently capacity-constrained.

## DMR SITE CONFIGURATION

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A DMR Tier III system typically consists of a number of sites, each containing one or more DMR base repeaters. At each site the repeaters are connected to the controller via an IP router or switch. The sites themselves are also connected over an IP backbone to a master router or switch that, in turn connects to the system controller and to other systems (such as a dispatch system or a network management system).

At each site the first repeater has one control slot and one traffic slot. The remaining repeaters at the site are all traffic channels with two slots per repeater. The two-slot arrangement permits a transmission). This 'back channel' communication provides a handy option for controlling DMR equipment 'on the fly'. In this example it allows a user to be removed from a call to be joined to an emergency call, without having to wait for the user to release the PTT.

## DMR TIER III FEATURES

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Although DMR Tier III is relatively new, it is nevertheless a feature-rich technology, offering a variety of call types, short data and IP data services, simultaneous voice and data calling, encrypted voice and data communications, and direct mode (radio-to-radio) communications.

Many of the advanced features of DMR Tier III are similar to (and even drawn from) the voice and short messaging services of the analog MPT1327 trunking standard. These include:

- Group call
- Individual call
- Broadcast call
- Radio check
- All call
- Call alert
- Radio disable/enable
- Remote monitor
- Emergency alarm
- Remote monitor
- Emergency call
- Status call
- MS authentication
- MS registration
- PTT Id

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“Although DMR Tier III is relatively new, it is nevertheless a feature-rich technology”

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## DMR TIER III COVERAGE

Broadly speaking, DMR coverage (whether Tier II or Tier III) is comparable to that of analog or MPT1327 radio with similar RF characteristics. Technology-specific factors that affect coverage include delay spread and its impact on DMR's 4FSK modulation, the guard time between the DMR time slots, and the link budget which defines the maximum signal loss that can be allowed between a DMR transmitter and a receiver before communications fail. The guard time required by DMR (1ms) gives it a theoretical range limit of approximately 75km (47miles).

In real equipment, however, other factors will reduce this range limit to a value that is nevertheless excellent. DMR terminal equipment can be designed with excellent receiver sensitivity (around -112dB uplink or downlink). DMR equipment can thus tolerate a relatively high signal loss before communications are lost. Consequently it is not unrealistic to expect DMR mobile coverage up to 65+km (40+ miles), and DMR portable coverage up to 9.5-13km (6-8 miles) indoor to the first wall, or up to 13-19km (8-12 miles) outdoors.

## DMR TIER III APPLICATIONS

DMR Tier III technology enables a range of mission-critical and business-critical applications to be deployed. Public safety, utility, and transport customers benefit from automatic vehicle location/automatic person location (AVL/APL) applications based upon the DMR location services standard (Location Information Protocol (LIP)) and from a full voice over IP dispatch console connection based upon the DMR Application Interface Specification (AIS). Utilities customers benefit from the reliable and secure transport of critical SCADA and telemetry traffic using a combination of DMR Short Data Service together with prioritization of user authentication and data encryption.

## DMR III MULTI-VENDOR AND INTEROPERABILITY SUPPORT

As an open standard, DMR Tier III is supported by a number of manufacturers (see <http://dmrassociation.org/manufacturers/> for a comprehensive list). The DMR Interoperability Process (DMR IOP) developed by the DMR Association ensures that equipment from different vendors will work together by certifying the combinations of equipment that pass the test program and publishing test results. Notifications of IOP certificates issued so far are to be found on the Association's web site at <http://dmrassociation.org/category/iop-certificates-and-test-results/>. With this information customers know that they can buy cost and quality-competitive equipment from more than one vendor.

Similar technologies that should not be confused with DMR Tier III include:

- Trunked MotoTRBO developed by Motorola. While Motorola makes a standards-compliant Conventional DMR product, Trunked MotoTRBO is not compliant with the DMR III standard.
- PDT (Police (or Professional) Digital Trunking) is a modification of standard DMR developed by the Information and Telecommunication Bureau of the Chinese Ministry of Public Security
- dPMR (Digital Private Mobile Radio) is a competing ETSI-managed standard for an FDMA technology operating in 6.25kHz channels. Currently only Fylde Micro together with Icom offer dPMR trunked systems, known as Mode 3.
- Nexedge is a proprietary FDMA technology developed by Kenwood operating in 6.25kHz channels; this should not be confused with dPMR.
- iDAS is a proprietary FDMA technology developed by Icom operating in 6.25kHz channels and is not available as a trunked system.

