Study on TETRA DMO and Mobile Ad-Hoc Networking

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Abstract

A study on how to apply Ad Hoc Networking technology into TETRA DMO is made in this paper. First of all, the technical and usability of this schema are investigated. Based on this analysis, a fast solution based on TAPS is given. Finally, the future solution based on Full IP and 3G convergence as well as the combination with Ad Hoc routing protocol is briefly discussed.

1 Introduction

1.1 TETRA General Overview

TErrestrial Trunked RAdio (TETRA) is the modern digital Private Mobile Radio (PMR) and Public Access Mobile Radio (PAMR) technology for police, ambulance and fire services, security services, utilities, military, public access, fleet management, transport services, closed user groups, factory site services, mining, etc.

With support of the European Commission and the ETSI members, the TETRA standard has been developed over a number of years by the co-operation of manufacturers, users, operators and other experts, with emphasis on ensuring the standard will support the needs of emergency services throughout Europe and beyond. The standard builds upon the lessons and techniques of previous analogue Trunked radio systems and the successful development of GSM during the 1980s. The work started in 1990 and the first standards were ready in 1995.

TETRA offers fast call set-up time, addressing the critical needs of many user segments, excellent group communication support, Direct mode operation between radios, packet data and circuit data transfer services, frequency economy and excellent security features. TETRA uses Time Division Multiple Access (TDMA) technology with 4 user channels on one radio carrier and 25 kHz spacing between carriers. This makes it inherently efficient in the way that it uses the frequency spectrum. For emergency systems in Europe the frequency bands 380-383 MHz and 390-393 MHz have been allocated for use by a single harmonized digital land mobile systems by the ERC Decision (96)01. Additionally, whole or appropriate parts of the bands 383-395 MHz and 393-395 MHz can be utilized should the bandwidth be required.

For civil systems in Europe the frequency bands 410-430 MHz, 870-876 MHz / 915-921 MHz, 450-470 MHz, 385-390 MHz / 395-399,9 MHz, have been allocated for TETRA by the ERC Decision (96)04.

TETRA trunking facility provides a pooling of all radio channels which are then allocated on demand to individual users, in both voice and data modes. By the provision of national and multi-national networks, national and international roaming can be supported, the user being in constant seamless communications with his colleagues. TETRA supports point-to-point, and point-to-multipoint communications both by the use of the TETRA infrastructure and by the use of Direct Mode without infrastructure.

TETRA standardization has reached a mature state. The major current activities are the continuation, by standardizing the next generation in TETRA Release 2 and by the maintenance of existing TETRA standards.

The objective of TETRA Release 2 is that EP TETRA produces an additional set of ETSI deliverables (and maintenance thereafter) in order to enhance TETRA in accordance with the following requirements:

a) **High Speed Data**. Evolution of TETRA to provide packet data at much higher speeds than is available in the current standard. This is to support multimedia and other high speed data applications required by existing and future TETRA users.

b) **New Voice Codec.** Selection and standardization of additional speech codec(s) for TETRA, to enable intercommunication between TETRA and other 3G networks without transcoding, and to provide enhanced voice quality for TETRA by using the latest low bit rate voice codec technology.

c) **Air Interface Enhancements.** Further enhancements of the TETRA air interface standard in order to provide 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.

d) **Interworking and Roaming.** Production and/or adoption of standards to provide improved interworking and roaming between TETRA and public mobile networks such as GSM, GPRS and UMTS.

e) **SIM Enhancement.** Evolution of the TETRA SIM, with the aim of convergence with USIM, to meet the needs for TETRA specific services whilst gaining the benefits of interworking and roaming with public mobile networks such as GSM, GPRS and UMTS.

f) **Coverage Extension.** Extension of the operating ranges of TETRA, to provide increased coverage and low cost deployments for applications such as airborne public safety, maritime, rural telephony and 'linear utilities' (e.g. pipelines).

These requirements are in addition to the user requirements for PMR/PAMR that are already satisfied by existing TETRA standards. The work will include completion and formal approval of outstanding work related to these existing requirements. The work will build upon the unique combination of services and facilities already included within existing TETRA.

1.2 TETRA DMO Overview

TETRA Direct Mode Operation (DMO) is a mode of simplex operation where mobile subscriber radio units may communicate using radio frequencies may be monitored by but which are outside the control of the TETRA Trunked network. DMO is performed without intervention of any Base Station.

