WHITE PAPER

Interconnecting TETRA systems

CONTENTS

1. PREFACE

The TETRA standard is a suite of standards covering different radio and network technology aspects, for example, air interfaces, network interfaces and its services and facilities.

Most of those interfaces have been successfully implemented and have been in daily operation around the globe for over a decade.

Amongst the many promises that have been delivered by the TETRA standard to its users, the only interface promise which has not yet been met is the Inter-System Interface (ISI) – however this interface is now gaining momentum within the industry and amongst customers. The first IOP certificates between two independent manufacturers have recently been issued in April 2009[1]. We haven't reached cruising altitude with ISI, but we are now finally airborne.

The lessons learned over the last few years have shown that ISI has become a victim of competition. It has repeatedly been sought by the marketplace, and indeed was one of the overriding ambitions of the many proponents of TETRA, and yet industry has struggled to deliver. Why?

It has become obvious that even to the inner circles of the TETRA community there is no real common baseline of knowledge on ISI – one community say ISI is available, enabling seamless connectivity between two independent but connected systems, whilst others are more conservative. This paper is intended to educate on the complexity of ISI, to cut through the marketing promises, and act as a reference for the marketplace separating facts from fiction, reality versus myth.

It is also evident that ISI might be too heavy an interface to enable smaller systems to be interconnected; when there is no need to have fully independent fleet maps nor a need for advanced security features, the need for a full ISI represents overkill to many of these customers. These small standalone systems are predominantly based on packet switching technologies, whereas the full ISI demands QSIG and ROSE circuit based protocols that represent unwanted complexity and operating costs. As a consequence, various bespoke solutions have materialised from different suppliers for connecting these systems together whilst avoiding the need for a full ISI, many of which are gravitating towards use of IP connectivity with a well defined API and offering the equivalent of a smaller subset of ISI services.

This paper will be updated regularly to reflect progress towards, and the remaining challenges associated with, the delivery of a TETRA ISI solution for the purpose with which it was originally intended, i.e. cross-border communications. In addition, the paper will also discuss the possibilities to use IP to interconnect smaller systems.

However, before we go there, with reference to its strategic importance within Public Safety Communications and Private Mobile Radio, the questions this paper will first address are as follows:

- Why was the TETRA ISI conceived?
- What precisely is the TETRA ISI?
- How should the TETRA ISI be used?
- When will the TETRA ISI be realised?

[1] http://www.tetra-association.com/uploadedFiles/Using_TETRA/Interoperability/Certificates/Certificate_v1_TetraSystemRel55EADI_DimetraIP61-ISIMotI_0309.pdf

2. WHY WAS THE TETRA ISI CONCEIVED?

Synopsis: The concept of cross-border communications between nations, particularly within Europe, using a single technology was one of the key motivations behind the TETRA standard.

The Schengen Agreements (circa 1985 & 1990) and subsequent Acquis that were made provisions of European Union law, were driven primarily by:

- Abolition of systematic border controls between nations within the EU
- Harmonisation of external border controls of the EU
- Cross-border cooperation of Police and Customs organisations

Whilst the last of the Schengen Agreements were signed, the European Telecommunications Standardisation Institute (ETSI) was demonstrating growing signs of success with the Global System for Mobile communications (GSM) standard for mass consumer, revenue generating, point-to-point telephony calls.

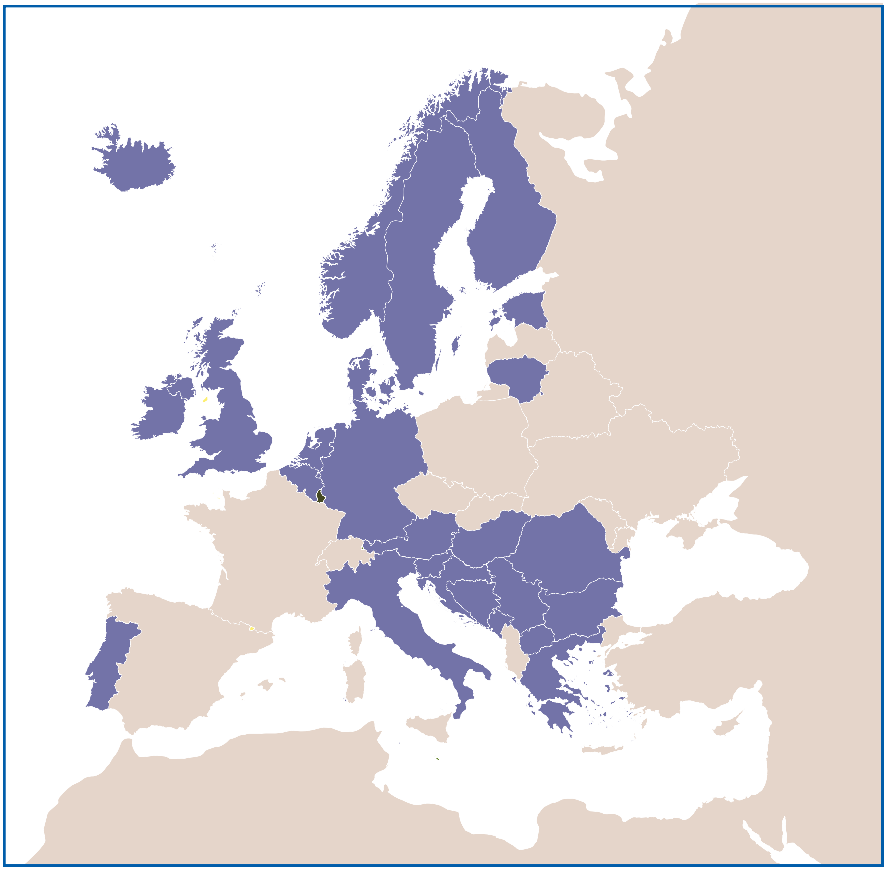

Figure 1: Deployment of Nationwide TETRA Networks

From 1990, requirements began emerging within the PMR community for a common digital communications technology that could achieve the economies of scale needed by governments focused on ever reducing budgets, whilst arming end-users with the latest innovations. ETSI, borrowing from the successful standardisation framework of GSM, therefore initiated work on the Trans-European TRunked RAdio (TETRA); later to be renamed to TErrestrial Trunked RAdio due to its worldwide appeal.

