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Technical Report

**Terrestrial Trunked Radio (TETRA);
User Requirement Specification TETRA Release 2.1;
Part 4: Air Interface Enhancements**

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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Terrestrial Trunked Radio (TETRA).

The present document is part 4 of a multi-part deliverable covering the User Requirement Specifications (URSs) for TETRA Release 2 and Release 2.1, as identified below:

Part 1: "General overview" (Release 2.1);

Part 2: "High Speed Data" (Release 2.1);

Part 3: "Codec" (Release 2);

Part 4: "Air Interface Enhancements" (Release 2.1);

Part 5: "Interworking and Roaming" (Release 2.1);

Part 6: "Smart Card and Subscriber Identity Module" (Release 2.1);

Part 7: "Security" (Release 2.1);

Part 8: "Air - Ground - Air services" (Release 2);

Part 9: "Peripheral Equipment Interface" (Release 2.1);

Part 10: "Local Mode Broadband" (Release 2.1);

Part 11: "Over The Air Management" (Release 2.1);

Part 12: "Direct Mode Operation" (Release 2.1).

Introduction

The Terms of Reference for TC TETRA approved at ETSI Board meeting #69, November 2008 is to produce ETSI deliverables (and maintenance thereafter) in accordance with the following requirements:

The Terms of Reference for TC TETRA are to produce ETSI deliverables (and maintenance thereafter) in accordance with the following requirements:

a) The provision of user driven services, facilities and functionality as required by traditional Professional Mobile Radio (PMR) user organizations such as the Emergency Services, Government, Military, Transportation, Utility and Industrial organizations as well as Public Access Mobile Radio (PAMR) Operators.

b) The evolution and enhancement of TETRA as required by the market with the provision of new services, facilities and functionality made possible by new technology innovations and standards.

c) Further enhancements of the TETRA standard in order to provide increased benefits and optimization in terms of spectrum efficiency, network capacity, system performance, quality of service, security and other relevant parameters.

d) The backward compatibility and integration of the new services, facilities and functionality with existing TETRA standards in order to future-proof the existing and future investments of TETRA users.

Technical Objective

TETRA is one of a number of digital wireless communication technologies standardized by ETSI.

ETSI TC TETRA produces standards and/or adapts existing standards for efficient digital PMR and PAMR voice and data services, including broadband evolution.

The present document provides the User Requirement Specifications for the TETRA air interface enhancements.

The URS is required by TC TETRA to guide the enhancement of the current TETRA standard, mainly the evolution of the HSD standard part towards broadband.

1 Scope

The present document provides the User Requirement Specifications (URS) for the TETRA air interface enhancements translated into terms of:

- network performance aspects;
- terminal performance aspects;
- location information aspects.

The present document is applicable to the specification of TETRA Release 2.1 equipment.

The user requirements contained in the present document are described in non-technical terms and are based on discussions in TC TETRA WG1 and on an analysis of the results for air interface enhancements from the 2001 TETRA Release 2 Market Questionnaire and the 2007 Future of TETRA workshop [i.1].

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 102 621: "Terrestrial Trunked Radio (TETRA); TWC2007 Future of TETRA workshop report".

[i.2] ETSI TR 101 987: "Terrestrial Trunked Radio (TETRA); Proposed Air Interface Enhancements for TETRA Release 2; Analysis and Feasibility Assessment".

[i.3] ETSI TR 102 021-8: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 8: Air - Ground - Air services".

[i.4] ETSI TR 102 021-11: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2.1; Part 11: Over-The-Air Management".

[i.5] ETSI EN 300 392-2: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)".

[i.6] 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)".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

TETRA Release 2: Work Programme with new terms of reference within ETSI Project TETRA to enhance the services and facilities of TETRA in order to meet new user requirements, utilize new technology and increase the longevity of TETRA within the traditional market domains of PMR and PAMR

TETRA Release 2.1: Work Programme within TC TETRA to enhance the services and facilities of TETRA in order to meet new user requirements, utilize new technology and increase the longevity of TETRA within the traditional market domains of PMR and PAMR

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AI	Air Interface
APL	Automatic Person Location
AVL	Automatic Vehicle Location
C-SCCH	Common Secondary Control Channel
CSL	Cell Service Level
DTX	Discontinuous Transmission
ETSI	European Telecommunications Standards Institute
GPS	Global Positioning System
GTSI	Group TETRA Subscriber Identity
HSD	High Speed Data
ITSI	Individual TETRA Subscriber Identity
LIP	Location Information Protocol
MCCH	Main Control Channel
MS	Mobile Station
OPTA	Operational-Tactical Address
PAMR	Public Access Mobile Radio
PMR	Private Mobile Radio
PTT	Press To Talk
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
SC	Subscriber Class
SDS	Short Data Service
TA	Timing Advance
TEDS	TETRA Enhanced Data Services
TETRA	TErrestrial Trunked RAdio
TR	Technical Report
URS	User Requirement Specification
V+D	Voice plus Data
WGS 84	World Geodetic System 1984

4 User Requirement Specification

4.1 Introduction

The enhancements of the TETRA air interface standard aim at providing increased benefits and optimization in terms of spectrum efficiency, network capacity, system performance, quality of service, size and cost of terminals, battery life, and other relevant parameters. Other possible air interface enhancements are providing increased coverage range and low cost deployments for applications such as airborne public safety, maritime, rural telephony and "linear utilities" (e.g. pipelines). Provisioning of location information is another service that could be provided by enhancements of the TETRA air interface standard.

4.2 Network performance aspects

4.2.1 Overview of network performance aspects

The network performance aspects to be enhanced or supported in TETRA Release 2 are listed below:

- improved spectrum efficiency;
- enhanced network capacity;
- improved end-to-end time delay performance;
- Base Station site RF coverage beyond the current 58 km radius limitation of TETRA Release 1;
- improved RF performance;
- location positioning accuracy better than base station site location (Cell ID);
- improved cell hand-over decision and management;
- SDS improvements including concatenation;
- user aliases.