There are four DMO reference models:

1. DMO terminal to DMO terminal

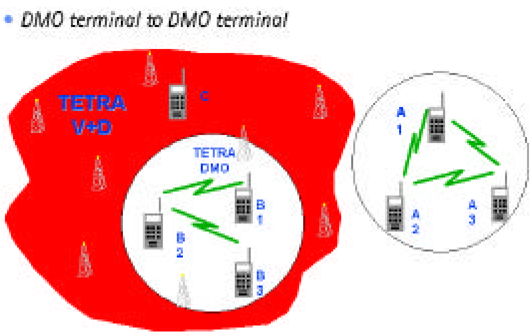

Figure 1: DMO terminal to DMO terminal

This operation model applies to a simple point-to-point or point-to-multipoint communication between DM-MSs using the Direct Mode Air Interface, Ud.

The DM-MS which provides the synchronization reference is defined as the "master" DM-MS. A DM-MS which initiates a call becomes the master for the duration of that transaction. Any DM-MS which synchronizes on a "master" DM-MS is defined as a "slave" DM-MS.

2. DMO Repeater

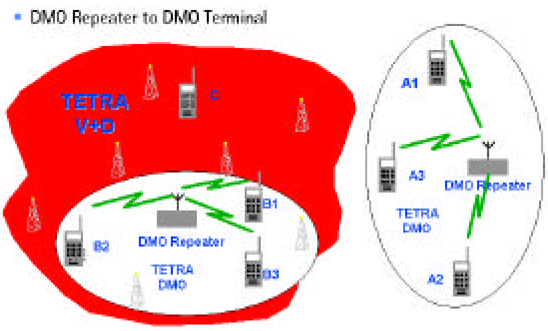

Figure 2: DMO Repeater to DMO Terminal

This model applies to operation using a DM-REO between the end MSs.

The DM-REP receives information from a transmitting mobile on an "uplink timeslot" and re-transmits this information to another mobile or group of mobiles on a "downlink timeslot". The DM-REP decodes and re-encodes bursts which it receives, to improve the overall link performance.

3. TETRA V+D to DMO Dual Watch

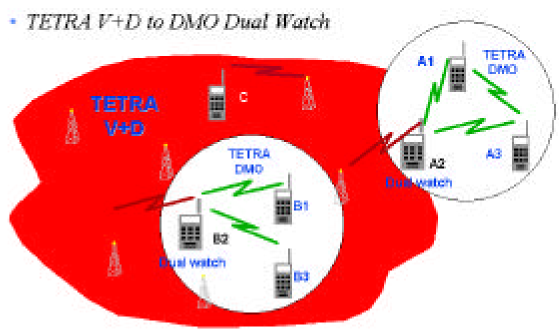

Figure 3: TETRA V+D to DMO Dual Watch Terminal

The DW-MS can be in one of three states as follow:

idle in both modes and periodically monitoring both the V+D mode control channel and a selected DM radio frequency carrier; or

a) communicating with another DM-MS via the Ud air interface and periodically monitoring the V+D mode control channel over the Um air interface; or
b) communicating with the TETRA Switching and Management Infrastructure (SwMI) in V+D mode via the Um air interface and periodically monitoring a selected DM radio frequency carrier.

Therefore, it is impossible for a DW-MS to simultaneously communicate over the two air interfaces

4. DMO Gateway

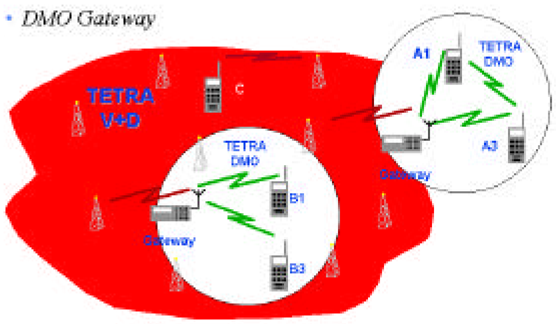

Figure 4: DMO Gateway to DMO Terminal

This operation model applies the usage of a DM-GATE into a TETRA V+D network. The DM-GATE caters for the differences in protocol between the Ud and Um air interfaces and provides for the required inter-connectivity between DM and the TETRA V+D network.

