Title:
The Use of Commercial Cellular Mobile Networks as a Solution for Public Safety Users in Norway

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1 Introduction

The Norwegian Ministry of Justice and the Police (JD) in 1995 started a formal co-operation with the Ministry of Local Government and Regional Development and the Ministry of Health and Social Affairs, on the feasibility study "A common radio network for the public safety services". A pre-study was issued in 1996. In 1998 a new project team was formed which subsequently produced a report[1] in March 2001.

The main conclusion of this study was that the radio systems of the fire brigades, the police and the health sector (the emergency services) no longer met the requirements for functional and reliable communications. Various technologies were considered for a new system, including GSM, GPRS and 3G, but a private mobile radio (PMR) communication system conforming to the European TETRA standard, designed specially for public safety and professional users, was selected as the best option.

GSM has been a huge commercial success and now has more than 680 million subscribers worldwide, representing 68% of the world wireless market (May 2002). In Norway there are two national GSM networks operated by Telenor and NetCom, and they have about 3.4 million subscribers between them[2] representing a penetration of around 78% of the population. With the award of 3G licences, an impressive set of features and facilities has been claimed for the future 3G networks.

A recent report[3] produced by Nexia/Preview suggests that a mobile communications solution for the public safety services in Norway could be best served by a solution based on the use of public mobile networks to provide a 'converged network'.

In the light of the Nexia/Preview conclusions, this report considers the latest situation with respect to the public GSM, GPRS and 3G networks in Norway and their suitability as the basis for a national public safety network in the manner suggested by the Nexia/Preview report. It is not intended as a comprehensive review of all the potential options for a public safety mobile service.

[1] Felles radiosamband for nød- og beredskapsetatene 05.03.01 – Justis - og Politidepartementet
[2] PT Rapport Det norske mobilmarkedet 4. januar 2002
[3] Konvergering av trådløse nett 28 juni 2002 – Preview/Nexia

2 Requirements for Public Safety Mobile Communications

Public safety users have the highest requirements of all mobile radio users. The proposed national network will serve the needs of the Police, Fire and Health users. It is not intended in this report to give a detailed list of all of the user requirements, as these have been described already elsewhere[1].

It is sometimes difficult for those outside the public safety community to understand why some facilities such as group communication or fast call set-up, are absolutely necessary. However, in order to appreciate this, it is necessary to understand how the emergency services operate in the field and the important role that mobile communication plays in this. For example, with regard to the police, communications are group based, to and from the control room. This 'all informed' communications, whereby all members hear all the conversations within the group, is important as it allows the officers in the field to communicate very efficiently with others and to be aware of other ongoing activities. Police radio users are highly disciplined, with the control room operator retaining overall control; thus, speech items are able to be relatively short and concise. The use of 'push to talk' group communications further reinforces this discipline. Calls are set-up by pressing the push-to-talk button; and fast call set-up and fast changeover of talking party is essential to allow group calls to 'flow' and be used operationally.

By their nature, the emergency services users are exposed to dangerous situations. Of particular importance to the emergency services is the emergency button facility, which allows the call to be set-up exceedingly quickly, freeing up resources by clearing lower priority calls as necessary. The use of the emergency button is intended for use in life and death situations, when the officer may be under physical attack or in immediate danger, and needs to get a short voice call through before being incapacitated.

It is obvious that public safety organisations, such as the Police, demand a high level of security in terms of freedom from interception of communications and also mis-operation of the network by un-authorised users. The Schengen Agreement also has requirements related to the use of standardised and interoperable secure mobile communications within Europe.

National Security Agencies may also impose additional security requirements relating to the passing of sensitive communications over mobile networks by public safety agencies. For example, the Police may need to pass 'Confidential' or 'Restricted' communications as part of their normal operations and, to allow this, the appropriate National Security Agency may put additional security requirements on the network, such as the vetting of staff, secure storage of cryptographic keys, secure partitioning of the network, physical security etc. These requirements will vary from country to country. Any particular national security requirements for Norway have not been considered in this report but will have to be taken into account, whatever the final solution.

To summarise for this report, perhaps the key requirements for public safety users are:

- group communication
- priority and pre-emption to support emergency communications
- fast call set-up
- security
- resilience
- coverage
- integration with control rooms.

3 Suitability of Current Commercial GSM Networks

3.1 Introduction

This section looks in general at whether current GSM networks, as the baseline case, could satisfy the requirements of Public Safety Users.

3.2 Existing GSM Network Architecture

GSM is intended for large public mobile networks where the primary requirement is for large numbers of point-to-point speech calls, either between mobile subscribers within the same network or between other networks such as the fixed telephone network (PSTN) or other mobile networks. The architecture is based on a strictly hierarchical structure of network elements (base station, base station controller, mobile switching centre etc.) with defined interfaces between the main functional elements. This allows the interconnection of different manufacturers' equipment within a GSM network which is an important commercial consideration for public network operators. In practice, this tends to split the supply of the network elements into two parts:

- Base Station Sub-System (BSS), comprising base stations (BTS) together with their base station controllers (BSC)
- Network and Switching Sub-System (NSS), comprising the mobile switching centre (MSC), gateway mobile switching centre (GMSC) and databases. For example, NetCom have BSS equipment from both Nokia and Siemens, whilst the NSS equipment is solely provided by Siemens.

Whilst this hierarchical structure serves the operation of a public network well, it does create some fundamental limitations. For example, call requests from a mobile have to propagate all the way through the network elements from base station to the switch and back again. This is not too much of an issue for point-to-point calls where, for example, a call set-up time of 5 seconds is perfectly acceptable to members of the public, based on their experience of the traditional fixed telephone network.

3.3 Group Communication

Other than a limited conference call capability, current GSM networks do not provide any group calling functionality.

