NOKIA

The Nokia TETRA Primer

What is TETRA? Why Nokia TETRA?

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Summary of changes

1 TETRA - the new global radio communications standard

For decades, radio communication has been the solution for flexible and efficient communication in the field. Radio enables instant communication between two or more people simply by pressing a button. This push-to-talk feature and the ability of people to communicate in groups is fundamental for authority communication.

In most Public Safety organisations around the world, communication is a hot item - in many countries old equipment must be renewed during the next few years. The change from conventional analogue to intelligent digital radio networks is a big one, involving both technical and financial complexity, especially for the users.

One of the leading standards in digital radio is TETRA, an abbreviation of TErrestrial Trunked RAdio. It has been defined and approved by the European Telecommunications Standards Institute (ETSI) to be the only official European Standard for digital Professional Mobile Radio (PMR). Accordingly, TETRA is a global standard for radio communication in the same way that GSM is the mobile telephony standard.

In their every day activities, public safety organisations need various kinds of communications services. TETRA offers both the usual cellular services as well as professional radio services such as group communication, field workforce management services (dispatching) and efficient data services. TETRA is a unique combination of group voice communications, mobile telephony and mobile data services specifically designed for authority use.

TETRA is a purpose built technology that offers public safety and security organisations major advantages over conventional radio systems to. It was developed to meet the needs of the most demanding professional radio users who need fast one-to-one and one-to-many radio communication using voice and data in their daily work. Users are typically public safety and security organisations such as police, fire and rescue forces. TETRA fulfils the needs of professional users and replaces old analogue and proprietary radio communication systems that no longer meet professional radio-communication needs.

1.1 From proprietary solutions to open standards

Even today, most police, fire, rescue and border services have their own, often-incompatible private radio systems, which are based on vendor specific proprietary technologies. These are usually analogue systems with no security features. In some cases, authorities are dependent on commercial services with no guarantee of availability in the event of a major catastrophe.

The world is changing fast and communications methods need to improve accordingly. With the introduction of TETRA, today's authorities can source their network from many vendors, ensuring greater choice, more cost-effectively and with higher quality. Interoperability between all vendors is vital for the market success of users, operators and manufacturers and TETRA meets this requirement also.

1.2 From conventional analogue systems to digital TETRA

A conventional radio system consists of one or more base stations, which receive and amplify the weak signal received from a radiotelephone. For this reason they are often also known as repeater systems. In a conventional radio system there is no intelligent switching in the network. All radio users who have tuned their radio to the same frequency i.e. channel, can hear each other and there is no call privacy. The users have to agree in advance, which channel they use for communication. Channel selection is typically done with a rotary knob on top of the radio.

In TETRA, groups of users are defined in the TETRA users' radios in advance and communication between group members takes place simply by selecting the group with a rotary switch or menu keys and pressing the press-to-talk button on the radio.

Only those radio users who belong to the same group can hear and participate in the communication. The channel is of no interest to the radio user, because the TETRA system automatically puts the group members onto a free channel. The same applies to a person-to-person i.e. individual calls.

In a conventional radio system, individual, private calls are not possible. In TETRA, individual calls work the same way as in cellular systems such as GSM. Call privacy is also granted.

Finally, conventional radio systems are in most cases analogue systems. TETRA is fully digital, which means better voice quality, more advanced data features and more efficient use of valuable frequency spectrum.

In the past, trunked radio technology was only available as a proprietary solution from specific manufacturers. This resulted in a large variety of overlapping private networks, each with its own frequencies and ways of

working. The possibilities for co-operation were minimal. This was also an expensive way to build networks.

1.3 From small private networks to nationwide

Like cellular networks, PMR networks also consist of base stations, which are connected to mobile exchanges. PMR networks can be divided into three main categories: private networks, commercial PMR networks and public safety and security networks.

Private networks are owned and operated by the organisations themselves. These networks may be relatively small, consisting of a few base stations covering a limited geographical area like an industrial plant, but can also cover thousands of square meters like in the case of oil fields or power companies.