DM services
TETRA DMO provides following services:

a) TETRA speech (Teleservice): Individual Call (point-to-point) and Group Call (point-to-multipoint)
b) Circuit mode unprotected data (Basic bearer service): 7.2kbit/s
c) Circuit mode protected data (Basic bearer service): 4.8 kbit/s and 2.4 kbit/s

Individual calls and group calls in TETRA DMO

An individual call is a point-to-point communication between one calling party and one called party. It may only be set up between two MSs which have selected the same DM radio frequency carrier. An individual MS has a predefined number which is called its indivual number and by which it is addressed. The normal node of operation is simplex.

A group call is a two way point-to-multipoint communication between a calling party and one or more called parties. It may be set up between MSs which have selected the same DM radio frequency carrier.

1.3 Ad Hoc Networking Overview

An ad hoc network is one that comes together as needed, not necessarily with any assistance from the existing Intemet infrastructure. For instance, one could turn on 15 laptop computers, each with the same kind of infrared data communications adapter, and hope that they could form a network among themselves. In fact, such a feature would be useful even if the laptops were stationary.

Besides ad hoc networking, similar techniques have been proposed under the names instant infrastructure and mobile-mesh networking.

Multihop routing is the second feature of ad hoc networking. Since the range of wireless transmission is often limited compared to the geographic distribution of the mobile wireless nodes. And there is not support from infrastructure routers.

In order to enhance the usability, following features are considered with ad hoc networking: automatic topology establishment, dynamic topology maintenance and self-starting.

Following characteristics are assumed with ad hoc networking:

- The nodes are using IP, the Internet Protocol, and they have IP addresses that are assigned by some usually unspecified means.
- The nodes are far enough apart so that not all of them are within range of each other.
- The nodes may be mobile so that two nodes within range at one point in time may be out of range moments later.
- The nodes are able to assist each other in the process of delivering packets of data.

As an example of a small ad hoc network, consider Figure 6, illustrating a collection of eight nodes along with the links between them. The nodes are able to move relative to each other; as that happens, the links between them are broken and other links may be established. In the picture, MH1 moves away from MH2 and establishes new links with MH7 and MH8. Most algorithms also allow for the appearance of new mobile nodes and the disappearance of previously available nodes.

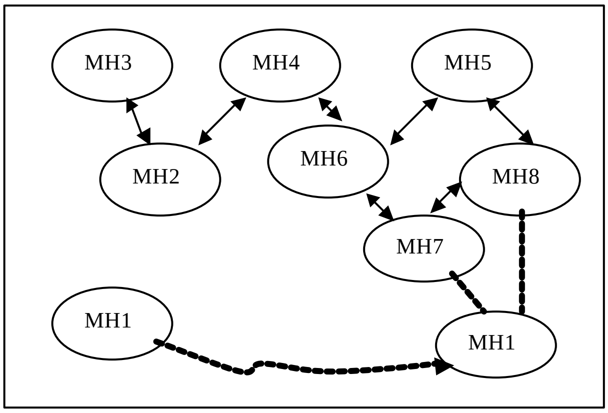

Figure 6: An Ad Hoc Network of Mobile Nodes

Within the last few years there has been a surge of interest in mobile ad hoc networks (MANET). A MANET is defined as a collection of mobile platforms or nodes where each node is free to move about arbitrarily. Each node logically consists of a router that may have multiple hosts and that also may have multiple wireless communications devices. The term MANET describes distributed, mobile, wireless, multihop networks that operate without the benefit of any exis ting infrastructure except for the nodes themselves. A MANET expands the present Internet vision in which wireless nodes on the edge of the network cloud are typically connected and supported by a single wireless hop to the fixed, wired infrastructure. A MANET network cloud is composed of autonomous, potentially mobile, wireless nodes that may be connected at the edges to the fixed, wired Internet.

Following ad hoc routing protocols and concepts were designed during the recent years:

- Destination-Sequenced Distance-Vector (DSDV)
- Cluster-Based Network
- Dynamic Source Routing Protocol (DSR)
- Ad Hoc On-Demand Distance-Vector Protocol (-(AODV)
- Zone Routing Protocol (ZRP)
- Temporally Ordered Routing Algorithm (TORA)
- Associated Bit Routing
- Source Tree Adaptive Routing

2 Requirements Analysis and Use Case for TETRA Ad hoc DMO

2.1 The reason for applying Ad Hoc Networking with TETRA DMO

There are several good reasons to apply ad hoc networking with TETRA DMO:

1. Terminal Cooperation

The cooperation between mobile nodes to route and transmit packets for other mobile nodes is one of the big obstacles for Ad hoc Networking application. However, in the case of TETRA DMO, this headache could easily be solved out.