Most of these elements are difficult to quantify by users. The user requirements can generally be expressed as the more improvement the better. Some of these elements require substantial standardization effort. These requirements will compete for standardization resources and, as such, compromise each other. In the 2001 questionnaire responses, users indicated how they judged the relative importance of these elements. This gives an indication which items deserve most standardization effort. Some enhancements may be satisfied by implementation rather than standardization.

The different aspects are listed in clauses 4.2.2 to 4.2.7 in descending order of TETRA user market importance as judged by the 2001 questionnaire panel, further clauses under clause 4.2 are in no specific order of importance.

4.2.2 Enhanced network capacity

Enhanced network capacity is the most important requirement for the general TETRA market and also in all market segments.

Most of the respondents (users/operators) in 2001 were still starting up their TETRA networks. These networks were not under normal or full load and most respondents could only estimate the capacity load of their systems. The majority of those users had traditional analogue private open channel PMR systems. Therefore, it was very difficult (depending on the individual user/organization behaviour) to estimate how effective the statistical multiplexing of TETRA trunking will be. It is likely that the capacity gain of trunking has been underestimated.

As a result of underestimating the trunking effect, enhancing network capacity could be too high on the list of the general user requirements.

4.2.3 Location positioning accuracy better than base station site location

Location positioning accuracy better than base station site location (Cell ID) is also a very important requirement for the general TETRA market. It is required in both Public Safety and PAMR market segments.

The requirements for location positioning are handled in detail in clause 4.4.

4.2.4 Improved cell hand-over decision and management

4.2.4.1 General improvements

Improved cell hand-over decision and management is an important requirement for the general TETRA market. It is required in both the Public Safety and PAMR market segments.

User/operators responsible for more mature TETRA networks tend to judge this item more important than users/operators with limited TETRA experience. This could indicate that the importance of this item is underestimated by the TETRA users/operators starting up their TETRA networks.

The relative importance of this item is probably higher than its ranking suggests.

Some problems experienced in the early networks were:

- cell dragging by an MS;
- handover to a wrong cell.

Important user requirements (for networks under normal or full load) include:

- load management;
- need for consistent behaviour from all MS suppliers;
- need for (future) flexibility in the handover methodology.

When the networks are under normal or full load, improved cell selection will also be part of the solution for enhancing network capacity.

Most networks can be considered as built in two layers; a macro layer and a micro layer. Some networks have also other layers, e.g. air-to-ground, that are not specifically covered below although the general principles should apply for them also.

The macro layer provides the general network coverage. This layer delivers coverage mainly in low to average user density zones; mostly rural areas. This macro layer generally uses very high (hilltop) sites, with antennas substantially above clutter height.

The micro layer fulfils an additional requirement, depending on the type of network. In PAMR networks the microcells deliver extra capacity in high user-density zones; mostly urban areas. In Public Safety networks this micro layer delivers mainly extra coverage (including indoor for hand portables) in urban areas. The Public Safety microcells differ from the macro cells mainly by their location (city centre instead of hilltop), not by their RF parameters, and as such these cells are not really small.

In both types of networks there is need for a cell selection mechanism to prevent too much traffic going via the macrocells. Macrocells should only be used when no other cell can be used because of bad signals or high speed.

In some micro layer solutions, especially in big cities with high cell density and a desire for indoor coverage, the signal outdoors becomes "too good", creating a cell dragging problem. Here one cell may provide very good coverage ranging beyond its neighbour cells" planned coverage area. An MS may be using this cell and move onto the other side of the neighbours, without a need to hand over looking based on the RSSI. Then, when the user goes behind a big building the signal may be completely cut off. If all neighbours get "cut off" at the same time too, the MS has to spend some time scanning the frequency band to establish a serving cell, creating a break in the service. Although careful tuning of the handover parameters and neighbour cell information can be used to minimise this effect, in these cases it would help if the terminals could be "tuned" to hand over earlier. However, it is recognised that handing over too early is generally not a good idea, so this feature should be geographically limited rather than a network wide setting.

The current standard limits the possibilities perhaps too much in some cases, forcing handheld and mobile terminals to work with the same threshold values. As mobile terminals tend to have more effective antennas and a higher transmission power this may lead to problems in some cases. In most cases, the ideal "handover sensitivity" would be similar from the user's point of view regardless of the type of terminal he is using.

Terminal aspects of improved cell reselection criteria are covered in clause 4.3.8.

4.2.4.2 Expedited handover

Radio network planning for road and railway tunnels is very challenging due to the fast fading nature of cells. Often, the received RF signal from the current cell degrades rapidly at the same time as the new cell's RF signal level raises rapidly, unlike "out in the open" where the terminal has more time to react to changed RF levels. Typical places where this happens are entry/exit points of tunnels and stretches of tunnels where the radio network has been built to enforce a handover by deliberately attenuating the signal within a short distance to an unusable level.

If the terminal is not prepared for this fairly sudden (but predictable) loss of signal, the user may experience a cut in service when the terminal starts to think about changing cell when the signal from the current cell is effectively lost already.

Careful tuning of network parameters can minimise the effects of the fast fading, but often creates other problems. Introduction of new fast train lines across the world means that the problems are likely to become worse in the future unless the handover process is improved to support a mechanism whereby the terminal is aware of the possibility, allowed to hand over faster than normally, and prepared for it.

For this feature to work properly, the network has to have a way of informing the terminals of this possibility and the handover rules have to allow a fast handover in cases where the received signal level disappears quickly, if it has been indicated that the terminal should do this.

However, in order to avoid a huge increase in handovers, it should be able to selectively apply this feature to dedicated cases (cell borders) where a typical radio user is expected to experience a predictable rapid reduction in the received signal level, e.g. when going into a tunnel.