# TETRA

## TETRA TECHNICAL OVERVIEW

The TETRA suite of standards has been developed since the nineties and has evolved into a feature-rich standard. It has been defined by ETSI with the assistance of operators and user organizations of the TETRA and Critical Communications Association (TCCA). While European public safety agencies and emergency services users provided the initial focus for the technology, the TETRA standard has been expanded and enhanced to serve military, local government, transport and utilities customers throughout the world and now is arguably the most successful digital LMR standard in the worldwide market. From the outset, TETRA was optimized to provide high-capacity cellular-style voice and data communications with an eye to dense urban environments but has been successfully deployed in rural settings as well. In contrast, DMR was designed to support lower-capacity voice and data traffic with optimized wide-area coverage.

The TETRA air interface uses 4-slot Time Division Multiple Access (TDMA) in a 25kHz channel spacing, providing superior spectral efficiency (since each channel can now carry four user traffic paths giving the equivalent of a 6.25kHz voice/data channel). The channels can be used for voice or for data. TETRA dynamically allocates channels between voice and packet data. The air interface utilizes  $\pi/4$  QPSK modulation (Differential Quaternary Phase Shift Keying) at 36 kilobits per second and includes outstanding forward error correction (FEC). TETRA uses an ACELP vocoder (Algebraic Code-Excited Linear Prediction) with 8kHz sampling rate for speech vocoding.

TETRA operation is purely trunked; there is no equivalent of Tier II (Conventional) DMR. According to the standard, TETRA can be configured for message trunking, transmission trunking, or a hybrid called 'quasi-transmission trunking'. Generally speaking, however, TETRA systems are set up to use message trunking and achieve the effect of transmission trunking by setting the hang timer to expire close to zero milliseconds, i.e. almost immediately. TETRA call set-up times are fast: typically around 300+ milliseconds.

## TETRA FEATURES

As the most mature digital radio technology, TETRA offers a wide and flexible range of voice, data, and supplementary services, including:

- Group call
- Individual call
- Broadcast call
- Include call
- All call
- Open channel
- Emergency call
- Priority call
- Pre-emptive priority call
- Late entry
- Stun and revive
- Discreet listening
- Ambience listening
- Call retention
- Area selection
- Talking Party ID
- Authentication
- Dynamic Group Number Assignment (DGNA)

“TETRA is arguably the most successful digital LMR standard in the worldwide market”

## TETRA DATA CAPABILITIES



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TETRA offers a 7.2 kbps raw data transfer capability in a single time slot. Aggregated, however, the four TDMA traffic slots can provide a combined high-capacity packet data pipe. Dynamic Data Slot Allocation enables TETRA to flexibly allocate time slots to voice or data transmission and to return to voice priority when required.

For data communications the TETRA standard provides for a number of data services including Packet Data and Circuit Switched Data over user-assigned traffic channels. For most users, however, TETRA's Status Messages and Short Data Services (SDS) are more than adequate. SDS data can be fixed length canned messages or free form text (variable up to 140 characters) over the main control channel and can be scaled upwards by adding secondary control channels.

With concatenation, however, short data messages up to 1000 characters can be sent, enabling a variety of flexible, fast, and reliable Short Data applications e.g. communicating SCADA and telemetry data, RFID tracking, database queries, job management, etc. For example, the TETRA SDS when combined with the TETRA Location Information Protocol (LIP) results in a fast standardized AVL solution for the technology.

## TETRA DIRECT MODE AND MOBILE GATEWAY

Although the default mode used by TETRA equipment is Trunked Mode Operation (TMO), TETRA portables or mobiles can communicate directly with each other using Direct Mode Operation (DMO) which bypasses the trunking network infrastructure altogether. One terminal (the 'DMO master') initiates and manages the DMO communication while the receiving terminal and any other joining terminals are 'DMO slaves'. In normal DMO, the master transmits on one of the four time slots while the DMO slave responds on another slot, leaving the remaining slots unused. This means that there can be only one DMO conversation per carrier at any given time.

