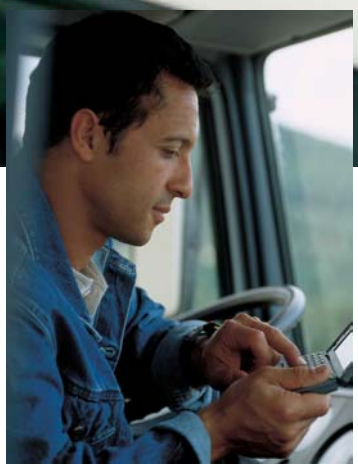
White Paper



Paging Services

NOKIA

CONNECTING PEOPLE

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Executive summary

The paging service is intended to reach a person carrying a paging receiver.

TETRA enables a complete, integrated public safety communication service, including paging.

The choice of a solution strongly depends on the set of requirements particular to each case. This means that there is a variety of solutions, each with benefits but also with challenges and limitations.

Nokia TETRA system supports various methods to implement paging services and provides for easy integration. In addition, mixed use of paging methods is possible.

Background and history of alarms

There has always been a need to be able to warn a community by sounding an alarm. Throughout history, horns, church bells, and sirens have been used to call the people to fight a fire, prepare to battle, or run for cover.

Today, there are generic alarms such as sirens and FM broadcasting, and alarms meant for specific persons only. On-duty professionals such as fire, rescue, and police organisations are alerted through dedicated, fixed alarm systems, whereas on-call personnel such as doctors or even volunteer fire fighters are signalled using individual alarms, also called *paging*.

There is also need for mobility as never before: people need to be within reach no matter where they are or what time it is.

Requirements for paging services

Paging service functions

The primary function of the paging service is to deliver some sort of information from a sender to a mobile receiver. The information shall at least be in the form of a visual/audio and/or motion alarm. Usually, the alarm arrives with a call-back number and additional textual information. A voice announcement is often needed. It has recently become possible to deliver maps and other value-adding information as well.

Speed of delivery is another important requirement. Delivering the message should not take more than 10...60 seconds.

In addition to being fast, information delivery should be reliable. Both the sender and the receiver need to be able to trust the information delivery mechanism.

The confidentiality of the delivered paging information may be anything from public to secret, according to whether the information is a mere alarm or if details of the incident, or patient data are included.

Paging should also be efficient and manageable. Therefore, it should be possible to send the information to many receivers at a time, mainly within a certain geographical area. So that the overall management of the incident is efficient, the paging service usually has to be integrated into the Command & Control system. This system should also manage which individuals are signalled based on their competencies and - if provided - also on their location. Feedback is another requirement that contributes to efficiency: there should be an acknowledgement path that enables the notified persons to let the sender know whether they are coming or not, for example. This way, the sender can notify only the required persons instead of extra persons just to ensure that enough help will be coming.

Last but not least, the service should be simple to use and self-explanatory. This reduces the need for training, at least in the receiver end.

Paging network functions

The fundamental requirements for the paging network are:

- sufficient coverage so that the persons can be reached
- enough capacity for the information load
- sufficient speed of delivery
- reliability enabling a meaningful service.

The requirement for radio coverage varies from coverage “at the door” to coverage even when in the basement.

The requirement for capacity is usually related to the speed of delivery: the system shall guarantee a certain delivery time in all situations. It is also often true that the paging service is required to be independent of other technical systems and users. This is, in fact, a requirement on the speed of delivery and reliability.

Reliability in the paging network is generally interpreted to consist of system redundancy and service availability, which is measured over long-term performance.

The paging system shall also be able to be very tightly integrated into command and control (C&C) systems. This is to make it possible to use and manage the service from the same central point. The need for efficient workforce management from the C&C may set a requirement for paging technology to support an acknowledgement path for feedback information.

Legislation and public opinion may set limitations to the maximum output power of the paging transmitters and to the number of paging transmitters. Since the required output power level depends on the number of transmitters, a balance may be difficult to find.

Use cases

A person that needs to be within reach carries a paging receiver of some sort. The paging alarm can be sent to the receiver for the person to react.

Volunteer fire fighters. They hold regular jobs and live their personal lives, but they are committed to being on-call if there is an emergency. Paging is used to signal them to come to the fire station.