Expedited cell reselection is covered by EN 300 392-2 [i.5] with other cell reselection types.

4.2.5 Improving end to end time delay performance

Reducing end-to-end time delay for voice was earlier required in both the Public Safety and PAMR market segments but not identified in the 2007 TWC workshop as an area that requires further improvement.

4.2.6 Improved spectrum efficiency

Spectrum efficiency is important for the PAMR market segment and required by some Public Safety users.

Since most of the respondents (users/operators) to the 2001 questionnaire were still starting up their TETRA networks, it was possible that the TETRA network capacity could have been underestimated. If this was the case, spectrum problems could have also been overestimated. Whatever the underlying reason, by 2010 experienced TETRA operators had identified lack of spectrum to be a real problem for expansion and in some cases even for keeping up with the slowly increasing capacity demand from their current user base.

Improving the frequency reuse factor could be a way to improve spectrum efficiency and this has been taken into account in Release 2 HSD development. The size of cells and resources put into frequency planning also play a part in how spectrum efficient TETRA networks can be.

4.2.7 Base station cell size beyond the 58 km radius limitation of TETRA Release 1

Base station cell size beyond the 58 km radius limitation of TETRA Release 1 (due to time slot structure) is required by Public Safety, the military and utilities.

Requirement scenarios include mostly aeronautical and maritime use where there are little or no obstacles between the transmitting and receiving parties.

The aeronautical use case and more detailed size requirements are covered in URS part 8, Air-Ground-Air services TR 102 021-8 [i.3].

The air interface standard EN 300 392-2 [i.5] allows a larger maximum path delay responding to a maximum cell radius of 83 km or a 100 % increase to the (theoretical) coverage area of a cell.

4.2.8 Improved RF performance

An improvement in the RF performance by means of better receiver sensitivity, better air interface error correction or similar solution(s) is needed to improve usability in rural areas and indoors. The extended cell size does not help in these cases where the problem is not the distance between the base station and the terminal. Other solutions should be sought to solve these problems. Private TETRA networks do not have the same subscriber numbers as commercial cellular networks, making the economic justification for simply adding base stations and other coverage solutions much harder.

These two cases might require separate solutions as indoor coverage tends to be needed in built up areas where the outdoor signal levels are normally reasonably high, whereas in the rural areas the outdoor signal level and quality is low due to the attenuation caused by hills, forests etc and where one part of the problem might be reflections from big nearby objects.

Requirement scenarios include private houses and other indoor locations where special coverage solutions are not economically justifiable, "linear cells" (e.g. pipelines, railways) and large rural cells (large low-traffic areas).

4.2.9 SDS improvements

One of the highest scoring improvement areas in TETRA according to the participants of the 2007 workshop "Future of TETRA" [i.1] was "increased speed, capacity, and efficiency of SDS".

Even though the SDS service has been serving the TETRA community adequately for several years, the workshop attendees thought that there is a need to improve the efficiency of the SDS service (e.g. under highly loaded network conditions) for applications which may require faster delivery, a higher data capacity (beyond the current maximum) and more SDS message capability in the TETRA network.

Many early data applications utilise SDS as the data bearer and the wide availability of GPS-enabled terminals lead to common use of LIP or other location information protocols, all typically using the SDS messaging service. A more efficient mechanism, either available all the time or during network congestion, would keep the users happy and continue the success of AVL and APL solutions.

The requirement applies to SDS messages carried over either V+D or TEDS. The experience based limitations at the 2007 workshop were naturally V+D related. An HSD-only network introduced by direct access TEDS in Release 2.1 should be able to provide similar or better SDS performance as the Release 2.1 V+D part does.

4.2.10 SDS concatenation

In addition to a faster and more efficient SDS service there is a need to have longer SDS messages. It should be able to send these both to individual and group addresses.

These longer messages should support, but not be limited, to text messages.

There is a delicate balance between the convenience of using SDS and the size of a data file, e.g. a text message, reaching the destination within a reasonable time, taking into account that radio is an unreliable bearer and therefore each extra part increases the probability of at least one bit getting corrupted on the way. Additionally, it should be remembered that SDS messages use the control channel and sending large files using SDS service is not recommended for this reason.

One normal SDS message can carry 140 bytes of payload. It is expected a suitable balance between the restrictions mentioned earlier and the advantages of using SDS instead of packet data is somewhere around maximum 500 bytes to 1 500 bytes of payload in one concatenated SDS message.

An MS user should always be informed about the reception status of a concatenated SDS message. It should be clear to the recipient whether the whole message is presented or are there still some message parts to be received. An example of a message that should be displayed also when partially received is a long text message. The (partial) message should be available for display once the first part has been received and should be displayed up to the first part not received yet.

The recipient of an individually addressed concatenated message should be able to acknowledge the whole message when it has been successfully received and ideally also each part separately as they arrive, to enable the sending party to re-send either the whole message or the missing parts. In addition to acknowledging each part separately it would be good to have some means of requesting missing parts after it is obvious one or more have been lost.

The concatenated SDS service should support end-to-end encryption, ideally supporting two ways of doing this; the whole message encrypted as one package and each part encrypted separately. While there may be benefits in encrypting the whole message as only one packet, encrypting each part separately would allow also partial messages to be used by the receiving party.

The transport mechanism of concatenated SDS messages is covered by EN 300 392-2 [i.5].

4.2.11 User aliases

There is a requirement for users to be aware at all times of who is talking (by their alias). Some users might also need to know who else is in the call and their group membership(s). To satisfy these kind sof requirements there is a need to easily, quickly and efficiently dynamically update and change aliases network wide on a regular basis.

Some examples are:

- individual call aliases;
- group membership of a selected group of users or all members of a talk group, e.g. table with radio aliases in the first column and current group membership(s) in the second column;
- more information about the ongoing communication (talking party, new group members, etc.).

A typical radio user would only be interested in knowing who is transmitting at the moment, whereas e.g. control rooms or field commanders might be interested in the wider set of the functionality described in this clause.