DMO enables TETRA users to communicate in difficult circumstances:

- when the trunking network is overloaded, or
- as a fallback when the network is unavailable, or
- when RF signal strength is poor, or
- when access to the network is simply not needed (e.g. while monitoring oil lines).

But the main public safety advantage of DMO is that it enables a group of users (a SWAT team, for example), to communicate securely outside of the network or to keep in touch when connection to the network is lost (in an underground carpark for instance).

DMO can be used as a range extender for terminals that are out of range of each other or outside of the network coverage. A repeater (which can be a DMO portable or mobile in repeater mode) that is in the range of the terminals can link them via a single DMO conversation. And a mobile gateway unit that sits between a terminal and a base station and is in the range of both can be used to relay calls between the terminal and the network via a single normal DMO conversation per carrier. This allows TETRA users who might be temporarily outside coverage to

communicate with network connected users. With DMO they can make individual or group or emergency calls, identify callers, send text and status messages, or use AVL services.

Operationally, a TETRA DMO gateway offers a flexible, low cost extension to a trunked network which can be especially useful during early stages of the network rollout, for use in an emergency, or simply to extend services temporarily to occasional users.

## TETRA SITE CONFIGURATION

A TETRA network typically consists of a number of sites, each containing one or more TETRA base stations. At each site the base stations are connected via IP to a router or switch. The sites themselves are also connected over an IP backbone to a master router or switch that, in turn, connects to the system-level IP switch and to other subsystems (such as a dispatch system or a network management system), thus forming the TETRA Switched Management Infrastructure (SwMI).

At each site the first base station transceiver has one control slot and three user traffic slots. The remaining base station transceivers at the site are all traffic channels with four slots per repeater. The 4-slot arrangement permits a radio unit to receive a signal even while a user is talking (for example, to interrupt the talker's transmission). This 'back channel' communication provides a handy option for controlling TETRA equipment 'on the fly'.

A TETRA base station Site can support up to 8 transceivers (32 slots) of which a maximum of 4 slots can be used for control and short data, while the remaining can be allocated for voice or data calls.

Since TETRA is a TDMA technology, clocking at the sites is required to ensure that all sites work together in a time-coordinated fashion with their control channel and traffic slots time-aligned. GPS clocks inside the repeaters are commonly used to provide frequency and timing. This allows a base station site to run fully time-synchronous with other Sites for optimum cell re-selection and smooth 'in-call' handovers.

TETRA optimizes its use of power in terminals, thus saving operational battery life. Open loop power control is implemented whereby the terminal RF power is reduced depending upon the strength of the RF paths to and from the network. During an emergency, when battery life is critical, TETRA terminals self-adjust power consumption to deliver the maximum communication time.

Now a de facto standard, TETRA infrastructure equipment is also power-optimized, with the ability to switch off unused carriers. Even finer-grained power-saving is available in the most modern equipment, allowing system operators to disable output power on time slots when they are not carrying traffic.

## TETRA MULTI-VENDOR AND INTEROPERABILITY SUPPORT

As an open standard, TETRA is supported by a number of manufacturers (listed in the TCCA website under <http://www.tandcca.com/PageRender/about/themembers.htm> ) and is underwritten by a well-established Interoperability Process (IOP) developed by the TCCA and managed by its Technical Forum. The IOP, which is supervised by an independent organization ISCOM, ensures that equipment from different vendors will work together by certifying the combinations of equipment that pass the test program, publishing test results, and issuing TETRA Interoperability Certificates. This is by far the most thorough and mature interoperability process within the LMR industry and is one of the reasons why TETRA has been so widely adopted. Customers benefit in the knowledge that they can buy interoperable equipment from more than one vendor.

## TETRA COVERAGE

As a technology developed for mission-critical communications, TETRA has had to provide coverage to meet the stringent coverage requirements of public safety and other users in whatever environment they operate. Coverage depends upon many factors, including frequency, transmission power, receiver sensitivity, environmental topography and conditions, and so on. TETRA equipment is generally available in UHF frequency bands, as well as 800 MHz, spectrum. (Specifically, in the US, the FCC allows TETRA to be used in non-NPSPAC parts of the 450-470 MHz and 809-824/854-869 MHz spectrum).

TETRA RF power, unlike DMR or P25, is generally measured and specified out of the combining equipment. This means that the output power of TETRA equipment is actually higher than the specifications suggest. Thus, a 25W TETRA site is in fact equivalent to a 60+ W DMR transceiver in terms of RF power.