Commercial networks are often also called Professional Cellular networks, because their operating philosophy is similar to commercial cellular networks such as GSM. The operator invests in the network and sells the PMR service to professional organisations such as transportation, taxi and bus companies, security services, courier companies and similar organisations, which need the specialised services provided by the PMR network. Professional Cellular networks are typically nationwide networks.

Public safety and security networks are typically nationwide networks, which provide PMR communication services for police, fire, ambulance and other public rescue services. These network investments are typically financed from public funds.

2 Special features for professionals

Typical reasons to adopt PMR services are related to the need for special functionality such as group calls, instant communications with a sub-second call set-up delay, security and specialised dispatching services. The latter means managing the organisation's field operations and related communications. For public safety organisations, security is a fundamental issue and includes authentication of the users in the network as well as encryption of the voice and data communication itself.

For many organisations, having control of their own network resources is crucial and in many cases PMR services also offer the lowest overall communication costs.

2.1 Push-to-talk operation

Instant call connection and push-to-talk operation to set up a call is probably one of the most important features in TETRA. In cellular networks such as GSM, calls are mostly one-to-one i.e. individual calls, which are initiated either by dialling the called-party number using the phone's keypad or using the speed dial key. In both cases the call set-up time i.e. the delay from dialling until the called-party's phone starts ringing is typically in the range of a couple of seconds. The B-party has to press the answer button on his/her phone to answer the call. This kind of communication is too slow to match the quick pace of communication needed by professional users such as police or firemen.

In TETRA, a call is initiated with a push-to-talk button and connection is established in less than half a second. In addition, there is no need to answer the call – the calling party can start talking right away.

2.2 Communicating in groups

Another differentiating feature between TETRA and cellular services is group communication. In addition to individual calls, TETRA also supports group calls. The members of the groups are predefined and a group may consist of tens or even hundreds of members. A TETRA handset typically has an easy way to select the group, typically by using a rotary knob or easy-to-use menu.

The selected group is then the default communication group for the user. The call is initiated by pressing the push-to-talk button and all users who have selected the same group can hear the communication.

Cellular services cannot provide group communication functionality. Conference calls in cellular systems are not suitable for the fast-paced group communication needed in field operations by professional users. It is all too clumsy to set-up and the number of members in the conference call is limited.

In addition to predefined groups, a group can be created dynamically over the air during field operations. This is especially important in rescue operations where users from different organisations need to communicate together. The co-ordinator of the field operations, often called a dispatcher, can place the members into the dynamic group and the new group is created instantly over the air. The members of the newly created group get an indication that they belong to a new dynamic group and by selecting this group, they can start group communication immediately.

2.3 Managing fleet operations – dispatching

A dispatcher is a person who manages the field operations in a PMR network. Typically the dispatcher has a special graphical workstation i.e. dispatcher workstation, which helps to control the communication activities in the field.

For example, in a police organisation the dispatcher manages the radio communication with the mobile units in the field, gives task orders and instructions and receives information from the field force either as voice or data messages. The graphical dispatcher workstation helps him to communicate and get an overview of the status of units in the field.

The main tasks of a dispatcher are:

- keep track of operations, the active members in the operations and if possible, the location of the units participating in the operations
- steer the field operations in order to optimise the performance of the field force
- follow and participate in intra- and inter-group communications and individual calls
- allocate the most suitable units or groups for each task

- exchange status and textual information with the radio users participating in the operations
- create groups dynamically for special incidents
- subscriber management and control of user rights

Efficient dispatching is not possible without a graphical dispatcher workstation. The Nokia TETRA Dispatcher Workstation (DWS) supports all the necessary functionality and dispatcher tasks listed above. The communications activity in each group is shown in its own window, which makes it easy to form an overall picture of field operations. The Nokia TETRA DWS also has administrative functions to create, modify and delete groups and control their user rights.

The Nokia TETRA System has been designed to offer efficient dispatching facilities for both PSS (Public Safety and Security) and professional customers' organisations. The basic functionality serves both user sectors well, but in large public safety networks more advanced command and control systems are typically needed.

2.3.1 Integrated command and control solutions

In addition to the standard TETRA dispatcher workstation, the Nokia TETRA System offers products for developing customised command and control applications for integrated command and control solutions. One of these products is TETRA Communications Server (TCS). It provides the necessary communications and control functions needed to build complex dispatching applications and integrated command and control solutions.