3.4 Priority and Pre-emption

Current GSM networks do not offer any priority or pre-emption facilities for call set-up. GSM does include an access class feature although this is somewhat restrictive for practical use (see Section 6.5 for a more detailed discussion of this).

3.5 Fast call set-up

Current GSM networks typically have a 5 second call set-up time and do not offer any faster call-set up.

3.6 Security

Current GSM network security is based on the commercial requirements of a public mobile network for point-to-point calls and includes authentication. GSM systems use several security elements, designed to safeguard the interests of the user, network operators and service providers. Recently, an upgraded algorithm, the A5/3 encryption algorithm has been developed by ETSI.

The A5/3 encryption algorithm specifically supplies signalling protection, so that sensitive information such as telephone numbers is protected over the radio path; and user data protection, to protect voice calls and other user generated data passing over the radio path.

3.7 Resilience

A highly resilient network, with a very high availability is a pre-requisite for public safety users. The main areas include:

3.7.1 Power Backup

The ability of the network to continue working during periods of loss of public electricity supplies is paramount. This is primarily related to the provision of adequate battery back-up and generators rather than the technology of the network. However, at base station sites the power consumption of the base station equipment will limit the practical standby times.

In general, a public network has a lesser requirement for power back-up than dedicated public safety networks, and so current GSM networks would probably require some upgrades to their current power back-up arrangements.

3.7.2 Transmission

The resilience of the transmission network is essentially independent of the network technology and measures such as diverse routing or redundant rings can be used. However, the required transmission bandwidth, particularly at base stations, may limit the possible resilience solutions.

Depending upon the current transmission implementation, GSM networks may require some upgrades.

3.7.3 Duplication of Network Elements

Critical network elements can be duplicated in order to provide a very high availability and this is largely independent upon the network technology. However, depending upon the particular implementations by the manufacturers and the configuration of the current GSM networks, some upgrades may be required.

3.7.4 Failure of MSC/Fallback

One critical area on GSM networks is the consequences of the failure of an MSC. Because call control is centralised at the MSC, the loss of an MSC effectively causes loss of coverage from all its base stations; and as MSCs are big switches, this can affect a large area. Whilst there is considerable duplication of critical elements within the MSC, the loss of an MSC, or serially connected elements such as the transmission network, cannot be ruled out. This would be catastrophic for the emergency services, especially if it occurred in a big city such as Oslo at the same time as (or caused by), for example, bad weather.

Most modern private mobile radio networks are able to provide local intelligence at the base station (known as ‘fallback’) such that if communications with the switch fail, local communications are possible. This is not practical for GSM, because of the highly centralised architecture.

3.8 Coverage

The outdoor coverage requirements for a national Norwegian public safety network have been stated[2] as being equivalent to the combination of the current GSM, NMT 450 and public safety PMR networks. Consequently, additional coverage would have to be provided to the current GSM networks in order to meet this requirement.

3.9 Integration with Control Rooms

Control rooms play a very important role in public safety organisations as it is these locations that direct the users in the field using mobile communications, both for day-to-day operations and during incidents. Control room operators require dispatch type solutions that will allow them to communicate with mobile users as well as fixed telephony networks and databases and applications. It is anticipated that users will require an integrated type control room solution that allows access to multiple systems, mobile, telephony, applications etc, from a single terminal rather than dedicated terminals for each function.

Typical dispatch functionality includes:

- group calls
- group management
- monitoring of multiple groups
- fast call set-up
- priority and pre-emption.

No control room solutions exist currently on GSM networks.

3.10 Other Requirements

3.10.1 Direct Mode

The concept of direct mode is for direct communication between radios **independent** of the infrastructure. This is an important tool for public safety users in areas where there is no coverage from the mobile radio network. Facilities such as security, priority and pre-emption are still required.

There is no direct mode concept within commercial GSM and terminals are always under direct control of the network. Some GSM-R (see Section 5.2) terminals are planned to incorporate a conventional FM radio for use on a small number of dedicated GSM-R channels. However, these cannot offer any security priority or pre-emption and, given the very small market for GSM-R terminals, they are likely to be very expensive.

3.10.2 Airborne Coverage

Airborne coverage offers a huge challenge, whatever the technology, because of the long distances that radio waves can travel from aircraft and helicopters once they leave the ground. This requires a dedicated network, as the interference from an aircraft or helicopter, using the ground network (other than very close to the ground), could cause widespread disruption to large areas of the ground network. There is also potentially a large requirement for spectrum, related to the increase of interference to co-channel cells.

Because radio waves can travel long distances, any range limitations of the network technology (related to the radio protocol) may also be apparent.

The two challenges for a GSM airborne network would be:

- minimising the spectrum requirement, given that the minimum channel bandwidth is 200 KHz (compared to 25 KHz or 12.5 KHz for digital private mobile radio solutions)
- GSM network radio protocol range limit of 37 Km – leading to the requirement for a very large number of cells to provide national coverage. However, some manufacturers are understood to be able to offer solutions that can extend this range by reducing capacity, for example by only using alternate timeslots.

3.11 Terminals

An important requirement for public safety users is the availability of rugged terminals, whatever the technology. The development of these terminals will take time and, because of the relatively small volumes, the terminals are likely to be expensive.

3.12 Summary

Existing GSM functionality, cannot satisfy the public safety requirements for mobile communications.

4 Suitability of Current Commercial GSM Networks with External Enhancements

4.1 Introduction

This section looks at whether external enhancements could be added to current GSM networks, which could then satisfy the requirements of Public Safety Users.

4.2 GSM Pro

Is GSM Pro a credible solution for public safety?

GSM Pro is an Ericsson proprietary server solution to provide 'PMR like' features, such as dispatch and group calls over GSM. The GSM Pro server connects to each GSM switch using a standard SS7 ISUP GSM interface and, as such, is a pure add-on to a standard GSM network.