TETRA receiver sensitivity is also specified differently from DMR (or P25). Unlike DMR, in which co-channel interference (and thus RX sensitivity) is generally measured under static conditions, TETRA measures co-channel interference under dynamic conditions (for example, those under which a mobile car radio would typically experience in a noisy urban environment. The values given for dynamic sensitivity are typically lower than those given for static sensitivity. But comparing like for like, TETRA radios compare favourably with DMR radios. Thus the measured RF receiver performance of a high quality TETRA 1W portable unit has produced the following values.

- Receiver Static Sensitivity -112dBm (-115dBm typical)
- Receiver Dynamic Sensitivity -103dBm (-106dBm typical)

In terms of range, TETRA terminals deliver (approximately):

- Portable range (MS power class 3L (1.8 Watts)
  - 6-8 miles to first wall indoor
  - 8-12 miles outdoor
- Mobile – high power (10 watt RF power output (Class 2))
  - 30 miles

TETRA equipment provides additional solutions for enhancing coverage. For example, RX diversity is standard, ensuring that TETRA reception remains excellent under conditions of interference or fading. Moreover, where coverage holes are identified, pole mount outdoor repeaters can be provided to add to that provided by standard sites. In-building coverage solutions can augment traditional strategies such as the use of leaky feeders and specialized antenna systems, with strategically located compact DMO repeaters. In short, TETRA technology can supply coverage wherever it is needed.

## TETRA AND DMR USE CASES

### CASE 1: HIGH-DENSITY METRO SCENARIO

Requirements:

- 11 site system covering metro area
- 3000 users = high density
- Requirement for data integration

Good fit: TETRA

Here's why:

- Strong data integration and apps
- Voice requirement will be met by either DMR or TETRA. If duplex calls are required, then the choice will be for TETRA.
- In-call handoff between sites an advantage for TETRA, especially in an urban setting

### CASE 2: TRANSPORTATION USE CASE

Requirements:

- Transit organization
- Integration to Real Time Passenger Information
- Large amounts of location information

Good fit: TETRA

Here's why:

- Many transit integrators already use TETRA – good references
- AVL, text and data capability, using up to three secondary control channel slots

### CASE 3: WIDE-AREA VOICE SYSTEM

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Requirements:

- 100+ sites, most with two-four channels
- Low density of users per site
- Voice primarily, with some text messaging
- AVL-only data
- Wide area coverage

Good fit: DMR

Here's why:

- Use of two channels in 12.5 kHz
- Wide area coverage based on higher power
- Limited data requirement

### CASE 4: MIXED CITY/RURAL SCENARIO

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Requirements:

- 100+ Sites, Mix of high density metro (7-8 talk paths) and low density rural users (1-2 talk paths)
- Voice primarily with some text and status messaging (users base), AVL and low volume SCADA
- Wide area coverage
- Access to 25kHz channels

Good fit: both DMR and TETRA will work well for this user.