By moving towards a single technology, governments were able to procure a single nationwide communications infrastructure, replacing the plethora of analogue and proprietary regional systems. Tendering for such a system on a nationwide scale would drive value for money, as suppliers would be prepared to offer higher discounts due to the increased volume of business versus regional system procurement. Terminal interoperability with any network provider would ensure strong competition, driving up functionality and lowering costs to end-users.

TETRA's mandate was clear, its focus would be meeting the needs of mission critical end-user organisations seeking access to the latest digital innovations for increasing their operational capabilities and effectiveness, replacing MPT1327 plus other legacy PMR systems and addressing newly emerging PMR needs, whilst importantly for governments it would provide value for money through competition (in the form of interoperability). However, there was also a longer term vision behind TETRA, aligned with that of the principals behind the Schengen Agreements, i.e. to provide European cross-border communications capability between nations to combat international crime, terrorism and manage major crisis within the EU more effectively; these nations operating their own independent secure and reliable TETRA networks.

At that time, many were sceptical that this utopian 'cross-border' vision could be realised, certainly within their lifetime. Since then, proponents of TETRA have worked long and hard with unrelenting enthusiasm, drive and ambition to influence their own colleagues, key decision-makers, suppliers and partners in pursuit of this 'cross-border' vision. Daily news reinforces the need for nations to cooperate in order to defeat those elements intent on causing harm. Despite these valiant efforts and the successes with terminal interoperability, the TETRA Inter-System Interface (ISI) is still not in operation today.

More recently, now that TETRA nationwide networks are in common place, a number of governments within the EU (and for that matter other nations) are deploying nationwide crime fighting forces with the remit to operate anywhere within their borders, enabled in part by the seamless roaming capability that the network now offers them.

3. WHAT PRECISELY IS THE TETRA ISI?

Synopsis: The TETRA ISI represents a set of basic services necessary to support 'break-connect' cross-border communications between independently owned and operated TETRA networks; relative to the TETRA air interface today, it will provide a limited subset of TETRA services.

The TETRA ISI is not a new addition to the ETSI standard. ETSI standardisation of the TETRA Air Interface and Inter-System Interface began way back in 1990. Standardisation of the ISI was then put on hold a few years later, diverting resources onto completion of the air interface terminal standard, which was seen as the overriding priority amongst end-users at that time; it was deemed more important to get the national networks implemented with the greatest level of functionality. Note that the projected development costs for the TETRA ISI were considered substantial, even at this early stage in standardisation, and the return on investment for both suppliers and governments to go beyond the basic set of services meant that there was little value in going any further until a number of networks had completed rollout.

As well as the Inter-System Interface (ISI) and Air Interface (AI), the Peripheral Equipment Interface (PEI) and Direct Mode Operation (DMO) were also defined within the ETSI TETRA standard along with references to gateways to external de facto systems such as PSTN, PABX and ISDN. Further standardisation of other subsystems (e.g. consoles, base stations) within the infrastructure and terminal were not seen as value add, and would have stifled innovation as well as prolonging time to market of products and solutions; nota bene this potential delay may have impacted the overall success of TETRA.

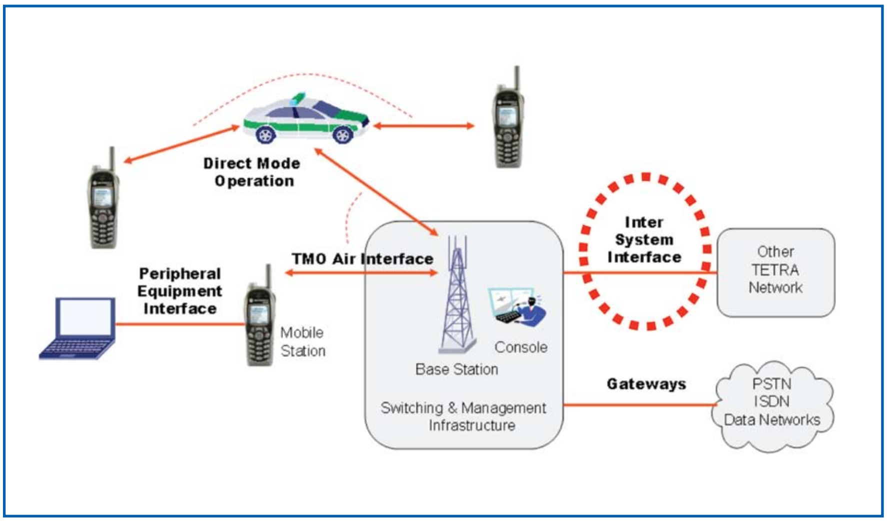

Figure 2: ETSI Standardised Interfaces of a TETRA System and Terminal

To date, infrastructure and terminal manufacturers have collectively invested over a billion Euro (est.) in research and development in TETRA, yielding a rich, diverse and comprehensive set of services within a TETRA network between infrastructure and terminals.

TETRA ISI has become a chicken and egg situation. Government users needing ISI wanting to see and feel the product in advance, but there was no justification for the large R&D investment necessary to provide even a basic set of services between these complex and markedly different infrastructures provided by different manufacturers.

Unlike the 'roaming' capability in GSM systems, which was driven by the business opportunity to generate substantial new revenue streams for international operators, the TETRA ISI was expected to be used by a few users from each system occasionally roaming (or in TETRA terminology 'migrating') to a neighbouring country's TETRA system. The TETRA networks in this instance are owned and operated by governments on a 'not for profit' basis. The problem has therefore been all along, where should the funding for TETRA ISI development come from, and indeed this is still the dilemma we face today!

Despite the absence of customer funding, two key suppliers returned to ISI standardisation activities with renewed vigour from 2003, being driven by the Three-Country Pilot (3CP) initiative and field trials between the Netherlands, Belgium and Germany to, and more recently, various proof-of-concept test sessions. The industry is now at the point where substantial investment is required to turn theory into practice, and put plans in place to deliver a real mission critical ISI solution for cross-border communications, again principally driven by the Netherlands, Belgium and Germany.