With TCS, third party applications have access to the NTS and are able to:

- control TETRA voice calls
- send and receive status and short data messages and callback requests, as well as messages based on a set of Short Data Service (SDS) protocols
- manage group memberships
- manage groups
- perform tasks related to dynamic data management, i.e. receive updates of data related to TETRA radio subscribers, groups and organisations from the Nokia TETRA exchange

Third party command and control systems using the Nokia TETRA TCS interface are commercially available.

2.4 Security

Commercial cellular services cannot provide the ultimate security needed by professional users. Security consists of several issues:

Reliability

Nokia TETRA can maintain effective radio communications in even the most extreme situations. Where other communications networks may fail, Nokia TETRA's fault-tolerant design can survive the failure of individual network components, and continue to provide an unbroken service.

Availability

In disasters, people's natural reaction is to call their relatives and friends. Public telephony and cellular services can become choked quickly. However, Nokia TETRA has built-in priority mechanisms that can be set up in advance to maintain communication between critical rescue units.

Authentication of users

Authentication is a two-way procedure - on the one hand the TETRA network verifies that the terminal is authentic i.e. really belongs to the network and on the other hand, the TETRA radio makes sure that the network is authentic. Authentication takes place during registration i.e. when the radio terminal is switched on and tries to connect to the network. It consists of sophisticated message exchange between the radio terminal and the network. Authentication of all radios used in the network ensures that fake radios cannot be used. In addition, a TETRA radio can be removed from the list of accepted users as soon as it is reported stolen, so the stolen unit becomes useless.

Secure communication

Conventional analogue radio systems expose all communication to potential eavesdropping. Almost 100% of police forces worldwide still use analogue radio systems that offer no security against eavesdropping. Anyone can listen to police officers' communications with equipment that can be bought from a near-by shop. In Nokia TETRA, security is achieved through strict authentication of the radios used in the network and encrypted communication, which uses frequently changing encryption keys. These effectively prevent unauthorised access to the network and eavesdropping on communication.

Direct mode operation and base station fallback

Direct mode operation (DMO) is a special operating mode in a TETRA terminal, in which TETRA radios can communicate directly with each other without the TETRA network. DMO enables communication in areas where network coverage is not available, for example in the basement of a building, where radio waves cannot propagate. This feature is very important for firemen, who have to communicate in extreme conditions.

Base station fallback in turn enables communication within the coverage area of a certain base station if the link between the TETRA base station and TETRA exchange is lost e.g. due to cable damage.

2.5 Frequency efficient technology

Frequency spectrum is a limited resource and hence frequency efficiency has become increasingly important. In a trunked radio system such as TETRA, the radio channels are in a common pool and the TETRA system automatically allocates the radio channels to the radio users at the beginning of each call. This automatic channel allocation from a common pool is called trunking and systems using this method are called trunked mobile radio systems.

TETRA is based on digital Time Division Multiple Access (TDMA) technology. One 25 kHz wide TETRA carrier occupies four time slots or channels for communication. Old analogue systems are typically based on frequency modulation and one channel typically occupies either a 12.5 kHz or 25 kHz carrier. Hence TETRA is two-to-four times more frequency efficient than analogue conventional systems.

Nokia TETRA is available on three different frequency bands. In Europe the frequency band 380-400 MHz is reserved for public safety and security use. The 410-430 MHz band in turn is reserved for commercial PMR use.

Outside Europe, the 800MHz band has become a dominant frequency band for TETRA.

3 Data services in Nokia TETRA

3.1 Instant access to data

In addition to efficient voice communication services, Nokia TETRA provides versatile data services. These include short data similar to text messaging in GSM networks and status messaging, which is an extremely efficient way to send frequently used status information such as ‘On duty’, ‘Off-duty’, ‘At lunch’ etc.

TETRA data can occupy either a single time slot (channel) or multiple time slots for data transmission. Single slot data provides approximately 4 - 4.5 kbit/s net speed when using IP packet data transmission. In the future higher data speeds can be used using multiple time slots for transmission, the same as in GPRS.