Preferably there should be only one place (database) in the system where the one-to-one relation between ITSI (or GTSI) and the "alias" (name) is made. If a subscriber receives a call within a group and/or from a user for whom it does not know the aliases, these should be delivered over the air-interface. For the best user experience, a centrally managed over-the-air phonebook solution, refer to TR 102 021-11[i.4], could be used to ensure that all likely needed aliases already exist in the MS.

As nationwide TETRA networks may contain hundreds of thousands of users, it is assumed that not all user aliases will be programmed and maintained in every MS. One way to provide the user "alias" (name) dynamically to all recipients of the call is to use OPTA, see annex A.

4.3 Terminal performance aspects

4.3.1 Overview of terminal performance aspects

The terminal performance aspects to be enhanced in TETRA Release 2 and Release 2.1 are listed below:

- size reduction;
- weight reduction;
- improved battery operating life for daily PMR shift use;
- improved battery-operating life for Telephony use;
- improved battery operating life for data use;
- co-existence of terminals and network;

- harmonised cell re-selection criteria;
- operational-tactical address.

The majority of these elements are difficult to quantify by users. The user requirements can generally be expressed as the more reduction or improvement the better. Some of these requirements are compromising others. The user responders to the 2001 questionnaire indicated how they judged the relative importance of these elements. This gives an indication what terminal aspects could be compromised when it is not possible to improve all aspects.

The different aspects are listed in clauses 4.3.2, 4.3.3, 4.3.5 and 4.3.6 in descending order of TETRA user market importance as judged by the 2001 questionnaire panel, other clauses under clause 4.3 are in no specific order of importance.

4.3.2 Improved battery operating life for daily PMR shift use

Improved battery operating life is a very important user requirement in all market segments and in all user organizations. Improved battery operating life for daily PMR shift use is the most important user requirement in the general TETRA market.

In PMR, the majority of the calls are group calls. These calls happen at a high frequency and are very short (compared with individual calls).

Increasing call setup time or losing fragments of speech is unacceptable for Public Safety users. The network should in the first place be always available and reliable. "Sleeping" terminals would probably not meet those requirements.

Discontinuous Transmission (DTX) will probably bring almost no improvement for PMR users since they release the PTT when not talking. It would probably also be unacceptable for Public Safety users because it could compromise the use of "ambience listening" (used in emergency calls).

Note that, even if it is found that techniques such as DTX and energy economy mode are not beneficial for some types of PMR users, it should be straightforward for these features to be disabled for these users. The function could potentially even be de/activated according to the profile of the individual user.

4.3.3 Improved battery operating life for telephony use

Improved battery operating life for telephony use was in 2001 seen as the second most important user requirement in the general TETRA market. It was seen as more or equal important to improved battery operating life for daily PMR shift use by the utility and PAMR type users. For Public Safety users this aspect had the lowest priority.

For telephony use (calls are longer and less frequent compared with PTT type calls) increased call setup is less noticeable and as such not considered as a problem.

For this type of use "sleeping" terminals and DTX could be very beneficial and acceptable for all users.

4.3.4 Improved battery operating life for data use

With the introduction of HSD in Release 2 and improvements in Release 2.1 the use of mobile data will move to become a real alternative for commercial cellular mobile services, with the extra benefit from TETRA's inbuilt security and other services. This change in operations will enable the users to use more complex data applications on their TETRA devices than before.

Even moderate increase in data use places a significant extra burden on batteries that should be taken into account, noting that even when the device is not sending or receiving data, the user may be using the device to fill in fields, look at the pictures, etc. typically with the screen lit up, all of which requires power. In these situations the terminal is often out of its (protective) holder and there is a greater chance for utilising solar energy than in normal holder-based voice communication cases, which could be a partial solution for extending the battery life. However, the batteries should also provide a reasonable working cycle during night shifts and other cases where solar energy is not a viable option.

For example, Automatic Person Location (APL) services (see clause 4.4) place a burden for portable radio equipment, both when calculating and keeping track of the location and when communicating with the location server over the air. APL is normally done transparently to the user of the radio, i.e. the user does not need to do anything, nor can he do anything to prevent the battery drain except to turn the device/APL service off.

4.3.5 Weight reduction

In the general TETRA market in 2001 this requirement was far less important than improved battery operating life. For Public Safety users however this requirement was second on the requirement list when the user requirements were gathered for Release 2, not so far behind the requirement for improved battery operating life for daily PMR shift use. However, the developments in this area since then have reduced the importance of this area.

4.3.6 Size reduction

In the general TETRA market this requirement had the lowest priority in 2001. For Public Safety users however this requirement was seen during the Release 2 URS work as more important than improved battery operating life for telephony use. As the terminal sizes have come down since then, (further) size reduction is seen by Public Safety as less important for Release 2.1 than it was for Release 2.

However, new markets where TETRA competes against other technologies have identified a need for further size reduction based on requests from their customer base.

4.3.7 Co-existence of terminals (MSs) and/or base stations (BSs)

TETRA terminal user experiences from several countries have shown that some TETRA terminals have difficulties to operate in close vicinity of each other. These terminals however comply with the current TETRA specifications. TETRA specifications should be tightened to allow closer co-existence between MSs.

Transmitting terminals in close vicinity of some receiving terminals seem to degrade the reception of those receiving terminals, sometimes to the extent that the connection with the network is lost. These terminals could operate in uncorrelated communication, e.g. they do not communicate with each other but with third parties not in close vicinity. The degraded receiving terminal could also be in idle mode.

The behaviour of those degrading receiving terminals is a problem for the users in the public safety community. They need reliable terminals in all of their normal operational conditions. The current terminal behaviour could cause loss of lives in critical situations.

Typical scenarios of these normal operational conditions are given as examples.