Rugged terminals and basic PC based 'dispatch' applications are also available.

The key advantage of GSM Pro is that it leverages existing GSM coverage to provide some PMR type facilities for small groups of users. However, it has a number of serious disadvantages that make it unsuitable for larger networks or more demanding users such as public safety:

- inefficient use of resources - each participant in a group call uses an individual timeslot and the number of participants is limited (typically 16 group members)
- PMR capability is limited by the use of a standard GSM bearer – no additional priority or pre-emption
- group calls are created by setting up an individual call to each group member and then bridging the calls in the GSM Pro server
- call set-up time as per standard GSM for each group member
- single manufacturer of GSM Pro server
- connection to non-Ericsson GSM switches may require additional integration
- inflexible (groups have to be pre-programmed)
- no talking party identification.

4.3 Intelligent Network (IN) Platforms in GSM

Could the addition of an IN platform give a credible solution for public safety?

4.3.1 What is an IN?

In an Intelligent Network (IN), some of the 'intelligence' is taken out of the switch and placed in an external platform. This allows the operator to develop and control services more efficiently. In operation, the originating GSM switch effectively passes incoming call requests directly to the IN without connecting the call itself. This is triggered by pre-defined criteria such as numbering range. The IN platform then processes the call request and, based on the required service and functionality, instructs the GSM network how to connect the call. The IN platform is connected to the GSM switch by SS7 signalling links.

IN platforms have been very successful in allowing new services to be added to GSM networks in a fast and cost-effective manner. Examples of the services provided include:

- short code dialling
- personal numbering
- flexible billing
- pre-pay
- location based services.

4.3.2 Use of IN platforms for Public Safety

The table below summarises the impact of adding an IN platform to a current public GSM network in terms of providing public safety functionality in various areas:

Functionality	**Effect of addition of external IN Platform**
Coverage	No Effect – dependent upon GSM coverage
Fast call set-up	**Worse** - serially connected device in call-set up path
Group calling	No Effect – GSM switch upgrade required
Priority and pre-emption	No Effect – GSM switch upgrade required
Security	No Effect – primarily GSM air interface

In terms of coverage, resilience and security, these are primarily concerned with the radio access network and so are dependent upon the core GSM network and independent of any IN functionality.

In terms of fast call set-up, the IN server is serially connected within the call set-up path and so will inevitably cause some additional delay to the standard GSM call set-up times. Whilst for public networks some additional delay over and above the typical call set-up of time of 5-10 seconds may be quite acceptable, this would be unacceptable to public safety users.

The core functionality required for group calls would have to be provided within the GSM switches anyway, using Advanced Speech Call Item functionality (see ASCI enhancements in Section 5.1 later). Even if the switches were upgraded, the current IN interfaces do not support group and priority functionality and it is difficult to see what benefit an IN platform could bring. More importantly, the real time nature of group calls, possibly across multiple switches, could not tolerate the additional signalling delay associated with an IN platform.

4.3.3 The market for Public Safety IN solutions

Is there a large international market for IN solutions for Public Safety networks that could particularly benefit the IN development expertise in Norway?

It has been shown above that the majority of the development for public safety solutions would be needed in the core GSM networks, not add-on IN equipment. Therefore, it can be expected that any development would be carried out where the manufacturer's core switch competence is located, e.g. Sweden, Finland, Germany or UK rather than locally in Norway.

4.4 Summary

External enhancements, such as GSM-PRO or intelligent network solutions, to existing GSM networks, cannot satisfy the public safety requirements for mobile communications.

5 Enhancements to Core GSM Networks

This section looks at the possible enhancements that could be made to the core GSM network to give additional functionality, rather than the addition of external equipment which was considered in Section 4.

5.1 Enhancements to GSM Standards

The original GSM standards, known as Phase 1, were first produced in 1990. The first commercial networks appeared in the early 1990s, providing basic point-to-point circuit mode speech and data calls.

The GSM standard has continued to evolve through to 'Phase 2+' which brought a number of enhancements including High Speed Circuit Switched Data (HSCSD), general packet radio service (GPRS) and some special voice functions primarily required for railway operation, known as Advanced Speech Call Items (ASCI). ASCI supports group calling as well as priority and pre-emption. In order to implement ASCI, major changes to the core GSM call-control software are required as well as the addition of a group call register (GCR).

It is important to remember that it is not mandatory for networks to support any of these items and, consequently, implementation of a particular feature is market driven. Hence, today, we have seen the widespread introduction of GPRS, the more limited introduction of high speed circuit switched data (HSCSD) but no implementation of ASCI in commercial networks.

5.2 What is GSM-R?

GSM-R is a variant of GSM intended to be used to build private railway GSM type networks within Europe, with additional voice functionality (using the ASCI priority and pre-emption and group calling features) as well as support for railway signalling. There are only two manufacturers of GSM-R infrastructure equipment: Siemens and Nortel. Various trials have been carried out in Europe and a GSM-R network is planned for Norway.

GSM-R uses a different frequency band to Public GSM and is implemented using variants of standard GSM hardware. The special requirements of the railway environment, in terms of very high performance, and the level of signalling that is to be carried over GSM-R, mean that the network planning is likely to be more stringent than for a conventional commercial GSM network. For example, for the West Coast Main Line in the UK it was originally envisaged that in order to meet the high availability and coverage requirements, a fully duplicated network, providing overlapping coverage from different switches at all locations would be required[4]. This very high, '200%' coverage requirement was primarily thought to be related to the requirement to support the highest level of train borne signalling, where line side signals are removed (ERTMS level 3). It is now expected that the original signalling requirement will be relaxed and, whilst a high level of resilience is still required, full overlapping coverage will not now be required. Typically, this will include the use of ring type transmission for the base station (which is relatively easy to implement on a linear network, where the base stations are usually coincident or very close to the track-side transmission network). Dual MSCs can also be used, each with sufficient capacity to control the whole network should the other MSC fail. Switching of transmission in this case from the failed to the operational MSC could be carried out by the transmission equipment within, say, 30 minutes.