Health personnel, such as doctors and paramedics. They are called to duty as the situation requires.

In some countries, a paging service is used for communicating increased preparedness in the risk of a national crisis. Most often it is the key individuals that are paged, but the service can also be used to trigger sirens or announcements to warn the entire population.

Paging receiver

The paging receiver can be a pager, dedicated to receiving paging messages, or it may be a multi-function device such as a GSM (Global System for Mobile communications) or TETRA terminal with a transmitter.

A pager should be very simple to use, it should be small and lightweight, and its battery should last a long time. A pager should not cost much and it should provide at least an audio/visual or motional alarm. A display for showing the call-back number or other textual information is generally required in addition to the mere 'in service' indication. The ability to play voice is sometimes considered essential.

The paging receiver should be relatively robust. In addition, people often prefer to have a single device that would serve both as a radio terminal and as a paging receiver. This usually means a larger device with many functions. Such a multifunctional device will unavoidably be more expensive than a simple pager.

Financial requirements

The financing party requires value for money both in capital and operational expenditure. It may seem that purchasing the least costly paging receivers makes business sense. However, if the cheapest receivers are based on soon-to-be obsolete technology, there is the definite risk that operational costs will skyrocket.

The more people or organisations share the service and technology, the less will be the cost per person.

Political requirements

Politically, a public safety paging service is a strategic decision of ownership and control. As a rule, one of the following two options is chosen.

1. The government invests in and obtains the paging network, acquiring full control of the resource. This way, the governmental bodies determine the access and security levels.

2. The service is bought from a commercial company that has a business interest to maintain the paging network.

A question then follows: in addition to serving the public organisations' needs, could the same paging network be used to provide service for individual persons or companies on a commercial basis? This would certainly require a political decision.

Yet another question with significant political influence pertains to the integration level of the public safety radio communication system and paging service: is every service provided by one system, by separate systems or by something in between, such as by sharing sites and transmission.

Furthermore, the political decision level provides the financial framework, setting another limit for the solution alternatives.

Paging service in TETRA

TETRA is the only ETSI (European Telecommunications Standards Institute) standardized digital technology for Professional Mobile Radio (PMR) users such as police, fire, and rescue organisations. Other key users come from the utility and transport sectors.

TETRA is a mobile radio network, which functions in the 380-400 MHz range for public safety and in the 410-430 MHz range for the commercial sector. The 800 MHz variant is supported as well; it is in use outside of Europe. TETRA is a voice and data technology designed to meet the needs of operational communications. Most importantly, TETRA networks are fast, reliable, and highly secure.

At the moment, any alternative technology is not foreseen to emerge that would fulfil the PMR user requirements. Proof of maturity of TETRA technology and the openness of the standard is that more than 15 independent manufacturers have delivered TETRA networks and terminals to the market.

Active paging

Benefits

In TETRA, the radio devices and TETRA base stations engage in active two-way communication. This fact is a huge benefit for implementing paging. After all, the alarm system, dispatcher, and command and control, for example always know the location of the radio devices - at least they know which base station covers them. Even more precise positioning is possible, if a terminal-assisted location solution or Global Positioning System (GPS) is employed. Furthermore, the owner of each radio device is known, and can be linked to the person's competence, responsibilities and user rights. Since TETRA is a standard for both voice and data, the system and the radio device can exchange all the necessary information, ranging from audio/visual alarms and text, to voice, or even maps.

When a TETRA terminal is used for paging, the users can have all their communication tools in a single device. This also means that if the person is being paged to come to the scene of an incident, the communication tool need not be retrieved separately, and the person can go there directly.

When TETRA paging services are used, a dispatcher can also monitor if the TETRA radio has received the paging alarm. In addition, the paged person can acknowledge the paging either by voice or by a message.

Encrypted communication and other versatile security functions in TETRA also guarantee the information security for paging.

Challenges

The major challenge in the use of TETRA for paging is related to network coverage. Coverage depends on radio wave penetration capability. This capability is determined by both the wavelength (i.e. used frequency) and the field strength in the given spot. In Europe, TETRA is operated on around 400 MHz, and the maximum output power for a base station is approximately 25 W. Field strength can be adjusted only by the number of TETRA base stations. Therefore, achieving optimal coverage is primarily an equation of service/cost. Adding a base station to the network is costly: it means purchasing the base station and transmission; on the other hand, it will bring more capacity and improve the coverage and redundancy of the network.