In daily authority communication, data volumes are relatively low and the data speed provided by TETRA covers more than 90% of the needs of professional users. The majority of the data applications consist of database queries, where instant access to the data and ease of use are more important than high data speeds. In TETRA, the connection set-up time i.e. transaction overhead is very short. This, combined with the ease of use provided by Nokia TETRA professional WAP, makes TETRA an efficient tool for professional users. Complementary technologies such as GPRS, 3G or WLAN can be used for specialised applications such as full motion video or high volume file transmission.

TETRA also offers powerful Internet Protocol communications. TETRA can be used to send photos or other graphical information from the field to command and controls centres, or vice versa, to give additional information and a better overall picture of the situation.

Figure 1. TETRA data applications open new opportunities in daily operations

3.2 Professional WAP

Wireless Access Protocol (WAP) is an open standard, which enables professional users to easily access Web-based information services on the Internet or intranet from the keypad and screen of their mobile radios. For example, a policeman can retrieve vehicle information by entering the license number of the car. The WAP service will return the requested information to the display of the radio terminal. Maintenance of WAP services is easy, because all applications are maintained in the WAP servers and hence there is no need to update the terminals individually if the application changes.

Internet and intranet capability allows field officers to access authority databases to view vital information. TETRA's professional WAP service makes it easy to use applications with a radio terminal, without the need for external computers.

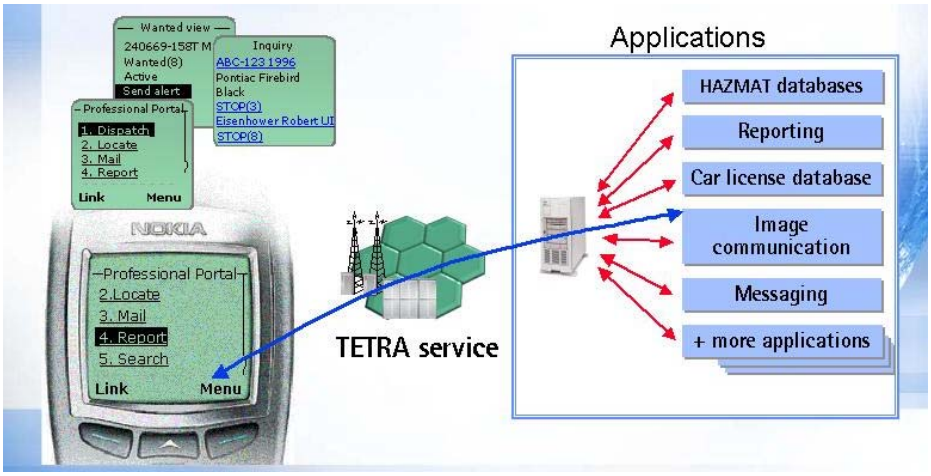

Figure 2. TETRA data services and professional WAP enable easy-to-use applications

Professional WAP complements the effective group communication and dispatching features in TETRA. It reduces the workload of the dispatchers by giving users direct access to information without a dispatcher's contribution. Traditionally, a radio user calls the dispatcher who in turn retrieves the required information from a database using a separate computer. With professional WAP, the radio user can retrieve the information himself directly from the database and get the answer on the display of his radio terminal without dispatcher intervention. This not only reduces the dispatcher's workload but also frees radio resources for other communication.

3.3 Value added third party applications

Third party applications complement the functionality and services in Nokia TETRA networks. The TETRA Wireless Solution Partner (TWISP) programme is an extensive Nokia TETRA partner programme, which makes detailed technical documentation, knowledge bases and simulator tools available to partners developing applications for Nokia TETRA networks. The TWISP programme and partner network also provides an excellent framework for global co-marketing and sales promotion.

3.4 Complete solution portfolio

Professional TETRA customers look for a complete solution comprising the core network functionality complemented by add-on applications, which will provide a seamless working environment for daily operations. For example, in public safety networks, call recording, Automatic Vehicle Location (AVL) and information management are areas that need to be considered as a part of the overall system. Third party companies also help to integrate these diverse applications into an easily manageable integrated solution such as a command and control system.