The ETSI TETRA ISI standards that were drafted in the initial phase began focusing on a small window of functionality vis-à-vis that available from the TETRA air interface. Specifically, the following features and functions which were seen as the most important aspects of any ISI solution:

- Allowing terminals to use a foreign 'independent' network when required
- Allowing users in one network to communicate with users in another 'independent' network
- ISI Gateway to control the system's access policy regarding foreign users
- Basic services such as Group Call, Individual Call and Telephony services

In addition, security remained a key concern for those contemplating the TETRA ISI, and there are still no agreed solutions on how this will be achieved. The TETRA cryptographic systems[2] that protect each network either side of the ISI are completely independent, even if those networks are supplied by the same manufacturer. Therefore, trying to find some middle ground that protects both networks from each other, whilst allowing foreign users to utilise communication resources securely, is a difficult challenge for suppliers, governments and end-users alike.

In the past few years, the scope of the TETRA ISI has been revised significantly, in light of lessons learned from the 3CP trials between Netherlands, Germany and Belgium. The industry parties involved in 3CP wanted to share the experience from the pilot with other companies in the industry, providing full transparency to the TETRA User Community. In particular, a new document was published by ETSI entitled "Functional requirements for the TETRA ISI derived from Three-Country Pilot Scenarios" [2], issued in May 2005, wherein it describes the ISI functionality viewed as most critical to end-users for cross-border operations.

Since it was widely accepted that it would not be feasible nor practical to implement in one go all the functionality described by ETSI in [2], the priorities in terms of the phasing of functionality have recently been agreed amongst potential TETRA ISI customers and consolidated within a new TETRA Association document, entitled "ISI Adoption" [3] and issued in April 2008 - see Appendix for an executive summary of [3]. From this latter document, it is apparent that IOP Phases 1 and 2 are considered by many parties as a mandatory part of any long term ISI solution, with IOP Phases 3 and 4 being optional to others.

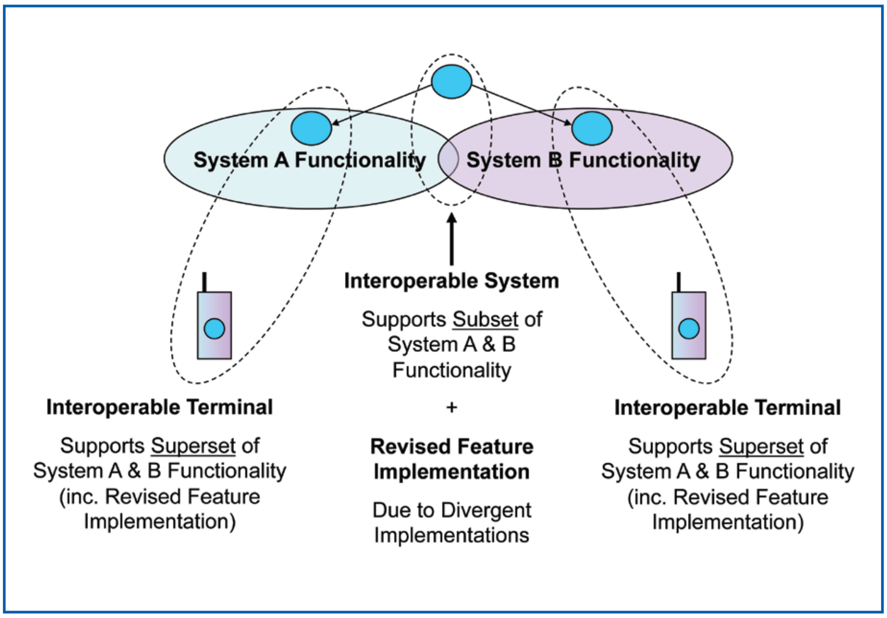

Figure 3: TETRA Inter-System Interoperability

Manufacturers must avoid overselling the capabilities of the TETRA ISI, as this will set false expectations with the TETRA User Community. Even when two networks from different suppliers are connected together, which both comply with the ETSI standards and have demonstrated full interoperability with many suppliers' terminals, they are very different from one another through their chosen system implementation. For example: one network will have Single Slot Packet Data, Scanning and perhaps MS-ISDN Dialling, whilst the other will be optimised to support Multi-Slot Packet Data, Group Cipher Key (GCK) Air Interface Encryption plus others.

Furthermore, the differences between some feature implementations are so different that they are completely incompatible between users of different countries, such as national End-to-End Encryption solutions. These aspects are illustrated in the Figure 3 below (and also later by Figure 6, Page 14), highlighting the fundament fact that unless manufacturers' implementations are completely identical, which for all intents and purposes is unrealistic, a migrated terminal will only have access to a subset of basic services over the TETRA ISI.

Networks connected together via a TETRA ISI operate as independent networks. From a terminal perspective, it will see a different Mobile Network Identity (MNI) broadcast from these networks; one corresponding to its provisioned 'home' network. The terminal will cling to its home network for as long as possible, before the signal becomes unusable and the terminal is forced to scan for other available networks which will range from a few seconds to half a minute or more. If and when the terminal receives a signal strong enough from the other network, it will perform what is referred to in TETRA as 'migration', beginning in relative terms a long chain of events between this visited network and the terminal's home network, culminating (if successfully authenticated) in the terminal having access to a subset of services from the visited network and, what is likely to be, an even smaller subset of services with users in its home network. Call handover performance is therefore nowhere near seamless, described more as a 'break-connect' service between networks, compared to that offered within the home network; when operating within a home network, handover performance is near-seamless with today's generation of TETRA networks and terminals.

In summary, the TETRA ISI is now principally defined by two important documents [2] and [3], which have taken significant time and effort from the TETRA User Community to converge and agree priorities on. This functionality represents the needs of users for cross-border operations; nota bene that even if governments are able to invest in all four phases of functionality, ISI functionality will still remain a fraction of that available today from the TETRA Air Interface between infrastructure and terminal.

[2] TETRA implements a portfolio of security mechanisms above and beyond those available from GSM or UMTS based systems. Migrating from one network to another is therefore not simply a case of mirroring what commercial networks have achieved in the market today.

4. HOW WILL THE TETRA ISI BE USED?

Synopsis: From the outset, the purpose of the TETRA ISI has always been to serve cross-border communications between independently owned and operated nationwide TETRA networks. It would be used by small numbers of users, in a small number of instances, but when called upon must deliver basic PMR services flawlessly. Over time a separate need has emerged to use ISI to interconnect smaller systems to form larger networks.