Other challenges are related to the size and price of the terminal and the duration of its battery.

First-generation TETRA terminals were not yet comfortable to carry around all the time. The second-generation TETRA terminals, such as the Nokia THR850 TETRA handset and Nokia THR880 TETRA handportable radio, are easy to carry, as they resemble GSM phones when it comes to weight and form. A simple TETRA device used for paging alone is also a concept that has been discussed, but it would no longer have the benefit of integrating all services into one device; nor does there seem to be a business case for such a device.

Battery duration improves all the time, approximately 10% per year. The newest Nokia TETRA terminals reach up to 60 hours standby time, yet are small, and support immediate response to any signalling. If the terminal can be allowed to sleep (enter energy economy mode) periodically, even 100 hours standby time can be reached.

TETRA terminals offer versatile functions, so naturally they are more expensive than, for example, a mass-produced POCSAG (Post Office Code Standardization Advisory Group) pager. If, however, an encrypted pager is needed, the difference in cost is considerably smaller. Furthermore, the growing worldwide TETRA market and the open standard will mean even better and less costly TETRA products.

Technical solution

Paging in TETRA is usually implemented using Short Data Service (SDS), with status messaging, text messaging or both. Nokia TETRA system supports sending and receiving status and text messages to/from TETRA terminals, dispatcher stations, command and control applications, as well as through an Application Programming Interface (API).

The paging alarm can be addressed to a group, which is fast and requires very little capacity, as only one transmission is required per related TETRA base station. The alarm can also be addressed person by person, if more control over the recipients is needed, or when the reliability of spreading the information is very important.

To accommodate the use of TETRA terminals for paging, Nokia has developed Selective Alert functionality. Selective Alert gives dedicated status values for alarms. On receiving this status value, the terminal will give a loud and clear audio/visual alarm no matter which state it is in. Selective Alert may be followed by a voice call, or by a text message of further details about the incident. It is possible to send street plans over the TETRA network, for example.

Selective Alert has also been included in the TETRA Interoperability Profile (TIP) specification to encourage all TETRA terminal vendors to support the feature.

Further operational possibilities include linking additional services to the paging alarm, such as changing the receiver's call rights, or invoking downloading actions. These require applications that are tailor-made to meet the specific operational needs.

TETRA is the only technology that can seriously begin to answer the operational challenges in the future.

Passive paging

In passive paging, communication is one-directional: the receiver never sends a signal back to the transmitting base station. As the TETRA standard is an active one, passive paging conflicts with the TETRA philosophy.

The claims for passive paging presume that the receivers will be smaller and cheaper. In addition, it is expected that better radio coverage can be achieved without substantial additional investments into the network infrastructure.

Theoretically, the coverage is the same in both passive and active TETRA paging, because the frequency as well as the output power of the TETRA Base Station are the same. However, obstacles such as walls may dampen the radiation power of the return path enough to prevent transmitting acknowledgements.

On the other hand, passive paging requires more capacity than active paging. The alarm message and other information must be transmitted several times and over a wide area, because the location and identity are not known. Nor will there be an acknowledgement, which means that there is no way to know whether the receiver has received the alarm.

There are no passive TETRA pagers commercially available today. On an estimate, a commercially viable passive TETRA pager should be around 40% cheaper than a regular TETRA terminal

Apart from the transmitter and keyboard, a passive TETRA pager requires very similar components as a TETRA terminal does. Software could be reduced, but this would bring no savings when the full-featured software already exists. Therefore, production cost for a passive pager is likely to be the same as for a full-featured TETRA terminal, or, in fact, slightly higher because of the lower expected volumes. In addition, as most of the components as well as the frequency area would be the same, a passive pager would also be very close in size to a full-featured terminal. It is also worth noting that a passive receiver to a trunked network is significantly more complex than an ERMES (European Radio Messaging Service) pager, for example. Therefore, it is difficult to see the business case for a passive TETRA pager.

Even if passive paging in TETRA were commercially viable, it would require software development for the network infrastructure, such as defining a passive receiver class, creating offline mechanisms for introducing the passive receivers to the system, and defining their addresses. Furthermore, passive paging service would need to be prioritised in relation to the other services to ensure capacity for high-priority communications. Some amendments to the TETRA security standard might be needed as well.