Scenario 1: radio users in the same car

Two or more policemen (uniformed or secret) often operate while they are in the same car using portable radios. Each of them needs the possibility to communicate independently of the others, at the same time, in a group call, individual call, simplex call or duplex call.

Scenario 2: radio users at the same table

Two or more radio users (commanding officers of different organizations) meet during crisis management around the same table. They have put their portable radios in front of themselves on the meeting table. Their radios are involved in uncorrelated communication, e.g. they normally do not communicate with each other using their radios but communicate with third parties not in close vicinity. Their radios could also be in idle mode. At any moment all of them should be able to communicate independently of the others, at the same time, in a group call, individual call, simplex call or duplex call.

There is therefore a user requirement for terminals to operate located in close proximity to each other (e.g. when the terminal users are sitting next to each other) without any noticeable differentiation or degradation of service.

4.3.8 Harmonised cell (re)selection criteria

4.3.8.1 Priorities

Not all terminals support all the functions defined in the TETRA standards. If there is information available for cell (re)selection that is not applicable to a specific terminal, that terminal should ignore that when placing available cells in priority order.

The priorities defined in this clause should be used to rank the cells under consideration, providing a prioritised list of cells for the terminal so that when it decides to change cell it will go to the best, i.e. highest ranking, cell. It should be noted that in real life networks most of the broadcasted information will not change dynamically and therefore the extra load on the terminal should be minimal even if it monitors all the information elements provided to it by the network.

Some flexibility should be left to optimise the terminal behaviour in case the network does not have a uniform service support. For example, if some cells support only TEDS, the priority of this over voice when making a choice between cells will depend on the users' needs and the terminals used and should not be mandated by a standard. The most obvious example is where a terminal does not support one of the mentioned services, in which case it should ignore the respective information as previously stated.

The received signal strength should be the lowest ranking differentiator as the other ones are more important from the user's point of view. Also, anything less important than RSSI would be ignored as it is highly unlikely that two cells would provide the same RF level for any reasonable time. However, this does not mean that a cell with an unusable RSSI should be selected.

In most networks, system-wide services should always be preferred over fallback solutions. Also, for public safety networks especially but possibly for other TETRA networks as well, support for air interface encryption is essential. In a normally working network both of these values tend to be the same in all cells.

The Subscriber Class (SC) information should be the highest ranking cell information element that operators generally could use to inform which cells are for which user groups and which cells rank higher/lower than others. Location Areas and pre-programmed cells/frequencies should be considered together with the SC information but with lower preference, e.g. never overriding an SC mismatch.

The services the terminal requires should be considered next to ensure the terminal prefers cells which can provide the service the user needs. In most Release 1 networks the same services are offered by all correctly operating cells supporting system-wide services, but with Release 2 and later releases the likelihood of services varying between neighbouring cells increases.

The Cell Service Level information, when available and supported, can provide an effective way of sharing network load between neighbouring cells. However, selecting a cell with low traffic is less important than getting the correct service.

HSD terminals can detect signal quality, which can be used to differentiate between cells that have reasonably similar RSSI.

Finally, the terminal should not spend too much time or other resources in monitoring any of these parameters from neighbouring cells unless it is otherwise ready to do a cell reselection.

Some of these requirements are looked at in more detail in clauses 4.3.8.2 to 4.3.8.5.

4.3.8.2 Use of the Cell Service Level

The TETRA Release 1 air interface provides two bits for indication of the Cell Service Level (CSL). These can be used to spread the load between overlapping cells more evenly, also called load based or load directed roaming.

Direct Access TEDS will provide a separate cell load indicator that is not considered in the present version of the document.

For networks that do not utilise this possibility the CSL should be set to the value reserved for "unknown". For others this could be turned on cell by cell if deemed suitable. For example, in areas without much cell overlap the operator may choose not to use this feature, while in busy areas such as city centres the same operator might be using CSL to support load based roaming. Partial use of CSL will also exist when the operator is in the process of upgrading from a network which does not utilise CSL to one that does.

In cases where not all cells utilise CSL the MS has to be able to cope with some of the neighbouring cells it sees having a meaningful CSL whilst others are "unknown". Unknown values should not be taken as worse or better service level than any of the other values CSL can carry. It is expected that in these cases the MS will rank a neighbouring cell with an "unknown" CSL on the same CSL level as the current cell.

When used, CSL has three values; Low, Medium and High. This should reflect the load on the cell. As traffic profiles between networks vary as do the numbers of carriers per cell, absolute values for where the cut-off point between two of these values is cannot be given in the present document. However, CSL should be based on both the control channel (both MCCH and C-SCCH) and traffic channel loads, indicating the higher of these two. The network supplier may also use additional information to calculate the correct value of CSL if that is deemed important.

CSL implementation should avoid unnecessary oscillation between radio cells, but should be able to react to changing conditions reasonably fast.

The terminals supporting the use of Cell Service Level should use the CSL information received in the cell broadcast messages as indicated in tables 1 and 2. This information can be used to influence cell re-selection criteria and/or delivered to internal and external applications to enable them to dynamically adjust to the changing load status. For example, a LIP application might be programmed to send location updates less frequently in a highly loaded cell in a network where the control channel load is known to be an issue.

Table 1 defines the ranking order of neighbour cells what comes to Cell Service Level for MSs that are either idle or engaged in a group voice or data session. These MSs should not consider the CSL of the serving cell when making cell reselection decisions. This is because it is expected that an MS changing cell in these cases will not make a big impact on the Cell Service Level of either the old or the new serving cell as idle terminals do not create much traffic and group calls tend to be short in nature, dropping the MS that was in a group call soon to idle.

Table 2 defines the ranking order of neighbour cells in relation to the current serving cell what comes to Cell Service Level for MSs that are engaged in an individual (point to point) voice or data session.