In commercial TETRA networks, third party applications and solutions help operators to differentiate themselves from competitors. Voice mail, AVL, advanced dispatching, telemetry and diverse professional WAP applications are examples of these kinds of differentiating solutions. On the other hand the operator needs third party supportive applications to run the operator service effectively. This includes customer care and billing, call statistics and network performance analysis applications.

3.5 TWISP – a worldwide network of solutions

The Nokia TETRA Wireless Solution Partner (TWISP) programme helps third party application developers by providing them with detailed technical documentation about TETRA WAP, IP packet data and Application Programming Interfaces (API), such as the TETRA Communication Server (TCS), Customer Care API (CUS API) and Short Data Service Interface (SDSI).

The TWISP programme makes detailed information, simulation tools and documentation about these interfaces available to the application development houses and system vendors.

End user organisations benefit from the TWISP programme by getting the latest information about available solutions worldwide so they can select the best solution portfolio from among proven, tested solutions.

The TWISP programme, which is free for certified partners and has no membership fee, already has more than 170 partners. More information about the TWISP programme can be found on the Nokia TETRA web pages.

4 From a system to a solution – The Whole Product

In large public safety and security networks the radio communication system is an essential part of the overall solution. However, even more important is the seamless integration of all required subsystems into a working, easy-to-use and easy-to-manage solution. The spectrum of subsystems includes an advanced call-taking subsystem to handle fixed line calls, a variety of information management systems and databases, digital maps, automatic vehicle location system, call recording and finally the radio network itself with advanced dispatching and command and control system. The latter integrates the various subsystems into a more easily manageable entity for the dispatchers.

4.1 Nokia TETRA - the wireless backbone of a public safety communication system

Radio systems are still the backbone in a modern public safety and security network, because the field operations rely entirely on its functionality and reliability. The supportive systems mentioned above are imperative to carry out the field operations effectively, but many of these rely on the radio network in communication between the control centres and the field workforce. For example, an AVL system uses the radio network to transmit the vehicle location from the vehicle to the AVL system, radio users access databases using WAP or a short data service. The call recording system needs to interface with the call-taking system and radio system to record voice communication.

For the above mentioned reasons, the radio system used in modern public safety and security networks must have the necessary open interfaces to connect external third party systems to the radio network and enable them to use the network services. The Nokia TETRA System has been designed to offer optimised interfaces for the subsystems. These include the Short Data Service Interface (SDSI), TETRA Communications Server (TCS) and Customer Care API (CUS API).

The ‘Whole Product’ thinking enables efficient and seamless integration of the Nokia TETRA System and the best subsystems and applications in the market into an optimised overall solution for the customer – the Nokia TETRA Solution.

5 Use of multi-agency networks improves efficiency and co-operation between authorities

Until now, public authorities such as the police, fire and ambulance services have each operated their own regional radio networks. This makes co-ordinating emergency responses difficult, especially when an incident covers a wide area. Today's wireless technology now makes it possible to build a single nation-wide communications network shared by all the different agencies. Nokia TETRA is the ideal solution for these networks.

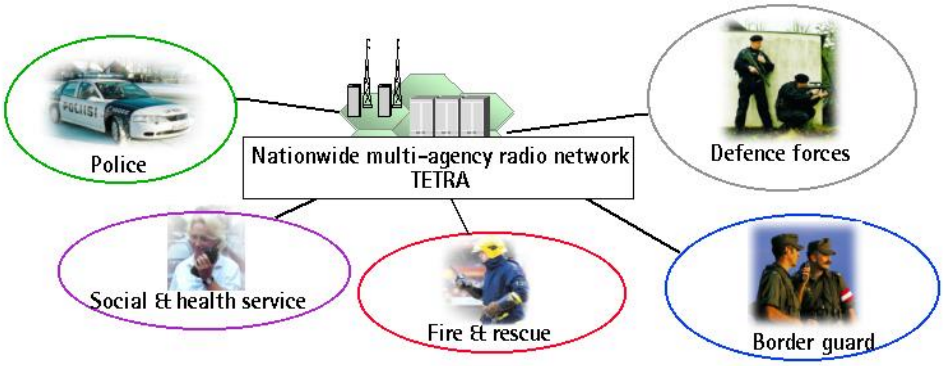

Figure 3. Multi-agency TETRA network

5.1 Multi-agency use for seamless co-operation

A single nationwide network makes it easier for different authorities to communicate seamlessly, but each authority must also be able to safeguard its

privacy. Nokia TETRA tackles this dilemma with a concept called Virtual Private Networking (VPN). All the agencies share the same physical network, but they can each operate in isolation.