Since TETRA system is usually operated and managed by a single organization (e.g. police.), therefore, the cooperation among their terminals could be guaranteed.

2. Communicatoin Improvement.

TETRA DMO's basic operation model, the so called 'back-to-back' need improvement.
With the 'back-to-back' model, the range a DM-MS could reach is quite limited. And the connection between two DM-MS would be broken whenever either of them moves out of the their radio coverage, and

- There is no repeater available, or
- Repeater is occupied by other pairs of DM-MS connection.

Thus, the freedom of communication between TETRA DMO terminals is largely limited. Therefore, some improvement to TETRA DMO to enable the freely communication is expected.

2.2 TETRA DMO Technical Requirements

While applying ad hoc networking technology into TETRA DMO, the original features and requirements for TETRA should be kept or even further developed.

Following is a brief discussion of the general TETRA features and technical requirements:

1. Fast call set-up time (group call ~ 300 ms)
2. All-informed "Open-channel" mode
3. Pre-emption + Queuing
4. Group/ Ack. Group & Broadcast Calls
5. Trunked operation
6. Flexibility - bandwidth on demand

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2.3 Ad Hoc TETRA DMO Use Case

1. TETRA DMO terminals communicating with each other with multihop in between.

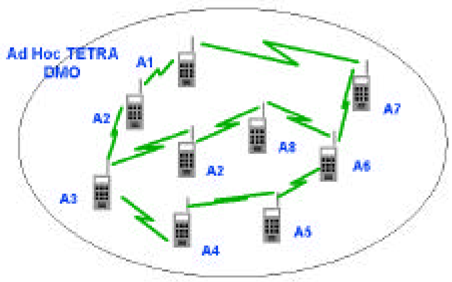

Figure 7: Ad Hoc TETRA DMO

Description:

- No repeater is needed anymore.
- Cooperation among terminals

2. Ad Hoc TETRA DMO terminal group call.

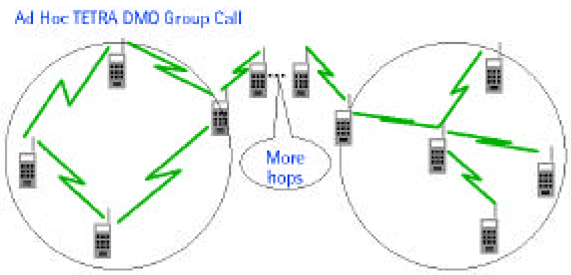

Figure 8: Ad Hoc TETRA DMO Group Call

Description:

- No repeater, no gateway are needed.
- Cooperation among terminals.
- Group call could be made over large area, multi-hops.

3 Proposal for Evolving TETRA DMO to Ad-hoc Networking

In this section, the proposal for evolving TETRA DMO to Ad Hoc Networking is carried out.

The basic requirements are set as following:

- Keep as many the current TETRA DMO components as possible.
- Introduce Packet Mode into TETRA DMO.
- Multi-hop routing among Ad Hoc TETRA DMO terminals must be supported.
- No repeater is needed.
- Multicast or Broadcast (one-to-many) is optional.

However, the technology obstacles lie in:

- TETRA DMO is circuit mode, TDMA.
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Therefore, the key point is to adapt TETRA DMO to packet mode.

3.1 TETRA DMO Air Interface (AI)

In TETRA DMO, DM-MS is connected to DM-MS via DM air interface, Ud

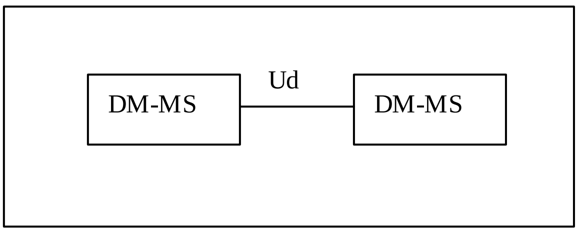

Figure 9: DM-MS connected to DM-MS via DM air interface, Ud

Ud air interface applies to a simple point-to-point or point-to-multipoint communication between DM-MSs. The DM-MS which provides the synchronization reference is defined as the 'Master' DM-MS. A DM-MS which initiates a call become the master for the duration of the transaction.