The current TETRA standard supports temporary 'receive only' mode or Transmit (Tx) Inhibit, as it is called. This feature makes it possible for a TETRA terminal to receive TETRA group calls, status as well as paging and some text messages without transmitting anything to the system as long as it stays within the coverage of one base station. This functionality has been designed to enable carrying of TETRA terminals in hazardous and sensitive areas like hospitals. In this mode, active paging appears to be passive paging as no signalling is sent to the TETRA base station.

Paging services in GSM/UMTS

Global System for Mobile communications (GSM) is the most widely adopted consumer mobile communications technology in the world. In Europe, the vast majority of the persons targeted to be paged already have a GSM mobile phone.

GSM is a cellular technology, which supports individual voice communication and data communication ranging from text messaging to Internet Protocol (IP) data over General Packet Radio Service (GPRS) technology. Many GSM networks, particularly in the urban areas, operate at the very limits of their performance capacity.

Universal Mobile Telecommunications System (UMTS) is a technology developed to serve the same consumer market as GSM, while providing capacity and data rates that GSM cannot match. However, in the near future UMTS networks are expected to cover only the most densely populated areas.

GSM and UMTS networks are not suitable for critical public safety communications.

Benefits

Both GSM and UMTS standards are active: they intend the communication to be bi-directional. This means that the return path mechanism is given and the user's location can be measured, enabling effective paging management applications.

The GSM terminal market is huge, which has made it possible for the vendors to offer reasonably priced, yet very inspiring mobiles phones. UMTS is not quite there yet, but the development is expected to follow the GSM lead.

Challenges

Both GSM and UMTS systems have been designed and built for one-to-one communication. The network operator's business case is based on using the capacity of the network to its very limits. Providing spare capacity or redundancy is considered purely against the risk of losing income in case something goes wrong. Therefore, congestion is acceptable during peak times, such as at New Year's, or during major events.

It may therefore be challenging to get a GSM or UMTS operator to guarantee the necessary capacity and throughput for a paging service at acceptable cost.

Further challenges are related to managing the receivers' numbers, as users can change their operators.

Using Short Messaging Service

Short Messaging Service (SMS) is a very common method for exchanging textual information in mobile networks. Up to 160 characters can be transmitted in one SMS message.

SMS fulfils most of the requirements for paging service, including audio/visual/vibrating alert, textual information and mechanism for acknowledgements. However, the Short Messaging Service Centre (SMSC) operates on the first-in-first-out principle: it does not support priority queuing. This means that when the SMSC is congested, a paging alarm message remains in the queue until all prior messages have been delivered. This is why GSM and UMTS network operators today do not give any guarantees for message delivery times.

Using voice service

Another way to implement paging in GSM is using a one-to-one full duplex call with a recorded message. Again, GSM mobile phones support audio/visual/vibrating alerts. The benefit of the voice service - provided that the air interface capacity is available - is the delivery time of few seconds, which the call set up in GSM/UMTS system requires. On the other hand, paging would generate a large number of calls, which are all metered and charged for. Operation would thus be very expensive.

Other GSM/UMTS services

Multimedia Messaging Service (MMS) resembles SMS, but provides the possibility to include further information alongside text, such as maps, or recorded speech.

MMS is gaining popularity, and all UMTS and almost all new GSM mobile phones already support it. However, no one can tell yet what the MMS delivery times would be when the network is loaded. Pricing is also not competitive for paging purposes.

A GPRS dedicated paging application could also be developed.

Solution with Nokia TETRA System

Nokia TETRA system can be cross-connected through an API with a GSM or UMTS network. Generating and sending paging messages is done in the same way as when using TETRA for paging (by a dispatcher, command and control centre, or application). The TETRA SDS message is converted in API to a GSM SMS message. Alternatively, the GSM network operator may also offer Internet access based on HTML (Hypertext Markup Language) or XML (Extensible Markup Language). Then the GSM network generates the paging SMS message.

Traditional paging systems

Traditional paging systems are divided to paging networks and standalone paging transmitters (the so-called on-site paging system). The systems use one-way communication in a low-frequency area with high output power, which provides good coverage.