[4] West Coast Route Modernisation Report To Office Of The Rail Regulator Final Report - R/00282 London June, 2000

The architecture of a GSM-R rail network compared to a conventional wide-area public GSM mobile network is slightly different in that:

- the linear nature of the rail network and the natural use of a transmission link along the track (usually fibre) means that it is relatively simple and cost-effective to provide a level of transmission redundancy to base stations
- the high speed of GSM-R operation means that the coverage has to be planned to give a large overlap between cells in order to achieve reliable handover. Therefore, the effect of failure of a single base station is likely to be less severe than for a conventional public GSM mobile network
- the use of a dedicated private GSM network for a railway application allows a better control of resources which should make it easier to bound network performance (e.g. call set-up time) - this would not be the case in a shared public network.

5.3 IN Platforms

IN platforms may well play a role in ASCI enabled commercial GSM networks, by adding some particular functionality or flexibility. For example, it is understood that one GSM-R manufacturer will use IN to provide functional and location based addressing for their GSM-R networks.

However, in terms of this report, it is argued that the key functionality requirements for public safety users, such as priority and pre-emption, cannot be met by the addition of IN alone. Major upgrades to the core GSM switches would be required before the core network could support key items such as group or priority functionality. Therefore, the big issue is the upgrade of core GSM networks rather than the inherent capability of IN.

5.4 Summary

Additional functionality has been incorporated in the GSM standards, known as ASCI, specifically for railway applications. GSM-R is a special network solution for European railways, using ASCI functionality. The use of private dedicated GSM networks for GSM-R solutions allows better control of network performance.

6 Suitability of ASCI Upgraded Commercial GSM Networks

Could commercial GSM networks be upgraded to implement public safety functionality?

6.1 Introduction

Optional ASCI features within the GSM standards are intended to provide group and priority functionality for the railway sector within the limitations of the existing GSM architecture. This section looks at the technical feasibility of satisfying some key public safety requirements if ASCI features were fully implemented on a public GSM network.

It must be stressed that this is very much a theoretical exercise, based on the published ETSI specifications. There is considerable freedom within the ASCI specifications for implementation by manufacturers and so any future solutions would be dependent upon the actually implemented functionality.

6.2 Group Calling

6.2.1 Group Functionality

Group calling using ASCI requires special functionality to be added to the existing core GSM infrastructure including:

- A dedicated Group control register (GCR)
- Use of a single channel per cell on the downlink independent of the number of group members participating in the call (conventional GSM conference calls use one channel per group member)
- Distribution of speech to all base stations within the group area
- Fast changeover of speaker in order to preserve the dynamics of a group call
- Late entry to an ongoing group call.

ASCI group call is described in the Phase 2+ Voice Group Call Service (VGCS) specifications[5].

Whilst the GSM Phase 2+ standards for voice group call functionality exist, they offer a wide variety of implementation options and so the exact functionality that could be provided within a commercial GSM network will depend very much upon the individual manufacturer's implementation. However, there appear to be a number of limitations with the existing standards:

- Each user can only belong to a maximum of 50 groups
- An additional receiver may be required in the terminal in order to reliably receive group signalling messages[5] (whilst this would not be too much of an issue for a train mounted radio, it would rule out conventional hand portable handsets and increase the size of the terminal)
- Over the air key distribution is not yet defined[5]
- The numbering range available for groups/group area is limited to 256 (8 bits) entries for some dispatcher calls
- Limited facilities for scanning and no 'dual watch' between the trunked and direct mode

[5] e.g. ETSI TS 100 933 V8.2.0 (2000-08) Technical Specification Digital cellular telecommunications system (Phase 2+); Voice Group Call Service (VGCS); Stage 2 (GSM 03.68 version 8.2.0 Release 1999)

- Group capability is restricted to speech items and does not include any group data capability
- No mechanism for the dynamic creation of groups (required for incidents).

6.2.2 Speech Item Priority

A group call will usually consist of several speech items from different members within the group. It is important to be able to assign different speech item priorities to members of the group, giving authorised members the ability to pre-empt or break-in to the speech items of others. This priority is usually given to control room operators but is also required for local commanders in the field. For ASCI group calls [6] it is stated that *'The right to be a talking service subscriber is allocated on a first come first served basis without queuing'*, which does not allow specific members of the group to have priority. Dispatchers always have control of the downlink and so can, in effect, be heard by users at any time.

6.2.3 Implications for Network Capacity

It is also important to consider the potential traffic load on a commercial network where group calls are used extensively. The operation of group calls is fundamentally different from the normal point-to-point calls for which the GSM networks have been designed. Each individual group call requires the use of a single timeslot in a number of cells simultaneously. If we now consider that each public safety agency may be using many group calls simultaneously, then it is clear that this can cause a significant traffic load on commercial networks. This would have to modelled extensively before implementation, and additional capacity will undoubtedly have to be provided.

The billing of group calls will also pose a challenge to the operators.

6.2.4 Security

- Group cipher keys are expected to have a relatively long lifetime. Secure storage of these keys is very important within terminals. The current SIM to handset interface within the terminal is not secure enough to protect these keys from being intercepted locally.
- The TEA2 algorithm for air interface encryption has been specially developed for Schengen users. How secure is the GSM algorithm?
- There is no secure enable/disable (Stun/Kill) within the GSM standard. This is important to allow stolen terminals to be permanently disabled, and their key material erased, under remote command from the network.
- There is no over the air key distribution
- Any public safety solution within Norway will have to comply with the Schengen requirements for mobile communications. Whilst this has been satisfied with the use of technologies such as TETRA, it is not clear whether a GSM type solution could satisfy these requirements.