Table 1: Using CSL information when MS is idle or engaged in a group call or group data session

Cell Service Level of neighbour cell A	Cell Service Level of neighbour cell B	Impact on ranking of neighbour cell B
Low	Low	0
	Medium	-
	High	--
	Unknown	0
Medium	Low	+
	Medium	0
	High	-
	Unknown	0
High	Low	++
	Medium	+
	High	-
	Unknown	0
Unknown	Low	0
	Medium	0
	High	0
	Unknown	0
NOTE: ++ ranks neighbour cell B higher than neighbour cell A and neighbour cells ranked as + + ranks neighbour cell B higher than neighbour cell A 0 ranks neighbour cell B on the same level as neighbour cell A - ranks neighbour cell B lower than neighbour cell A -- ranks neighbour cell B lower than neighbour cell A and neighbour cells ranked as -		

Table 2: Using CSL information when MS is engaged in an individual voice or data session

Cell Service Level of serving cell	Cell Service Level of neighbour cell	Impact on ranking of neighbour cell
Low	Low	0
	Medium	-
	High	--
	Unknown	0
Medium	Low	+
	Medium	0
	High	-
	Unknown	0
High	Low	++
	Medium	+
	High	-
	Unknown	0
Unknown	Low	0
	Medium	0
	High	0
	Unknown	0
NOTE: ++ ranks neighbour cell higher than the serving cell and neighbour cells ranked as + + ranks neighbour cell higher than the serving cell 0 ranks neighbour cell on the same level as the serving cell - ranks neighbour cell lower than the serving cell -- ranks neighbour cell lower than the serving cell and neighbour cells ranked as -		

4.3.8.3 Subscriber class

Subscriber classes can be used by the operator to guide the terminal base to use or avoid specific radio cells. TETRA supports 16 subscriber classes, of which 1 to 16 can be enabled on each cell and each terminal. In addition to having the match/mismatch functionality guiding the terminals, there are several preference levels defined within the subscriber class set.

Generally, with the exception of one highly preferred subscriber class internationally agreed to be used for Air to Ground service, all subscriber class use is to be defined by the operator as part of their radio network planning.

The standard allows the network to assign a new set of subscriber classes to the terminal when it connects to the network, but this is not mandatory, in which case the terminal should know beforehand which classes it supports and which not. When working in a foreign network it is the network's responsibility to ensure that the visiting terminal gets the correct set of subscriber classes as otherwise the terminal will have to assume all classes to be valid, with the exception of the Air to Ground class.

Out of the 16 classes, two have been designated to be Highly Preferred, two Preferred, and the rest "normal". The "normal" cells are assumed to be building blocks for the majority of the network. However, it has been found out that these three preference levels are not enough. To enable the operator to use the subscriber classes to guide terminals away from some specific cells with limited capacity, but not completely prevent selecting and using the cells if they need to, there is a user requirement to designate some of the "normal" classes to be less preferred than the "normal" ones, called Least Preferred in the present document. As it is not expected to have many such cells within a network, assigning two classes to be Least Preferred is considered to be enough.

As a general rule, if a neighbouring cell does not have a matching subscriber class, the MS should consider it as a not valid cell and not include it in the cell reselection process even if the C1 goes below 0 and there is no valid cell in the neighbour list.

However, there may be some networks where the user requirement is that in the case when a mismatch cell is the only one with a $C2 > 0$, the MS is allowed to choose that cell when C1 of the current cell goes below 0. However, in that case the functionality allowed should only include basic mobility management and the possibility to initiate an emergency call. Due to this severely limited functionality, e.g. not being able to monitor the currently selected talkgroup or to send location update messages, this option should only be allowed after careful consideration to ensure the users know what to expect in such a situation. As a minimum in those circumstances, the MS should indicate to the user that the service is limited to initiating emergency calls only and the MS should actively search for a cell with a matching subscriber class, considering any matching subscriber class cell to have a higher preference level.

4.3.8.4 Pre-programmed cell/frequency information

Some MSs provide a possibility to pre-program preferred radio cells or Location Areas into the terminal. This may be useful for various reasons, e.g. to keep one local talkgroup members within one or selected few radio cells. Also, a similar functionality for pre-programming cells or Location Areas as "less preferred" than otherwise similar cells/Location Areas could be useful in some cases. However, using this opportunity should be done with cooperation with the network operator as this may limit the operator's options on how to manage the network (add/remove cells, etc.).

Where such pre-programmed parameters exist within the MS, this (non)preference should be taken into account in a similar manner as other preference levels, e.g. subscriber class preference levels, as defined in clause 4.3.8.1.

4.3.8.5 Effect of higher/lower cell preference levels to cell reselection

Some neighbour cell information such as subscriber class preference levels indicate that a neighbour cell should be ranked higher or lower than the current cell, effectively indicating how early the terminal should move to and from the current cell. This information may be pre-programmed into the network and/or the terminals, e.g. in the case of the subscriber classes, or be based on current status of the network, e.g. in the case of cell loading.

If several preference levels indicate different values, i.e. some higher and some lower than the serving cell, the terminal should consider those cells having preference levels based on what has been discussed in clause 4.3.8.1.

When considering a higher ranking cell, the MS should perform idle cell reselection when the C2 value of that cell reaches Radio Usable, unless the assigned channel on the serving cell provides better service than that higher ranking neighbour, in which case the cell reselection could be postponed.

The MS should only consider lower ranking cells when the serving cell's C1 < Radio Relinquishable.

Table 3 shows the requirements that the serving and the neighbour cell signals have to fulfil before the MS can perform a cell reselection.

Table 3: Cell reselection - signal level requirements

Service provided by the neighbour cell	Cell	Idle	Not idle
Lower	Current	Radio Relinquishable	Radio Relinquishable
Same	Current	Radio Improvable	Radio Relinquishable
Higher	Current	Any	Radio Relinquishable
	Neighbour	Radio Usable	

4.4 Location information aspects

4.4.1 Location positioning applications

A survey of user requirements highlighted the need for multiple applications. Those can be categorized in two types of applications with similar requirements:

- location positioning of vehicles using TETRA mobiles. This is called Automatic Vehicle Location or AVL;
- location positioning of persons using TETRA portables. This is called Automatic Person Location or APL.