On 20th January 2003, a Memorandum of Understanding (MoU) was signed by the Ministers of the Interior of Germany and Belgium, and the State Secretary of the Ministry of the Interior for the Netherlands, to support the Three-Country Pilot (3CP)[3].

The 3CP successfully evaluated the suitability of TETRA-based technologies for tactical cross-border operations between several Public Safety organisations within the border regions of Aachen, Zuid-Limburg and Liege. The end-user operational scenarios that were successfully demonstrated within the scope of the 3CP are illustrated below. At that time, the suppliers of the TETRA systems used in these regions were Motorola and Nokia.

The 3CP used what is commonly referred to as the 'Interim ISI' (or 'Phase 0 ISI') as the basis for a solution, and principally involved:

- Alignment of international fleet maps between these three systems
- Pre-provisioning of radios that would migrate from one network to the other
- Pre-provisioning of network services available to migrating radios
- Analogue audio patching of group calls between digital systems

Amongst others, the 3CP did not support Emergency Call, Encryption, Individual Call, Status or Short Data Service, between systems.

Subject to appropriate funding, discussions are now underway between these organisations concerning the concept of 3CP Phase 2, following on from the successes of 3CP Phase 1 in 2005. The scope of this 'proof-of-concept' trial is intended to align better with ISI IOP Phase 1 as described in [3], specifically involving basic registration scenarios, individual call, short data and telephony.

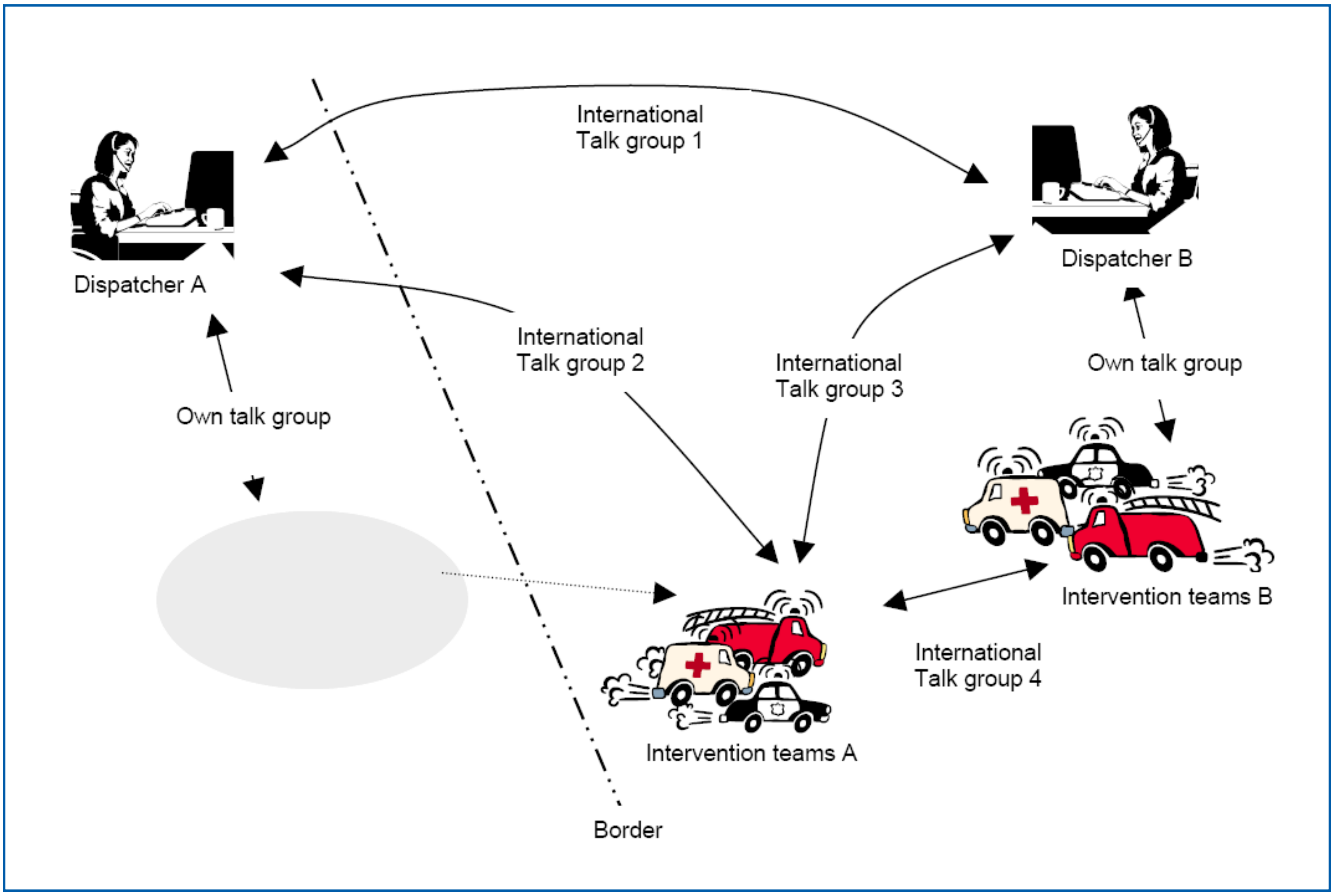

Figure 4: Three Country Pilot End-user Operational Scenarios

[3] Three-Country Pilot, Aachen-Luik(Liege)-Maastricht, Final Report, November 2003.

Can TETRA ISI be used to build large networks?

Plausible, certainly yes, but it will have some consequences. If all switching equipment is from the same supplier, it is absolutely possible. However, if the switching equipment is from different suppliers, it is an entirely different matter altogether.