Paging networks consist of a paging switch and base stations. Paging systems became popular before cellular networks were widely available, during the 1980s, when being within reach became important for people.

POCSAG became the de facto open technology. Its main benefit was the simple and cheap pager. On the other hand, the delivery capacity is modest, which means that the delivery of paging alarms may take time.

In the ERMES standard by ETSI, the capacity challenge has been solved and further functions, such as grouping have been added. Other technologies to solve POCSAG problems included proprietary Flex by Motorola.

Stand-alone paging transmitters vary from conventional PMR radios reused for paging to on-site paging base stations that transmit according to paging standards. Because there is no remote fault management, the only way to decrease the risk of lost paging alarms is to inspect the on-site transmitters frequently. Thus, maintenance is expensive, which has made this a rapidly diminishing market.

Paging through a paging network

A paging network can be integrated to Nokia TETRA system through a switch-level API connection. Standard TETRA SDS or status messages can be used for initiating a paging alarm in the paging network.

Nokia TETRA system or a command and control system is connected through the API to a gateway unit in the paging network. The paging network controller resolves the recipients of the paging message and passes the message to the transmission subsystem for delivery.

Because it is one-way communication, immediate acknowledgements are not possible without another complementary technology such as GSM or TETRA. The output power of paging base stations is 100-200W, and the commonly used frequency is around 170 MHz. This means significantly larger coverage per paging base station than in TETRA or GSM.

Traditional pagers are also small and lightweight, yet the battery duration may be significantly more than 100 hours. In addition, traditional pagers usually cost 100-300 Euros. Thus, integrating a paging network to Nokia TETRA system is a very potential solution for paging, especially in areas where TETRA indoor coverage is not foreseen.

Paging through a standalone paging transmitter

The stand-alone paging transmitters or base stations are connected to Nokia TETRA system through a TETRA terminal. The TETRA system will see the standalone devices as TETRA subscribers; thus paging is activated using a status or SDS message, similarly to signalling TETRA subscribers. The TETRA terminal passes on the paging message, which in turn acts as a trigger for the paging alarm. Speech can be relayed as well.

This solution is extremely cost efficient during migration, as the existing standalone paging systems can be used until the end of their lifetime. However, because there is no fault management, the risk of losing alarms increases over time, leading to continuously growing cost of maintenance. Therefore, this can hardly be a permanent solution.

In addition, this solution does not meet security requirements, as information is unsecured from the standalone paging transmitter onward.

Paging system market

Today, there are some 50 million paging users. However, they are migrating from commercial paging networks to cellular networks, which diminishes the paging market and leaves its future uncertain.

Data Radio Channel broadcasting system

Data Radio Channel (DARC) is a technology standardised by ETSI. It uses sub-carriers of FM broadcasting to broadcast digital information. A standard FM receiver will not hear the sub-carriers, but they can be demodulated with special equipment. The provided data rate is 16 Kbit/s, the net information capacity being 6 Kbit/s with robust error correction. Anything from paging to maps and digital audio can be broadcast using these sub-carriers.

DARC is a value-adding application for the FM broadcasting network. One of its main benefits is that very little investment is needed for the infrastructure: only an additional DARC transmitter per mast is needed to the regular FM broadcasting network. Another benefit is the usually very good network coverage of FM broadcasting. It is also possible to encrypt the information to be delivered. Furthermore, practically any kind of value-adding information can be transmitted.

However, because broadcasting is unidirectional, the return path for acknowledgements requires complementary technologies like TETRA.

Paging through DARC

The DARC paging server is connected to Nokia TETRA system through an API.

A standard TETRA status or SDS paging message initiates paging. The message is transformed into DARC format and broadcast through the broadcasting network over the required geographical area.

The technology is in the early phase of its adoption. Currently, the Swedish company Sectra provides the only available paging receiver. A trial is ongoing in Finland; its results will indicate how well DARC technology suits paging purposes.

Examples of public safety experiences of Nokia TETRA System and paging

VIRVE – the Finnish authority network

VIRVE is the national TETRA radio network for Finnish authorities. It has been completed and brought into full operational use. Its primary user organisations are police, fire and rescue, social services, customs, and frontier guards. VIRVE had around 30 000 users at the end of 2002, and it is expected to have up to 100 000 users by the end of 2005.