Most of the requirements listed in clauses 4.4.2 to 4.4.9 are covered by the Location Information Protocol (TS 100 392-18-1 [i.6]).

4.4.2 Location positioning accuracy and resolution

Accuracy is defined as the precision of the acquiring location positioning system whereas resolution is the precision of the transferred information.

The general requirement for location accuracy is a few metres. In urban environments it should be possible to know in what building the person has entered. In big buildings (e.g. factories) it should be possible to know where in the building (on what floor and where on that floor) the person is situated. Using routing applications (for public safety) is only possible when this accuracy requirement is met. Time to incident is critical in public safety and ending up in the wrong (one way) street is not acceptable. Public safety uses dedicated routing applications where traffic jams, temporary closed roads and incidents are introduced in real time.

From the requirements above it can be seen that base station site location (Cell ID) is insufficient for location positioning.

4.4.3 Location positioning updates

The maximum location positioning update rate needs depend on the user, the speed travelled, etc. and may in some cases, e.g. a high-speed car chase, be in the order of a few seconds. This is however a maximum rate, which is only needed during limited periods when special attention to that particular person or vehicle is needed. In general a much lower update rate is acceptable (in the order of a few minutes) if a mechanism allows for changing the update rate when needed. This mechanism could be by polling over the TETRA network by another system or operator. This mechanism could also be a rule-based system that decides autonomously (without instructions over the TETRA network) to change the update rate. A mixture of both could also be possible and would offer the greatest flexibility.

The update rate also depends on the location positioning accuracy. If the positioning accuracy is lower then the update rate could be lowered accordingly.

4.4.4 Location positioning availability

As more and more user- and organization-critical applications will depend on having location positioning, the requirements for availability are very high, especially in the public safety sector. Location positioning is needed in all locations where users may operate. These locations include inside buildings, tunnels, underground parking, forests, rural areas, and urban areas (narrow streets between high buildings in city centres).

It should be noted that having communication is even more user- and organization-critical (life-critical in public safety). It can therefore be assumed that the locations mentioned above will have TETRA coverage in well implemented TETRA networks.

4.4.5 Location positioning reliability

Users and organizations will start using more and more applications based on location positioning. These applications will become critical to fulfil their task. Control rooms and/or dispatchers will be so used to having location positioning that they will have great difficulties continuing their work when the location positioning fails (they become blind). The reliability of the location positioning system is a very important requirement and users should have knowledge about its reliability. They should be able to verify and preferably influence this reliability (service level agreements). Not only technical reliability is important but considerations should also be given to the long term availability of the location positioning system provider. Having the location positioning system as an integrated part of the TETRA system would be a great advantage in this respect.

4.4.6 Location positioning terminal impact

The general requirements for terminals are increased battery life, weight reduction and reduction in size. Adding location positioning functionality should also respect these requirements. Especially for APL the equipment volume, the equipment weight and the battery consumption should not increase substantially.

4.4.7 Location positioning air interface enhancement

The analysis and feasibility assessment of TG23, TR 101 987 [i.2], has shown that it is very difficult to add an integrated location positioning service in TETRA 1 V+D because of the modulation (symbol length/channel bandwidth) and the lack of timing systems (e.g. TA).

Having an "enhancement" changing the modulation (physical layer) would cause compatibility problems. Having an enhancement introducing a timing mechanism (e.g. TA which would also be useful for long range) may involve significant and unjustifiable implementation costs.

If work in TETRA Release 2 leads to evolutions of TETRA where the modulation is changed (e.g. high speed data), these location positioning requirements should be considered from the beginning. If this is not done, it may again be impossible to integrate the location positioning service afterwards.

4.4.8 Location information transfer to support APL/AVL applications

In the following a preferred technical solution for the "Emergency Services" is described. It should however be noted that there are several other solutions currently in use and others will continue to be developed, which may or may not necessarily meet the requirements of the "Emergency Services".

The location information transfer method should be open, standardized and optimized for the TETRA air interface.

The standardized location information transfer method should allow application providers/developers to make interoperable applications based purely and only on the information in the standard. (There should be no options or possibilities that require further agreements; profiles and/or information exchange between TETRA providers and/or application providers/developers).

The transfer method and information should be valid worldwide and not depend on parameters which are location specific. Any conversion to or from local grids should be done before and/or after transfer. (The transferred information should be in a globally recognized standard e.g. WGS 84). In special situations (decided by the sending station) the base station site identifier may be used instead of WGS 84-based location information.

The location information content and format should be TETRA-bearer independent (possibility to use SDS, IP, etc.).

The transfer method should be independent of the system used to acquire the location information, e.g. GPS, Galileo, proprietary non-satellite-based systems, manual input.

There could be multiple recipients for the location information. The multiple recipients could be all the members of a group. (It is expected that when SDS is used and when there are multiple recipients that are all member of the same group, group SDS will be the optimized method for the AI).

There could be multiple applications in the same network using the same location information transfer method or even using the same location information message from the same source at the same time.

It is expected that the service will have the same reliability/performance as SDS type 4 at basic link.

The location information transfer elements needed to support APL/AVL are listed in tables 4 and 5. The standard should support both types but users may wish to only use either the short message or the long message for their applications. Some users may use a long message initially with short messages being sent subsequently as updates from the same mobile station.

Note that all AVL messages are applicable to both the uplink and downlink.