Although limited, in recent years a few organisations have contemplated using the TETRA ISI as a means to build a cheaper national TETRA network from a montage of independent regional systems from different suppliers, perhaps influenced by those parties that were not aware of the original drivers behind TETRA, both functional and financial. This is in fact a misconception. Through dialogue with these parties, including further commercial and technical analysis, these organisations have found that use of the TETRA ISI for such an approach suffers a number of distinct disadvantages:

- Functionality, even in the long term, between systems and users (not just those users migrating from one region to another) will be severely limited, relative to functionality available natively between the home network and its home users;
- Performance between systems and users will suffer, resulting in a higher percentage of dropped calls, higher audio delay and longer call setup times, which would effectively impact all users (not just those migrating from one region to another);
- Security controls and management will be disjointed between systems and will only be as strong as the weakest suppliers implementation, e.g. government approved networks connected to non-government approved, resulting in the potential for loss of service altogether, either due to attack or through genuine human error;
- Network management of independent networks resulting in development outlay costs to create a Manager of Managers spanning different suppliers networks;
- Buyer's leveraging power is considerably reduced if a nationwide system is procured as a series of tenders for smaller systems resulting in lower discounts offered by suppliers due to reduced volume of business;
- Total Cost of Ownership (TCO) is considerably higher for equipment, spares, training, maintenance processes and procedures, resulting in higher lifetime OPEX costs which represent the major cost in any system;
- Management complexity overheads for mixed systems, platforms, software and roadmaps, interoperability, including customer test and reference systems.

In addition to the above, a substantial CAPEX outlay would be required to implement the TETRA ISI equipment and services to the necessary performance and capacity levels on all regional networks, fully interconnected to each other on a peer-to-peer basis – and all of this is of course dependent on when multi-vendor TETRA ISI solutions are available from the market across multiple vendors.

There are simply no sound financial nor technical arguments to justify building a nationwide TETRA network in this manner. The competitive tendering and procurement processes for a nationwide system provided by a single source supplier ensure the best deal is obtained due to the large economies of scale.

Furthermore, end-users also stand to lose the benefit of the rich set of services available within a TETRA network between infrastructure and terminal that suppliers have spent billions developing and perfecting. Instead, these customers will be limited to a basic set of PMR services, with cooperation between regions being severely limited in nature – to many users this could be viewed as a backward step in terms of what the TETRA technology has to offer.

Now, if all switching equipment is from the same supplier then most of the arguments above go away, however so does the perceived advantage of enhanced competition - why would anyone want to use standardised TETRA ISI to interconnect smaller independent systems from the same supplier when they can provide much better functionality, performance and security using internal interfaces.

The TETRA ISI does not enable systems with one set of performance parameters to interface seamlessly with systems having different sets of parameters, obviously leading to problems for the users of such a combined system. Technology should be second nature, so if the differences in performance, reliability and security of these systems are that vast, then it will simply be impossible to create a combined 'fit for purpose' nationwide system between them.

Due to the significant development effort involved in the TETRA ISI and the forecast time-to-market, smaller TETRA system suppliers have preferred to focus on alternative ISI solutions. These ISI solutions solve the communication challenge between systems differently, with varying functional trade-offs, and in a manner more cost effective to the market segments they serve, and this is expected to be the trend in that space for the foreseeable future. However, the bottom-line is that the TETRA community have not been able to make the investment in TETRA ISI.

Two companies (Motorola and EADS) have gone through the ISI certification process with early developments of initial functionality, but it is generally recognised this is a technical milestone rather than an indication for operational readiness. Both companies first certified against themselves (i.e. single-vendor operation), however the market did not view this as real progress. More recently, these two companies successfully connected their systems during an ISI IOP test session in March 2009. The list of functionality tested was limited – Individual Call and Short Data - and not yet suitable for operational use, principally due to the absence of the most important TETRA feature – Group Call. Lately, a third infrastructure manufacturer has also stated a readiness to begin testing in 2009.

5. WHEN WILL THE TETRA ISI BE REALISED?

Synopsis: Commitment is required from enough customers to warrant the investment from industry; infrastructure and terminal suppliers alike. Suppliers need to agree on common ground in terms of services they can offer collectively as part of a TETRA ISI, aligned with the priorities of the User Community. Only then can time and resource take affect to bring a solution to market.

To set the record straight, relative to the efforts and results associated with the TETRA Air Interface, the availability and interoperability of the TETRA ISI is still in its infancy. Given infinite funding and resources, the TETRA ISI as defined by [3] will take at least 3-4 years to deliver fully.

The User Community has now agreed on a set of priorities [3], however in the absence of customer funding, manufacturers are limited in what they can deliver. Despite this, the parties behind the 3CP are discussing a 3CP Phase 2 trial based on proof-of-concept functionality described in IOP Phase 1 [3].

In the past with an absence of customer funding, a number of manufacturers have devoted what resources they could afford to in progressing the TETRA ISI specifications, however clearly this has taken a long time and we're still not at the point where TETRA ISI has been successfully deployed between different infrastructure manufacturers. One company have declared they have at least one contract to deliver TETRA ISI, and are working to comply with these commitments.

The milestones that have to date been achieved are:

- Trial of multi-vendor 'interim ISI' trial as part of 3CP
- Single-vendor, partial compliance of IOP Phase 1: EADS[4]
- Single-vendor, partial compliance of IOP Phase 1: Motorola[5]
- Proof-of-concept, Multi-vendor, partial compliance of IOP Phase 1: Motorola & EADS[6]

The next milestones being planned or discussed are:

- Trial of multi-vendor, partial compliance as part of 3CP (2010/2012)

What is possible with full TETRA ISI?

As mentioned in Section 4, it is plausible to use TETRA ISI to interconnect smaller systems together, and as long as they have the exact same functionality, performance and implementation characteristics, users will get an acceptable service – in reality, this can only be guaranteed if the infrastructure is sourced from the same manufacturer to the same specification.

Interoperability of the TETRA Air Interface works on the basis that if terminals want to be interoperable across all infrastructures, then they must develop the superset of infrastructure functionality – see Figure 5 below. The terminal manufacturer's developments costs are then recouped through the sales of hundreds of thousands of terminals across these different infrastructures.