5.2 Multi-agency network means shared investment and improved economy

Separate, dedicated communication networks make it more difficult for emergency services to co-ordinate their efforts, so a shared network is obviously preferable. However, this is one area where 'better' definitely does not mean 'more expensive'. Sharing the same network between several organisations can save precious public money.

The cost of a public safety network is influenced by three factors: capital expenditure, implementation expenditure and operating expenditure. The total cost of the network i.e. the total cost of ownership, is significantly lower in a multi-agency TETRA network.

The economic benefits of a multi-agency TETRA network compared with separate networks are obvious. If police and fire departments built their own networks with equal coverage, roughly twice as many base stations would be needed as in a multi-agency network, where both organisations co-exist in the same network and use the same base stations and the same switching infrastructure. The savings come not only from lower investment in network infrastructure, but additional significant savings are achieved from implementation, operating and maintenance costs.

5.2.1 Capital expenditure (CAPEX)

Capital expenditure (CAPEX) consists of the infrastructure cost of the network i.e. base stations, exchanges, network management system etc., and the cost of the end-user equipment i.e. radio terminals. Although CAPEX is often one of the most important criteria when selecting the network infrastructure vendor, CAPEX and IMPEX typically form only about 20% of the total cost of ownership. CAPEX is however an important element in the selection process and hence it is important that the price of the selected TETRA solution offers the desired features, functionality and performance.

Open standards guarantee open price competition. Proprietary systems may be inexpensive at first glance, but there is a risk that prices will go up later when the customer becomes dependent on the vendor and has no chance of using an alternative system.

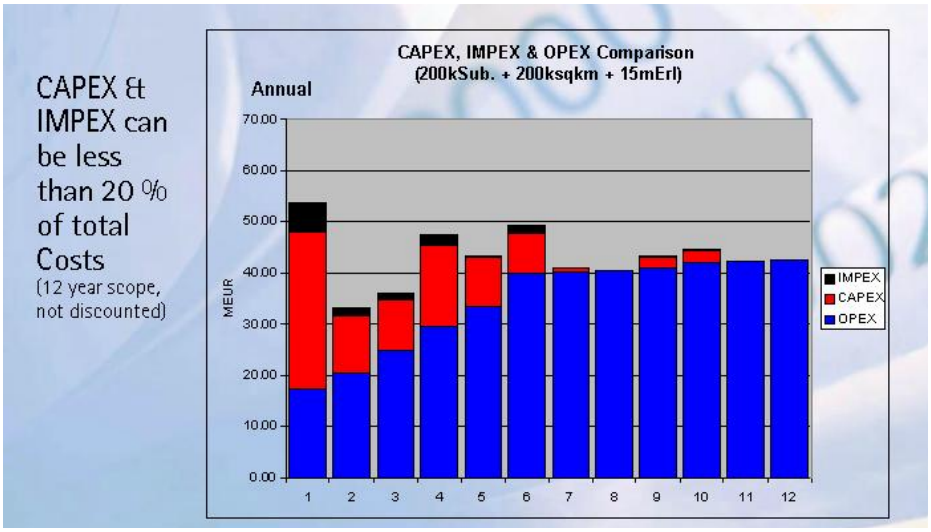

Figure 4. Elements of total cost of ownership

5.2.2 Implementation expenditure (IMPEX)

Implementation expenditure consists of network roll-out cost i.e. installation and commissioning expenses. During the migration process from old technology to new TETRA technology the end users have to use both technologies in parallel. This is an undesirable although unavoidable situation. The longer the roll-out period is, the higher the cost of running two technologies in parallel becomes. This extra cost is often under estimated or has not been taken into account at all when the IMPEX cost is evaluated.

For the above-mentioned reason, a vendor's roll-out capability and experience is extremely important and should be taken into account when selecting the vendor.