Table 4: Short message location information transfer elements

Information element	Mandatory resolution/range	Useful resolution/range	Comment
Latitude	2,5 m	1,25 m	
Longitude	2,5 m	1,25 m	
Time elapsed (time between acquiring and sending the location information)	5 s to 1 h at least 4 steps		
Speed	instantaneous speed in the direction of travel, range = 0 km/h to 500 km/h, resolution 1 km/h or 10 % whichever is greater	to 1 000 km/h	
Heading/Direction of travel	instantaneous heading resolution 22,5°		
User defined data	8 bits minimum	all left over bits	e.g. sensor status
Position accuracy	at least 4 steps, < 3 m minimum to > 3 km	< 3 m, < 30 m, < 300 m, < 3 km, < 30 km, > 30 km	

Table 5: Long message location information transfer elements

Information element	Mandatory resolution/range	Useful resolution/range	Comment
Latitude	2,5 m	1,25 m	
Longitude	2,5 m	1,25 m	
Altitude	From -200 m to 10 000 m 1,25 m up to 5 000 m nice to have 200 m above 5 000 m		
Speed	instantaneous speed in the direction of travel, range = 0 km/h to 500 km/h, resolution 1 km/h or 10 % whichever is greater	to 1 000 km/h	
Heading/Direction of Travel	instantaneous heading resolution 5°	1°	
Position accuracy	4 steps, < 3 m minimum		
Message reference (consecutive numbering)	range 1 to 10	range 1 to 1 000	
Time of position	range = 1 day, resolution = 1 s (in UTC)	1 month or 1 year (unless time-date stamp is included in AVL message) - 1 s resolution in UTC	unknown time indication should also be available
Time elapsed (time between acquiring and sending the location information)	5 s to 1 h at least 4 steps		especially useful if time of position is unknown
Terminal or location ID	should support at least any TETRA identifier		or any identity used by the location application (not necessarily TETRA Identity)
Acknowledgement request			should not be used with group addressing
User defined data	8 bits minimum	all left over bits	e.g. sensor status

The information elements are not dependant on the method used to acquire the location information (type of system, technical solution). This means that the status of (elements in) the acquiring system, if needed, can only be placed in the "user defined data" element because the used acquiring system will be user-specific There could even be no "technical" acquisition system at all, just a person entering information based on his knowledge.

It may be useful that a short message is part of a long message.

When SDS is used to transfer the information, the short message should fit into 0,5 + 0,5 timeslots and the long message should fit into 0,5 + 1,0 timeslots (using the Random Access method).

It is expected that a standardized control message will be needed to configure and control the transfer application.

With the control message it should be possible to initialize and update the transfer application. Parameters that should be initialized/updated/adapted via these control messages are listed in table 6.

Table 6: AVL control message elements

Information element	Comment
Transfer initialization configuration request	This could be used to contact a server that will deliver the needed initialization parameters to start the APL/AVL application.
Information destination	This could be an ITSI, GTSI, external subscriber number or IP-address.
Minimum time elapsed between messages	Minimum time elapsed takes precedence over the maximum time elapsed and maximum distance travelled to prevent excessive resource usage.
Maximum time elapsed between messages	
Maximum distance travelled between messages	
Specific location	This could be used to send the location information when the sender is at that specific location.
Location message request	The location message transfer is initiated after reception of this message.

There should be no mechanism which prevents the sender from initiating an information transfer at any time. This decision could be based on a manual (personal) intervention or based on a local system asking the sender to do so.

4.4.9 Location positioning security issues

The location information transfer method should be available during temporary disable. However this functionality should only be available if no external devices are needed to provide location information as no external communication should be allowed during temporary disable, neither should there be any indication of terminal activity to the user.

It should be noted that the message format described in the present document does not take into account many of the security issues. These should be considered before the implementation of a location positioning system, especially one with remote activation possibilities. To reach an acceptable level of privacy and security, the system might use methods such as pre-configured destination address lists, end-to-end encryption, end-to-end authentication, or manual user confirmation.

However, these solutions are not in the scope of the present document.

Annex A: Operational-Tactical Address

An ITSI uniquely identifies a subscriber in any TETRA network. An optional operational-tactical address (OPTA) is needed in some networks to provide additional information to the receiving end about the transmitting party's operational role or user organisation. At least the following type of OPTA should be supported: fixed length 24 bytes long text string with 8-bit Latin 9 coding.

OPTAs are not used for air interface addressing, e.g. for call setup. The user management function should be able to define an OPTA independently of a subscriber's ITSI and it should be possible to provision an OPTA to an MS remotely, over the air.

A user with a certain operational role might be registered to a network with two or more MS, so it should be possible to use the same OPTA for several ITSI (1:N relationship). One MS should only be used with one OPTA (1:1 relationship) at any given time. In most cases the user organisations will assign OPTAs to their users and provision the terminals with these OPTAs. There is no requirement to have any linkage between the ITSI and an OPTA of an MS, in fact, in some cases it might be preferred not to have such a link.

During an ongoing session of a circuit mode service (individual call, group call, circuit mode data), the sender's OPTA should be sent using stolen frames and presented to all receivers of this session after the data/speech item has been granted to the sender. Those MSs that do not support OPTA should ignore these stolen frames.

SDS type 4 and SDS-TL messages sent should also contain the sender's OPTA, encoded using the same coding as the rest of the message when applicable, otherwise using the same coding as used when transmitting OPTA during voice calls. In case of concatenated SDS, only one concatenation part of the multipart SDS should contain the sender's OPTA. Those MSs that do not support OPTA should consider OPTA as part of the SDS payload. Those MSs that support OPTA should recognise OPTA from the message and display OPTA and the message accordingly. When sending an earlier received SDS message, an OPTA supporting MS should send the SDS message with its own OPTA, either adding it to the message or replacing the OPTA earlier received.

During a packet data session, the OPTA of both parties should be transmitted at least once after connection setup. An MS not supporting OPTA should not consider this message to be anything special and treat it as a part of the normal packet data session.

A DMO gateway should not use its own OPTA when converting a service from DMO to TMO or vice-versa. The original sender's OPTA should be left unmodified in these cases. Likewise, a DMO repeater should not use its own OPTA when repeating DMO signalling or payload.

History

Document history		
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