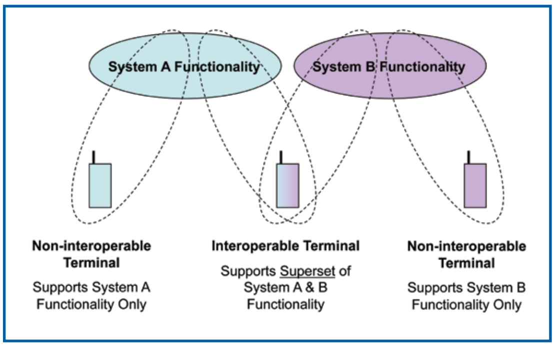

Figure 5: TETRA Air Interface Interoperability

[4] See http://www.tetra-association.com/tetramou.aspx?id=4274
[5] See http://www.tetra-association.com/tetramou.aspx?id=6688
[6] http://www.tetra-association.com/uploadedFiles/Using_TETRA/Interoperability/ Certificates/Certificate_v1_TetraSystemRel55EADI_DimetraIP61-ISIMotI_0309.pdf

With reference to Figure 3 (Page 7), interoperability of the TETRA ISI is on the other hand very different. Due to the limited number of customers and significant development costs involved, infrastructure manufacturers and customers are focusing on a few basic services that can be aligned and standardised across systems – see Figure 6 below for a detailed example.

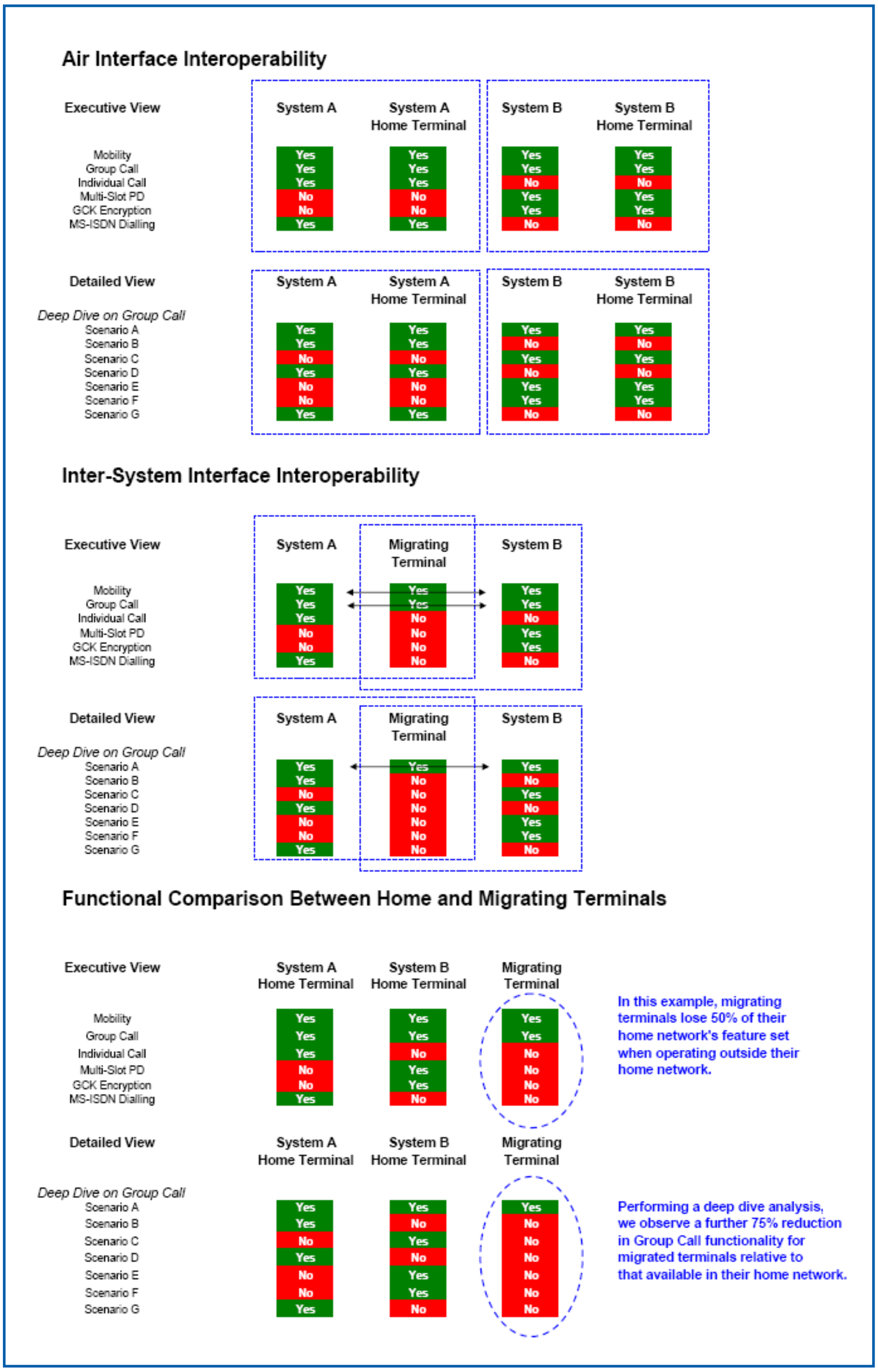

Figure 6: Functional Comparison: Home versus Migrating Terminals

Taking this pragmatic approach, the difficulties mainly arise, not by aligning some basic services, but more so from functional areas deemed necessary for cross-border communications that manufacturers have taken divergent development paths on, including innovative applications which could be proprietary in nature. Either one supplier agrees to adopt the other's implementation, or both parties agree to develop a new replacement function or service altogether.

Take the simple example of the Emergency Alarm function, which in one network could use a group-based addressing mechanism, whilst in another network could use an individual-based addressing mechanism; in this instance, one network would be required to implement, what is referred to in TETRA as, an Inter-working Function (IWF) that intelligently translates one implementation into another. The complexity of some IWFs can easily mushroom.

The *quid pro quo* with both these approaches is the strong possibility of impacting existing terminal behaviour within a subscriber's home network, which many end-user organisations would fervently defend against, understandably. The development costs for infrastructure manufacturers can therefore easily spiral if there are a number of divergent areas, and there may well be insufficient customers to justify such development. The difficulty for infrastructure manufacturers is therefore apparent. In spite of these challenges, there is general consensus amongst participating manufacturers that agreement can be sought.

6. HOW WILL THE TETRA ISI MARKET EVOLVE?

Synopsis: The TETRA ISI does not make any claims to be the market panacea solution. There are many stepping stones and possibilities in-between having no connection and using the full TETRA ISI for interconnecting systems together. This fact will inevitably lead to a plethora of ISI-type solutions, in response to the varying needs and budget constraints of users.

The availability of ISI solutions on the market today and heading into the future will comprise one or more of the following functional elements, each with their own distinct user benefits and impacts on operational procedures and costs. Note that the below list will be revised as and when new solutions or approaches become available from TETRA manufacturers.