Nokia has a proven track record in successful TETRA network roll-outs. There are more than 4,500 Nokia TETRA base stations and more than 100 Nokia TETRA exchanges in operation worldwide. This is a result of Nokia's experience as a leading supplier of GSM, GPRS and 3G networks and the experience of Nokia Professional Services. This makes Nokia a safe and reliable partner in TETRA projects.

5.2.3 Operating expenditure (OPEX)

Operating expenditure (OPEX) is clearly the biggest single cost area in public safety networks. OPEX consists of network operating and maintenance costs,

which in turn are directly influenced by the technology and architecture of the infrastructure. Because operating expenses are cumulative and influence the total cost of ownership throughout the lifetime of the network, it is important that the selected TETRA technology does not have flaws in its design that cause additional operational cost.

Nokia TETRA has been designed to optimise operational cost.

First, the network architecture is flexible and supports both full mesh and hierarchical network topologies, or any combination of these. This helps to optimise the transmission costs, which typically form a significant portion of the operating costs.

Another area, which significantly affects the total cost of ownership, is maintenance cost. Nokia TETRA has a best-on-the market network management solution for its TETRA network – Nokia TETRA NetAct. NetAct enables cost-effective management of Nokia TETRA networks no matter what the size of the network. The benefits of efficient network management become particularly evident in large networks. NetAct also enables proactive maintenance, which increases the quality of service.

Nokia TETRA has several features that help to achieve additional savings in operating expenses. Remote downloading of base station software is an example of these. New features and software updates can be taken into use without going to the site. This means huge savings in large networks. In addition new features can be taken into use more quickly.

6 Interoperability and Inter-System-Interface

6.1 Interoperability for an open TETRA market

TETRA is an open standard for digital PMR. This has created a basis for a true multi-vendor market and TETRA products from several manufacturers are being introduced. Interoperability aims to guarantee that TETRA products - especially TETRA terminals - can be used in any vendor's network.

Interoperability between the networks and terminals of different vendors is vital when building large shared networks. It enables more flexibility in products and prices for the end-user organisations.

In order to guarantee interoperability, a neutral party tests interoperability and certificates are granted according to the Interoperability Profiles defined by the TETRA MoU.

6.2 Inter-System-Interface for cross-border communications

The Inter-System-Interface (ISI) is a set of standards that provide the interface for a TETRA service across network boundaries. ISI can connect several TETRA networks together. The TETRA MoU's hard work extending the TETRA Interoperability Profile (TIP) specification coverage has reached further, significant milestones - in addition to the interoperability between networks and terminals provided by different vendors, the ISI is fundamental in building large nationwide TETRA services. Inter-working is just as important when neighbouring countries have TETRA networks from different vendors.

7 Nokia has a complete TETRA offering

The Nokia TETRA System incorporates all the necessary infrastructure elements for switching, base stations, dispatching and network management, all fully supported by a wide range of professional services. Radio users have a large choice of hand portable radios, mobile radios and accessories to suit different applications.

7.1 Nokia TETRA – Acknowledged quality

Three years in a row, a network based on Nokia TETRA technology has been awarded 'The best TETRA Service' prize by the TETRA World Congress, the most distinguished TETRA forum in the world.

In 1999, this award was given to the Dolphin network in the United Kingdom. Dolphin is still the biggest commercial TETRA network in operation, with tens of thousands of subscribers.

In 2000, 'The best TETRA Service' award was given to A.S.T.R.I.D. – the nationwide public safety network in Belgium.

The success of Nokia TETRA continued at the TETRA World Congress 2001, where the award was given to the Hong Kong Police public safety network.

8 Meeting increasing demands - standardisation work continues

The TETRA standard was introduced as the first truly open system standard for digital Professional Mobile Radio. It was developed by the European Telecommunications Standards Institute (ETSI) and has been rapidly adopted on other continents from the Americas to the Far East. TETRA has been developed together with the end user organisations to ensure it offers the best functionality.

The standardisation work is continuing with additional features to build and improve upon the inherent advantages of TETRA, packet data transmission, spectrum efficiency, high voice quality and extensive coverage reach as well as inter-working with other official mobile communications standards, including GSM, GPRS and UMTS.