6.3 Fast Call Set-up

The Phase 2+ ASCI enhanced Multi-level Precedence and Pre-emption (eMLPP) specifications define various classes of call set-up time, with the fastest (Class 1) specifying 1-2 seconds call set-up. The standard[6] acknowledges that *'The achievement of the set-up times depends upon the technical realisations and network planning'* . However, fast call set-up can only be achieved by sacrificing functionality and accepting a number of constraints:

[6] ETSI EN 300 924 V7.0.1 (2000-01)European Standard (Telecommunications series) Digital cellular telecommunications system (Phase 2+); enhanced Multi-Level Precedence and Pre-emption service (eMLPP) - Stage 1 (GSM 02.67 version 7.0.1 Release 1998)

- Authentication and air link confidentiality is not used
- If pre-emption is required, then the Class 1 call set-up may exceed 1-2 seconds
- Performance is only guaranteed for 'normal circumstances (no congestion)'.

The lack of authentication and confidentiality would be a serious limitation for public safety users and especially the police.

Initial GSM-R trials [7], in small dedicated networks, have suggested that 'fast' call set-up times in the order of 2 seconds have been achieved for the test systems with a single MSC for mobile-to-mobile calls. For group calls involving dispatchers, 'fast' call set-ups took between 4 and 5 seconds because of additional dispatcher signalling. These trials were carried out using a single GSM switch and, given that a national network would require several switches (current Norwegian GSM operators have between 6 and 14 switches), this would present an additional delay.

6.4 Priority and Pre-emption

Priority and pre-emption mechanisms are used when a network is congested; they work by progressively withdrawing the resources available to the majority of users and reallocating them to a relatively small number of important users. This inevitably means that the service experienced by the normal users is degraded. The standard[8] suggests the following levels of priority and pre-emption:

Priority level	Set-up time	Pre-emption	Examples
A	1-2 s	yes	Voice broadcast and group emergency applications
B	< 5 s	yes	Operators calls
0	< 5 s	yes	Emergency calls (GSM Teleservice TS12)
1	< 10 s	yes	Premium rate calls
2	< 10 s	no	Standard rate calls
3	< 10 s	no	Default for no eMLPP subscription
4	< 10 s	no	Low tariff calls

There are a number of limitations with this scheme for public safety users:

- The standard[8] notes that *'A pre-emption of an on-going call is not possible if the on-going call is a TS12 call (emergency call)'*. Whilst this is desirable in a public network it is not necessarily desirable for a public safety network, as this implies that multiple emergency calls from the public (possibly associated with the same incident) could block the network for public safety users who are trying respond to an incident.
- the top two priority levels, A and B, can only be used within a single MSC, effectively limiting the operational area of these call types to a single MSC.

[7] ASCI Features Summary Of Performance Tests On The MORANE Trial Sites (A 43 T 0003 2)

The ASCI enhanced Multi-level Precedence and Pre-emption (eMLPP) specifications define the priority and pre-emption features that can be applied to call set-up. It is important to realise that this does not include the initial random access phase, and the standard[8] specifically notes '*contention during the initial random access (no specific definitions apply for eMLPP. Delays due to access collision have to be managed by a corresponding planning of the network resources)'*. This is a serious limitation of the eMLPP functionality for Public Safety Users and is considered further in Section 6.5.

There are also other commercial issues to be considered by network operators if they roll-out and invoke priority/pre-emption features:

- the service experienced by their commercial customers (which represent a majority of their total subscriber base) is degraded
- there may be Regulatory issues associated with the use of pre-emption and priority within a public network
- network performance figures used for benchmarking the GSM operators will be degraded – this may cause dissatisfied customers to switch to other networks.

6.5 Random Access Priority

Random access is used by terminals in order to signal information to the network, such as a request to make a speech call. For a public network, which also supports public safety users, it is very important to be able to control random access attempts from terminals into the network during periods of congestion. Otherwise the network is effectively blocked to all parties, even those with eMLPP functionality (which only comes into place once the initial random access message has been received by the network).

This is particularly important because on a public rather than private network, public GSM users have little communications discipline compared to public safety users and, during congestion, will inevitably keep re-trying persistently to redial failed calls – further congesting the network.

A feature called 'Access Class' can be used in standard GSM to deny whole groups of mobile stations from random access to radio resources. Normal subscribers are divided into 10 balanced sub-populations, through a random allocation controlled by their home network. *Classes 11-15 can be allocated to important users.* The allocated class is stored on the user's SIM. In normal situations all classes are allowed access. When traffic needs to be reduced the base station can decide to deny access to a certain class or classes, typically class 1 to 10, so that important users can get through.

However, this is a relatively static process, clumsy in use, has no pre-emption and usually has to be activated manually for each base station within the area of an incident. Therefore, it is only suitable for infrequent use. It is also difficult to manage the logistics of user classes which are stored on the SIMs. It should also be noted that whilst access class can be used to restrict new call attempts, it cannot be used to pre-empt existing calls. This has been exploited by journalists in the UK who, on arrival at the disaster scene, often keep channels on their mobile telephones to ensure instant access to their editors.

6.6 Integration with Control Rooms

Whilst the ASCI group functionality includes the concept of a dispatcher as a group member, it does not include any specific features for the integration with control rooms.