Analogue Patching Between Networks

This functionality is required when terminals from one network need basic group call communications with terminals operating on another network.

This solution has already been deployed using a Generic 4-Wire Interface (G4WIF) between consoles from each of the different networks. Since the connection is principally analogue, only audio information is passed between networks; TETRA identity information is not available.

Due to its simplicity, both CAPEX and OPEX costs are minimal with this approach.

Digital Interfacing Between Networks

This functionality is required when terminals from one network need basic call services to terminals operating on another network, and where no loss of audio quality can be tolerated or end-to-end encrypted calls are to be conveyed between the two networks whilst avoiding any intermediate decryption / encryption functionality.

This solution is typically achieved using either manufacturer specific digital interfaces (e.g. ICCS Gateway, Digital Console, etc.) between these different networks, or using a fixed mobile connection from one network that is operating within coverage area of another network; note the latter is sometimes referred to as an Inter Sub System Interface (ISSI). Since the connection between these networks is digital, double vocoding between networks can be avoided and thus audio quality maintained.

The infrastructure functionality available from a proprietary API can either be more or less sophisticated compared to the TETRA ISI, depending on the actual chosen implementation by each manufacturer. However, the net result, whether a proprietary API is used or not, is that only the lowest common denominator in terms of functionality will be available between systems from different manufacturers.

Both CAPEX and OPEX costs will be slightly higher with this approach versus Analogue Patching, although eclipsed by that of the TETRA ISI. In addition, the OPEX costs associated with IP packet based networks used by various Digital Interface solutions, although subject to market forces, are likely to reduce further over time versus existing E1 circuit based technology required by the TETRA ISI, representing better value for money.

TETRA ISI

This functionality is required when terminals visit a foreign network and need levels of group call, individual call, telephony call, short data and air interface security functionality similar to that available in its home network, albeit with some inherent limitations as outlined in Figure 6.

This solution is based on use of E1 circuits running QSIG and ROSE, implemented on a point-to-point basis between the required networks. These circuits carry the detailed TETRA ISI protocol that supports Mobility, Security, Call Control and Maintenance, Short Data, Telephony and Supplementary Services. Since the connection between these networks is digital and provides access to the ISI services, both the functionality and performance required for cross-border communications are available between independent TETRA networks.

Both CAPEX and OPEX are significant, and thus this type of solution is only practical for large nationwide networks that are able to subsidise the large ISI equipment investment and absorb the associated running costs.

Multiple Mobile Network Identity (MNI) For Migrating Terminals

This functionality is required when terminals need to use designated foreign networks, in addition to their own home network. Note that communications from a foreign network to the home network of a migrating terminal is dependent on the availability of an inter-system connection to its home network, i.e. via Analogue Patch, Digital Interface or the TETRA ISI.

With this approach, when needing to change networks, the terminal user manually selects one of the networks available to the terminal from a pre-provisioned list of approved networks. By adopting this solution, the migrating terminal's Individual Short Subscriber Identity (ISSI) will need to be coordinated and consistent between home and foreign network(s). Furthermore, if TETRA Security features are also required for the migrating terminals, its Secret Authentication Session Keys (KS, KS') will also need to be closely and continuously coordinated between home and foreign network(s).

Air Interface Migration (AIM) For Migrating Terminals

This functionality is required when terminals need to use designated foreign networks, in addition to their own home network. Note that communications from a foreign network to the home network of a migrating terminal is dependent on the availability of an inter-system connection to its home network, i.e. via Analogue Patch, Digital Interface or the TETRA ISI.

By itself, AIM will enable the terminal to automatically select an available TETRA network from a pre-provisioned list of approved networks, when coverage with the home network has been lost. The migrating terminal's Individual Short Subscriber Identity (ISSI) will need to be coordinated between home and foreign network(s). Furthermore, if TETRA Security features are also required for the migrating terminals, its Secret Authentication Session Keys (KS, KS') will also need to be tightly controlled and coordinated between home and foreign network(s).

However, AIM can be complemented by the TETRA ISI feature referred to as Full Individual TETRA Subscriber Identity (ITSI) Migration, which will eliminate the need to coordinate a migrating terminal's Individual Short Subscriber Identity (ISSI) between independent networks. Furthermore, if Authentication over ISI is also deployed, then the migrating terminal's Secret Authentication Session Keys (KS, KS') will be managed automatically between networks.

7. APPENDIX 1 – ISI IOP PHASING

The following tables provide an executive summary for informational purposes only of reference [3] and the latest discussions surfacing from [4].

ISI IOP Phases 1 & 2

Feature	Scenario	Reference
Authentication		Section 8.1 of [2]
Individual Call (Hook Sig.)	• Individual call to a subscriber from the home SwMI (while migrated) • Individual call to a subscriber from the visited SwMI (while migrated) • Individual call to a subscriber from another SwMI (not a subscriber from the home nor from the current SwMI) (while migrated) • Individual call to a foreign subscriber (not migrated)	Section 6.2 of [2]
Group Call	• Group call when located in group home SwMI • Group call when not located in group home SwMI	Section 6.3 of [2]
Telephone Call	• Outgoing Calls • Incoming Calls	Section 6.5 of [2]
Status		Section 6.6 of [2]
Short Data Service		Section 6.7 of [1]

ISI IOP Phase 3

Feature	Scenario	Reference
Mobility Management	• Migration authorisation by the home SwMI, through pre-provisioning in foreign SwMI • Group access mgmt by the group's home SwMI, through pre-provisioning in the foreign SwMI	Sect. 5.1/2 of [2]
Air Interface Encryption	• DCK Encryption	Section 8.2 of [2]
Emergency Call		Section 6.4 of [2]
End-to-End Encryption		Section 8.3 of [2]
Supplementary Services	• Call Line Identification Presentation • Talking Party Identification • Preemptive Priority Call • Late Entry • Air-to-Ground-to-Air Operation	Section 6.9 of [2]

ISI IOP Phase 4

Feature	Scenario	Reference
Supplementary Services	• Enable/Disable • Individual DGNA • Preemptive Priority Call • Barring of Outgoing Calls • Barring of Incoming Calls	Section 6.9 of [2]
Air Interface Encryption	• OTAR of GCK • OTAR of SCK	Section 8.2 of [2]
Packet Data		Section 6.8 of [2]

8. APPENDIX 2 - MYTH VERSUS REALITY

Synopsis: TETRA ISI is a suitable solution for cross-border communications requiring basic services; for all other applications, such as building national networks, that demand more functionality and performance, nothing can substitute the need for an infrastructure sourced from a single supplier.