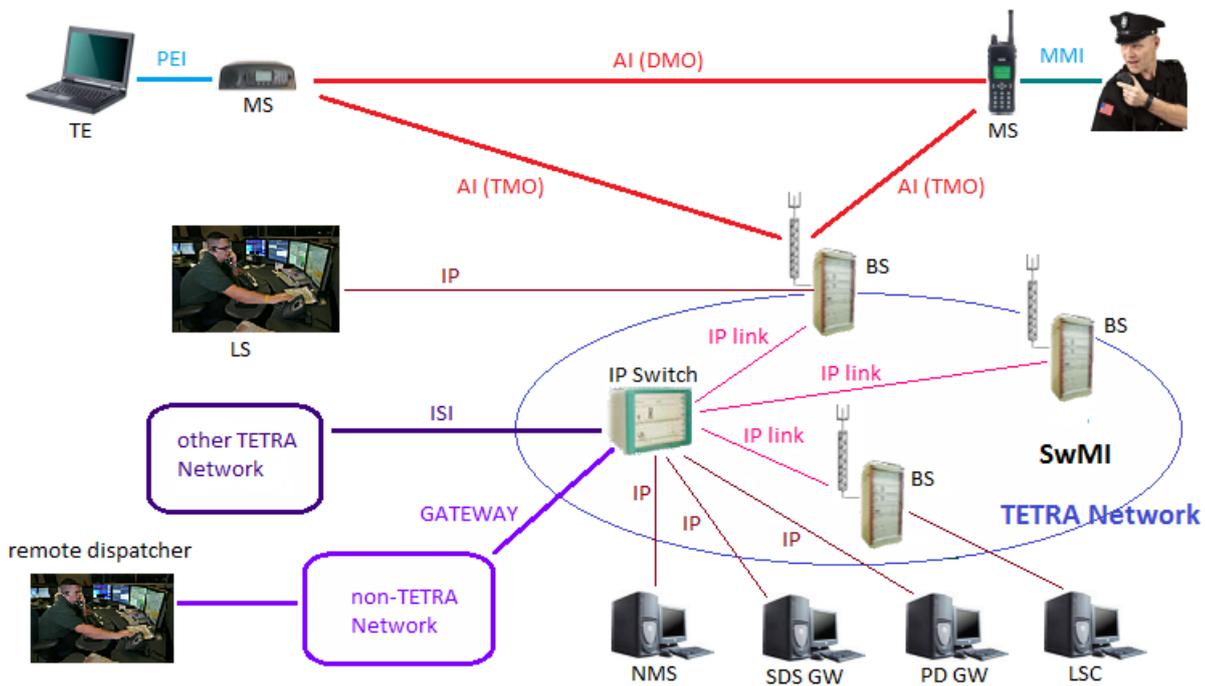
Here's why:

- DMR
  - Better wide area mobile coverage based on higher power
  - Limited data requirement
  
- TETRA
  - Use of portables with low power base stations in metro areas, in-call site handover
  - Lower RF channel count in urban areas to get the same number of simultaneous calls, lower losses in combiners
  - Use mobiles in rural low density areas, with mobile gateway to provide portable coverage



## GLOSSARY

<b>Base station</b>	A radio site (or cell, or tower site) which may be connected to other sites via a network backbone.
<b>Base station transceiver</b>	A single transceiver within a base station supporting in TETRA a 25KHz carrier. Equivalent to a DMR base repeater which uses a 12.5KHz carrier.
<b>Carrier</b>	A radio carrier consists of a frequency pair divided into four time slots i.e. user channels, with 25kHz spacing between carriers. A TETRA base station may have one or more carriers (frequency pairs).
<b>DMO</b>	Direct Mode Operation. When a terminal is communicating with other users directly, radio to radio, without using the trunked radio network.
<b>FDMA</b>	Frequency Division Multiple Access, in which access to a channel is via a specific frequency.
<b>TDMA</b>	Time Division Multiple Access, in which access to a channel is divided into time slots and each user operates in the channel via assigned time slots.
<b>Terminal</b>	A radio interface to the TETRA network. May be either a mobile / vehicle device, or a handheld. Not necessarily a voice radio.
<b>TMO</b>	Trunked Mode Operation. When a terminal is communicating with other users via the trunked radio network.
<b>TMO/DMO gateway</b>	A mobile that is able to link a trunk radio network user together with a direct mode user is called a TMO/ DMO Gateway. Often abbreviated as simply 'gateway'
<b>TETRA repeater</b>	A terminal in a DMO mode to repeat other terminal traffic, extending the range of direct mode communications, commonly used for special operations or urban canyons.



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|-----------------|---|
| <b>AI (DMO)</b> | Air Interface (Direct Mode Operation)   |
| <b>AI (TMO)</b> | Air Interface (Trunked Mode Operation)  |
| <b>BS</b>       | Base Station                            |
| <b>DMO</b>      | Direct Mode Operation                   |
| <b>IP</b>       | Internet Protocol                       |
| <b>ISI</b>      | Inter-System Interface                  |
| <b>LS</b>       | Line Station (dispatcher)               |
| <b>LSC</b>      | Local Switching Controller              |
| <b>MMI</b>      | Man-Machine Interface                   |
| <b>PD GW</b>    | Packet Data Gateway                     |
| <b>PEI</b>      | Peripheral Equipment Interface          |
| <b>SDS GW</b>   | Short Data Services Gateway             |
| <b>SwMI</b>     | Switching and Management Infrastructure |
| <b>TE</b>       | Terminal Equipment                      |

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