The Ud protocol Stack is shown in Figure 10.

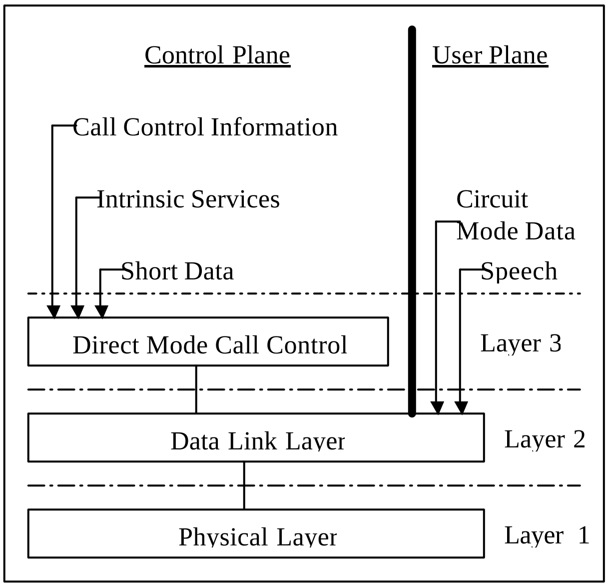

Figure 10: DM-MS Protocol stack for basic operation and operation with a repeater

The TETRA DM protocol architecture which is defined herein follows the generic OSI seven layer structure.

The base of the protocol stack rest on the Physical Layer (PL) (Layer 1).

The Data Link Layer (DLL) (Layer 2) shall handle the problem of sharing the medium by a number of users. At the DLL, the protocol stack shall be divided vertically into two parts, the User Plane (U-plane), for transporting information without addressing capability, and the Control plane (C-plane) for signaling with addressing capability, as illustrated by figure 5.

Layer 3, the Direct Mode Call Control (DMCC) entity, lies in the C-plane and is responsible for control of the call (addressing etc.), provides the intrinsic services supported in DMO, and supports the carriage of short data messages. U-plane access at layer 2 (DLL) supports the speech teleservice and the circuit mode data layer bearer services which are available in TETRA DMO.

3.2 TETRA Advanced Packet Service (TAPS) Air Interface (AI)

TETRA Advanced Packet Service (TAPS) adapts (E)GPRS technology to provide an overlay network for TETRA systems. This service provides high speed data at speeds approximately 10 times that available in existing TETRA V+D.

Within TAPS, two different bearer service types are defined. These are:

- Point-to-Point (PTP);
- Point-to-Multipoint (PTM).

The TETRA TAPS standard seeks to enhance the capability of TETRA to support enhanced data rate capability for packet data. In order to achieve this, additional standard interfaces are proposed as shown in figure 11.

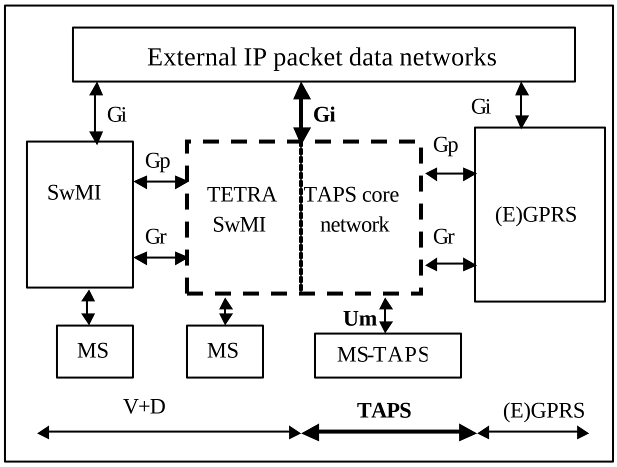

Figure 11: TAPS interworking implementation

The four interfaces within the scope of the TETRA TAPS standard are:

- Air Interface (Um)
- Packet Data Network Interface (Gi)
- TETRA-GSM Inter-network Interfaces (Gp and Gr)

The Um air interface protocol stack is shown in figure 12.