Myth 1

TETRA ISI standardisation and interoperability is already available.

Reality

Progress has been made over recent years to complete the ETSI standards, TETRA Interoperability Profiles (TIP) and Test Plans for the features that comprise Phase 1 & 2 as defined in the 'ISI Adoption' paper [3]. More recently, the Group Call specification and test plan has now been completed. Functionality described as Phases 3 & 4 remains incomplete, with some elements not yet agreed within ETSI.

The first proof-of-concept testing was completed successfully in March 2009 and witnessed by the independent test house. The functionality tested was individual call and short-data.

Myth 2

TETRA ISI is the same as connecting GSM systems together.

Reality

GSM 'roaming' is a significant revenue generator for operators. Substantial investment could be justified as the projected revenues were high. GSM is principally a point-to-point telephony service only, with a few supplementary services over and above. Since the complexity of the GSM system is relatively low, far more interfaces could be standardised before manufacturers delivered products to the market.

The plethora of features and functionality provided by a TETRA network is several orders of magnitude higher in complexity versus GSM, which anyone technically-minded and familiar with both standards would testify to, e.g. Group management, DGNA, Emergency, Pre-emptive Priority, Enable/Disable, End-to-End Encryption, Air Interface Encryption with Static, Derived and Group Cipher Keys, etc. Complexity adds development cost when trying to link these services together from different networks, especially when they have been implemented differently, but that is further magnified by the limited market over which to recoup these development costs, and therefore the cost to customers remains relatively high.

Myth 3

Interconnecting regional systems is just like interconnecting national systems.

Reality

Interconnecting national systems is required for cross-border communications. The TETRA User Community understand that to make TETRA ISI possible in a realistic timeframe for a realistic price, compromises need to occur in what services can be provided to users communicating between networks or within a foreign (i.e. non-home) network as a migrated terminal. Furthermore, the subset of services offered will be further reduced from the behaviour they enjoy within their home network due to differences in implementation of these features between networks.

Therefore, a network built from a set of regional networks connected together via a TETRA ISI will fall far short of the level of functionality and performance available today within a network from a single supplier. If terminals never leave their regional network, and never need to communicate with users outside their regional network, then they will enjoy all the TETRA services available from that regional network unhindered, and if this is the case then TETRA ISI is not needed. However, for all other cases, communications between users will be effectively reduced to just the basic subset of PMR services supplied over the TETRA ISI – users that have migrated to other regional networks will in a probability be communicating with fellow users situated back in their home regional network, bringing all users down to the same basic service. Not only this, the costs of such an approach are substantially higher from both a CAPEX and OPEX perspective; not to mention the complexity challenge of managing such a network.

Myth 4

A network built using TETRA ISI and regional systems costs less in the long run.

Reality

Buyer's leverage during commercial discussions is reduced significantly if a nationwide system is procured as a series of tenders for smaller systems, with the view that these will be later interconnected together. Instead, if procured as a single nationwide system through a competitive tendering process, the customer will enjoy the highest levels of discount representative of the increased volume of business on offer.

TETRA ISI gateway and interfacing equipment is required above and beyond the cost of normal infrastructure equipment. This would typically be required for each peer-to-peer regional network connection. So, for example, if a network were to be composed of say 9 regional systems, interconnected together using TETRA ISI, then this would represent 45 peer-to-peer connections. This cost should not be overlooked.

Multiple suppliers mean more subcontractors to manage, mean a larger subcontractor department and more complexity to manage. Each infrastructure supplier will have their own roadmap with features becoming available at different times. The interaction between these systems on constantly moving baselines of functionality will need careful testing and validation before it can be deployed on a live operational system. There will be the need for a comprehensive customer test system reflective of the actual system configuration, and covering all permutations of supplier equipment through different phases of rollout.

Mixing systems that are implemented so differently together is in fact the opposite of the trends in IT where in reality many customers adopt the same products universally within their organisations to keep the costs of training, testing, maintaining and other lifetime management costs to a minimum.

Should operational issues arise for end-users, if multiple suppliers are involved then it will likely take longer to root cause issues and decide on the right resolution which would ultimately impact the time to fix of faults and therefore could result in larger service outages for end-users which would be unacceptable to most. End-users may well have cost penalties imposed on the operator entity for such situations.

Myth 5

TETRA ISI avoids a monopolist position being taken by one supplier.

Reality

With single infrastructure supplier status, the common fear is that customers will not be given value for money for products, solutions or services outside of the main contract. This simply isn't the case in reality. It is not in a supplier's best interest to exploit the single supplier arrangement and the trust established with the customer.

There are many safeguards that ensure customers get a fair deal, including contractually. Customers are also free to talk amongst themselves and often share experiences with one another; indeed, there are many user forums in place today where such activities occur on a regular basis.

When everything is said and done, customers feel confident to award networks to a single supplier; this is borne out by the fact that the overwhelming majority of nationwide systems delivered to date are single supplier status.

Probably most important of all, it is worth pointing out that it is misnomer that procuring a nationwide network composed of regional networks from different suppliers is a safer approach than awarding it to a single supplier, as infrastructure enhancements to a regional network can only be sourced from its supplier. So, unless the customer has the same 'mutual' contractual safeguards in place across all infrastructure suppliers, the customer could even be more exposed, and certainly no better off than procuring the whole network from a single supplier.

9. REFERENCES

[1] Three-Country Pilot, Aachen-Luik(Liege)-Maastricht, Final Report, November 2003.

[2] ETSI Terrestrial Trunked Radio (TETRA); Functional requirements for the TETRA ISI derived from Three-Country Pilot Scenarios, ETSI TR 101 448, Version 1.1.1, 2005-05

[3] TETRA Association; ISI Adoption, Joint OUA/TF Meeting, 24th April 2008, Version 1.0.

[4] OUA & TETRA ISI Working Group Meeting, 27th April 2009.

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