[8] ETSI TS 100 932 V7.2.0 (2000-12) Technical Specification 3rd Generation Partnership Project; Technical Specification Group Core Network; Digital cellular telecommunications system (Phase 2+); enhanced Multi-Level Precedence and Pre-emption service (eMLPP); Stage 2 (3GPP TS 03.67 version 7.2.0 Release 1998)

To date, GSM-R only offers very basic dispatch terminals, which have similar functionality to fixed radio terminals. Large commercial GSM switches are not designed to provide the necessary interfaces that would be required for integrated or standalone control room solutions and some sort of communications server would have to be developed for public safety use.

6.7 Summary

This section has considered whether the addition of ASCI functionality to public GSM networks could offer a suitable solution for public safety users. The ASCI functionality is lacking in several areas for public safety use. Whilst some ASCI functionality has been demonstrated in private GSM-R networks, its incorporation into public GSM networks has not.

7 Suitability of General Packet Radio Service (GPRS)

Could GPRS be used as an alternative signalling mechanism for high priority or emergency calls?

7.1 Introduction

GPRS is a packet data service based on the use of IP. The IP data packets transit through the network from node to node until they reach their destination. This leads to a variable delay depending upon the route taken and the amount of congestion. The GPRS standard includes a number of quality of service parameters that can be requested by the application including latency. However, these have yet to be implemented in live networks and will depend upon the dynamic traffic load, network configuration and design. User experiences on current networks suggest latencies of 1-2 seconds, although this is difficult to measure and characterise exactly.

GPRS is implemented as a packet data overlay for a GSM system, using the same base station transceivers and antennas and sharing the channel capacity with the voice services. Various coding schemes are supported in the GPRS standard, which offer progressively higher data rates but at the expense of progressively poorer coverage relative to the existing GSM service.

It is important to remember that the packet data is a finite resource, which is shared amongst all the users at each particular instant. Therefore, the actual throughput available to the user can vary dynamically depending upon the number of other packet data users and, in practice, will be less than the peak values that are often stated.

In real networks, circuit mode GSM services (voice and data) are generally given priority by the operator, with the GPRS service being dynamically allocated any spare capacity. This allows the operator to make use of the spare capacity and increase revenue.

7.2 GPRS as an Alternative Signalling Mechanism

The use of GPRS for an alternative signalling mechanism for high priority voice calls would require two call set-up stages

- emergency ‘callback’ request sent over a packet data (GPRS channel)
- call back mechanism, whereby some external device calls the user using off-hook dialling and connects the call to a control room

A packet data channel such as GPRS is, by definition, a best-effort non-real time delivery service. There are currently no quality of service mechanisms that could guarantee delivery of this message within a specified time. If there is congestion on the data channel, the callback request would be delayed or possibly even lost completely.

The main issues with this approach are:

- An emergency call needs to be connected reliably and quickly – packet data channels are not suitable for such stringent call signalling (typical latency 1-2 seconds).
- Additional delay of voice call set-up back to user (typically 5 seconds)
- Whilst it may be feasible to call the user back using some sort of external device, it must be remembered that, without priority and pre-emption, this would be treated like a normal call set-up to a mobile user by the GSM network. If there is congestion the call set-up will be blocked. The GSM network and mobiles would also have to be configured for direct call set-up (the incoming call is automatically answered by the terminal with no user intervention).

7.3 Summary

The use of GPRS as a high priority signalling bearer together with a voice callback mechanism is totally unsuited to emergency calls, as it would be very slow and have no guarantee of connection of the emergency call.

8 Suitability of Third Generation Networks (3G)

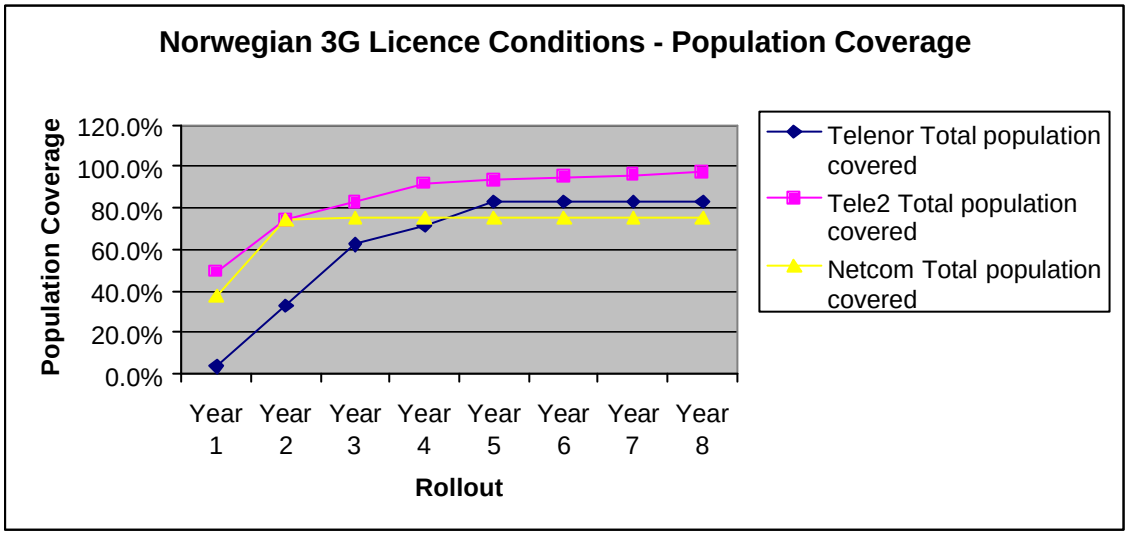
Could the planned public 3G networks meet the needs of the Emergency Services within Norway?