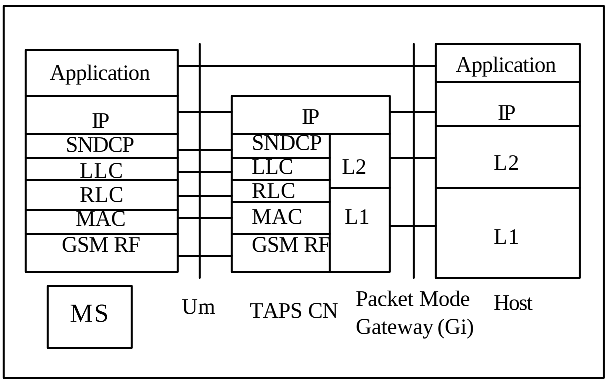

Figure 12: TETRA TAPS Air Interface Protocol Stack

3.3 Proposal - Adapt DMO Air Interface to TAPS Um Interface

Based on the above analysis, a proposal to adapt DMO air interface to TAPS Um interface is made. In this way, a DM-MS could make IP end-to-end addressing and routing, therefore, ad hoc networking protocols could be used in DM-MS without significant change.

This solution has some limitation. As the TAPS protocol is a GPRS adaptation, all the shortcomings of GPRS technology apply here.

Nevertheless, this solution only make the minimum changes to the existing TETRA DMO architecture, the time-to-marcket of this solution is considered to be quite short. This is the positive side.

However, in order to make full use of the radio resources as well as run IP and Ad-Hoc Networking functionality more smoothly, more advanced Air is expected. This is for further study.

4 Adapting Ad Hoc Networking Protocol to TETRA DMO

In this section, the TETRA future development is discussed. Then the Ad Hoc networking protocol, DSR is evaluated.

4.1 TETRA future development

TETRA is going to evolve towards 3G.IP convergence. So the future TETRA terminal (beyond TETRA release 2) will be FULL IP compatible.

No matter what is the layer 2 implementation of the future TETRA, the layer 3 will be IP.

The Ad Hoc TETRA DMO will share the common platform with TETRA in general. Therefore, it is expected that the future Ad Hoc TETRA DMO will directly use the ad hoc networking technology.

As TETRA is a special purpose mobile wireless application, the current ad hoc networking technology may not be fitted all of its requirements. Next section will briefly investigate this issue.

4.2 Dynamic Source Routing Adaptation

In this section, the Dynamic Source Routing (DSR) protocol is briefly investigated in order to know whether it is suitable for Ad Hoc TETRA DMO.

The Dynamic Source Routing protocol (DSR) is a simple and efficient routing protocol designed specifically for use in multihop wireless ad hoc networks of mobile nodes. DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure or administration.

The protocol is composed of the two mechanisms of Route Discovery and Route Maintenance, which work together to allow nodes to discover and maintain source routes to arbitrary destinations in the ad hoc network. The use of source routing allows packet routing to be trivially loop free, avoids the need for up-to-date routing information in the intermediate nodes through which packets are forwarded, and allows nodes that are forwarding or overhearing packets to cache the routing information in them for their own future use. All aspects of the protocol operate entirely on demand, allowing the routing packet overhead of DSR to scale automatically to only that needed to react to changes in the routes currently in use.

The simulation result of DSR seems to be quite positive while running with 50 mobile nodes. The packet delivery ratio is constant and relatively high. The routing overhead is relatively low.

Moreover, DSR has also been implemented into a test bed. And its usability is further verified.

However, in terms of Ad Hoc TETRA DMO application, DSR has some limitation:

- Multicast routing is not supported by DSR currently. This makes the point-to-multipoint application (e,g. group call) impossible to be implemented with this technology.
- Scalability issue. While dealing a large amount of mobile nodes, the performance or DSR is problematic.

5 Conclusion

The above study shows that there is actual requirement for the current TETRA DMO to evolve into the Ad Hoc TETRA DMO.

An intermediate solution could be the (E)GPRS technology based TAPS adaptation. This is the fast solution to implement Ad Hoc TETRA DMO.

The final solution for Ad Hoc TETRA DMO could be based on the convergence of TETRA to 3G.IP direction. Therefore, the current ad hoc networking technology could be applied with certain enhancement.

References

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