With its 1200 base stations, VIRVE was the world's largest public safety network in the end of 2002.

Finnish authorities really need paging services. For example, volunteer fire fighters routinely take part in fire fighting, and they will have to be alerted and called to duty. The primary solution for signalling them in the future will be based on DARC technology. By legal status, the national FM broadcasting network in Finland is defined as the information channel towards the population in crisis situations. Adding DARC ability to the already existing network was very cost efficient. In addition, the network provided very good coverage.

The nation-wide DARC service has been on-air from October 2002. An ongoing field trial tests how DARC technology suits paging and what the actual coverage of the network is. The final decision on adopting it is expected to be made during 2003.

During the transition period, existing standalone paging transmitters and base stations are used via TETRA. The goal is to adopt the new system as soon as the decision has been made, to avoid the increasing maintenance costs.

In some areas, both GSM SMS messages as well as fixed and GSM call robots are used as well.

TETRA is used as an additional paging system for the senior-level authorities that carry personal TETRA terminals at all times.

ASTRID – the Belgian authority network

ASTRID is the national TETRA radio network for Belgian authorities. It is primarily used by police, fire, rescue and custom services. At the end of 2002, one region was in operation and the number of users on the network was increasing rapidly. Network roll-out should be completed by mid-2004, and the network is sized to serve 40 000 users.

Paging services are needed primarily for the volunteer fire fighters. The decision on the paging solution was made in 1998 when TETRA terminals could not yet meet the requirements. The decision was to integrate the ERMES paging network by Tecnomen in the Nokia TETRA system.

The TETRA radio network and the paging network share the same transmission network and base stations sites. Because ERMES paging technology is very cost-efficient, this solution has enormous cost benefits. In addition, ASTRID as the owner has full control of both networks.

The ERMES paging network by Tecnomen is operational in the same areas as the Nokia TETRA system, providing indoor coverage and coverage of basement areas.

Dubai authority network

The TETRA network in the Dubai Emirate has been built to provide indoor and outdoor coverage for police, paramedics and fire fighters. Every user will have a personal TETRA terminal. Two-way TETRA paging is used, which means that personnel can be managed very efficiently. Response times can also be kept short.

Nokia THR850 TETRA handsets and THR880 TETRA handportable radios have proven to be well-suited for the solution. In addition, the personnel only need to carry one device; yet they have the advantage of full TETRA features at any time.

Recommendations on implementing paging services

In the light of experience, it is evident that TETRA provides the most features for paging. However, paging may require more extensive network coverage than is needed for radio communication. If that is the case, it is worthwhile to consider alternative and parallel options for implementing paging services.

The most cost-efficient paging solution is to integrate Nokia TETRA system with a POCSAG or ERMES network – if one is available. Even building a new paging network may be economically feasible. However, a solution based on one-way communication can never provide all the benefits that TETRA can.

If the requirements for the paging service are not critical, or if it does not matter to a second how soon the people get the paging alarms, GSM may be an alternative to consider. After all, it is very convenient for the end users. This might also be a secondary paging solution to complete the primary one.

However, the cost of SMS messaging must be managed.

If national FM broadcasting network services are available, the results from the Finnish DARC trial should be interesting. DARC technology possesses considerable potential.

Standalone paging transmitters or base stations should be used only during a transition period.

Glossary

API	Application Programming Interface
C&C	Command and Control
DARC	Data Radio Channel
ERMES	European Radio Messaging Service
ETSI	European Telecommunications Standards Institute
FM	frequency modulation
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
HTML	Hypertext Markup Language
IP	Internet Protocol
Kbit/s	kilobits per second
MHz	megahertz
MMS	Multimedia Messaging Service
PMR	Professional Mobile Radio
POCSAG	Post Office Code Standardization Advisory Group
SDS	Short Data Service
SMS	Short Message Service
SMSC	Short Message Service Centre
TETRA	Terrestrial Trunked Radio
TIP	TETRA Interoperability Profile
Tx	transmitter
W	watt
XML	Extensible Markup Language

NOKIA CORPORATION
Nokia Networks
P.O. Box 300
FIN-00045 NOKIA GROUP, Finland
Phone: +358 (0) 7180 08000
www.nokia.com

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