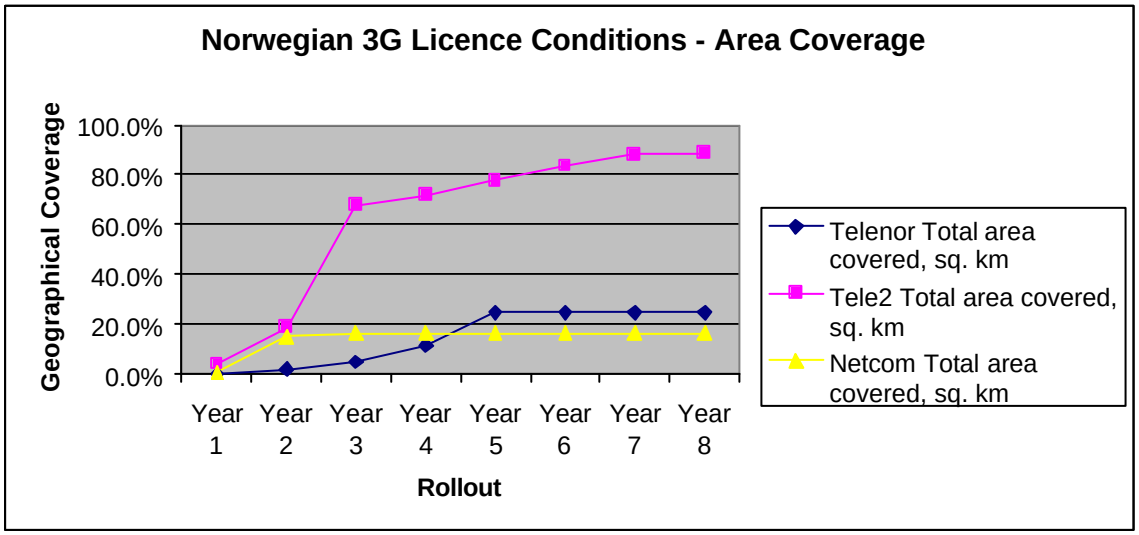
8.1 Introduction

On 1 December 2000 four UMTS licences were awarded by the Ministry of Transport to Broadband Mobile, NetCom, Tele2 and Telenor; the two GSM incumbents and two new operators. The licences have obligations for coverage in terms of population. The requirement is that the homes of 90% of the population in each densely populated area are covered within five years after the licence has been awarded.

Broadband Mobile (jointly owned by Sonera and Enitel) filed for bankruptcy and the licence was revoked on 17 September 2001.

The following graphs illustrate the coverage requirements for each of the three remaining licensees, based on the tenders submitted by each licensee.





It can be seen that the Tele2 plans are by far the most ambitious of all the licensees, with the most population coverage and by far the largest geographical area coverage. This was noted in the Norwegian PT (NPT)[9] in their evaluation of the tenders and they stated that *'It is difficult to draw the line between realistic and unrealistic business plans. The Norwegian Post and Telecommunications Authority has no basis for a reappraisal of the assessments made by Tele2 in relation to the planned roll-out. However, it should be noted that the company has used a statistic method of calculation of coverage and assumed the risk that, if they get a licence, considerable coverage requirements may be imposed on them'*.

However, it is now suggested by the NPT that the *'The total lack of activity in Tele2's UMTS project raises serious doubts on whether Norwegian mobile users will be offered a third 3G infrastructure'*.[10] This has just been confirmed by the CEO of Tele2, who has stated[11] that they will not now build their own network, rather they will offer a virtual network based on NetCom's infrastructure. Consequently Tele2 is not considered further in this report.

8.2 Rollout

It is worth looking at the coverage and roll-out obligations of the two most credible operators, NetCom and Telenor. In terms of roll-out, the following minimum requirements[12] apply, based on the licence issue date of the 1st December 2000:

> *1. 10 per cent of the total population in the 12 densely populated areas shall have coverage within one year after the licence has been awarded.*
>
> *2. 40 per cent of the population in eight of the 12 densely populated areas shall have coverage within three years after the licence has been awarded.*
>
> *3. 90 per cent of the population in each of the 12 densely populated areas shall have coverage within five years after the licence has been awarded.*

On December 31 2001, NetCom, Telenor and Tele2 each submitted a report to the NPT on how far they had progressed in their network projects. NPT has evaluated the reports and concluded that none of the licensees has fully met the conditions in their respective licences but that:

'Telenor is close to meeting their requirements. NetCom has a larger gap between the requirements and what they have actually done, but the agency concluded that this company has done everything that can be reasonably expected'

As of August 2002, nearly two years after the award of licences, no commercial 3G services have yet been launched in Norway. This is similar to the situation in other countries, where there is a great deal of uncertainty about the eventual availability and viability of 3G services. In Germany, one of the licensees has chosen to return their 3G licence. Therefore, it is difficult at this time to see that the roll-out target of 90% of the population by the end of 2005 will be met by any of the licensees in Norway.

8.3 Coverage

Within their tenders for the 3G licences, tenderers have commitments to provide a certain level of geographic coverage. By 2005, Telenor have committed to covering 75,500 Km^2 and NetCom to 50,046Km^2.

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[9] Post- og teletilsynet – Frekvensforvaltning
http://www.npt.no/eng/frequencies/fagomraader/3g/3g_recommendation.html

[10] UMTS - NPT recommends that the Ministry of Transport makes a decision on fining Tele2 [13.02.2002]
http://www.npt.no/eng/industry_information/networks_and_services/public_networks/news/data/2001/sanctions_press_umts.html

[11] http://www.telecom.no/art/5918.html

[12] Invitation To Tender For Licences For The Development And Operation Of A Third Generation Mobile Telecommunications System In Norway, 31 May 2000

These are equivalent to 24.7% and 16.3% of the total geographical area of Norway respectively. It is suggested[13] that Telenor will achieve this with 3923 base stations and NetCom with 1184 base stations.

The outdoor coverage requirements for a national Norwegian public safety network have been stated[2] as being equivalent to the combination of the current GSM, NMT 450 and public safety PMR networks. The total geographical coverage of NMT450 alone is approximately 80-85 %[14] and so it would be reasonable to assume that the total combined geographic coverage of NMT 450, GSM and PMR to be in the region of 85-90%.

This analysis clearly demonstrates that the expected geographic coverage of the 3G networks in Norway will be nowhere near the coverage requirements of the emergency services. To put it another way, Telenor would have to more than triple the size of its proposed 3G network to approach the required geographical coverage and, clearly, this is not a realistic proposition.

8.4 Functionality

It is unclear at present what public safety functionality could be provided by 3G networks. For example, there is ongoing work within the standardisation program for the third generation wireless networks (3GPP) to include priority and pre-emption features for future networks. Group functionality may be possible using multi-cast solutions. However, there is no guarantee that these features will be suitable for the emergency services or ever be implemented by manufacturers within their 3G equipment and, indeed, whether there is a strong business case for the operators to provide these features. There is a clear parallel with the ASCI features within GSM that have not been adopted outside the GSM-R world.

8.5 Convergence

There has been a great deal of discussion about the convergence of different mobile technologies to provide a single seamless mobile solution. For a public safety solution in Norway, the concept is for a seamless network providing all the key functionality requirements (groups, priority etc) across GSM, GPRS, GSM-R, or 3G bearers.

This report has argued that any provision of the key baseline public safety functionality for a nationwide network would have to be based on current national GSM networks, primarily because of coverage. Whether additional functionality above the baseline requirement could realistically be provided in areas of 3G coverage (centres of population) by a converged network remains to be seen. Difficulties are being experienced with the integration of the new 3G networks and existing GSM networks in order to provide a seamless 'converged' service to the user. It will be a great challenge to build a truly 'converged public safety solution' that can provide the demanding public safety functionality across several different networks.

8.6 Summary

It has been shown that in Norway, as in other countries, 3G networks will be targeted at centres of population which are concentrated in relatively small areas, rather than attempting to offer a wide area geographical coverage of Norway (which would be commercially unrealistic). Therefore, 3G networks, whatever their eventual functionality, cannot be considered alone as a solution for the emergency services mobile communications needs. Any practical public safety solution would, therefore, have to be based around the core GSM networks.

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[13] Evaluering av 3G søknader - Norwegian Post and Telecommunications Authority

[14] Future Use Of The NMT-450 Spectrum Invitation To Comment On Frequency Planning - Norwegian Post and Telecommunications Authority

9 Practical and Commercial Issues with ASCI Upgrades Commercial GSM

Is it practical to upgrade commercial GSM networks in Norway with ASCI features for public safety functionality?

9.1 Introduction

Earlier sections have concentrated on the technical suitability of various levels of enhancements to the current commercial GSM networks as well as considering other networks. Notwithstanding any technical or other limitations raised earlier, this section looks at the commercial and practical issues associated with an ASCI upgrade to a commercial Norwegian GSM network.

9.2 Operator issues

Both of the national Norwegian GSM networks have a multi-vendor infrastructure. NetCom use Siemens switches and both Nokia and Siemens base stations, whilst Telenor use Ericsson switches and both Nokia and Ericsson base stations. An upgrade of either network would require major developments by two infrastructure manufacturers and this effectively doubles the development effort whilst at the same time reducing any economies of scale. The upgrade of both national networks would require developments by all three manufacturers as well as cross network roaming functionality. Given the anticipated development and roll-out costs for the GSM ASCI functionality, and the risks versus the scale of potential additional revenue, the business case for the upgrade of a single GSM network is difficult to see, but to upgrade both networks would be out of the question.

Adverse market factors for the inclusion of ASCI in commercial GSM networks include:

- a very small number of potential ASCI users in relation to the overall number of public users (e.g. in Norway 50,000 specialist users versus 3,000,000 public users)
- a large software and hardware development would be required by the manufacturers to critical areas of the GSM software (call control)
- the risk associated with implementing major new software changes in a live commercial network and its impact of revenue and customer loyalty
- the costs associated with the roll-out of new hardware and software
- the degradation of service to, and loss of revenue from, existing customers if priority/pre-emption is invoked by the ASCI users or capacity is reduced because of group calls across several cells
- the use of wide area group calls, where group members are in several different cells can require the use of a time slot in each cell. Where multiple simultaneous group calls are expected (as would be the case for the emergency services), the GSM network may have to be upgraded to increase the network capacity.

Therefore, in practice, any GSM based public safety solution in Norway would have to be based on a single commercial network. This would exclude roaming with public safety functionality and would not be possible between the Norwegian GSM networks, and so the single network would also have to be made sufficiently resilient in its own right.

9.3 Market Issues

It is difficult to see an international market for public safety solutions on public cellular networks at the current time. In the light of the recent terrorist incidents, it is anticipated that some enhancements will be made to public mobile networks to allow some form of priority to be given to designated

associated emergency response users in times of crisis. However, the focus for the primary emergency services users (Police, Fire and Health) is a common dedicated private network that allows communication between the various agencies.

At the current time, no other country in the world has adopted a public safety mobile communications network based on a commercial GSM network. The majority of Europe has opted for, or is in the process of opting for, digital private mobile network solutions. Further afield, in the Far East and Australasia, TETRA is being used by Public Safety users and it has also been selected as the digital PMR standard for China. In the USA, APCO25 is being considered for police networks.

It is therefore difficult to see the basis for an international market for Public Safety solutions, based on commercial GSM networks, given that the current situation is that Public Safety users in other countries are choosing, or have already chosen, PMR-based solutions.

9.4 Manufacturer Issues

The commercial strategy of the three GSM manufacturers with significant installed equipment in Norway also has to be considered:

- Nokia do not manufacture GSM-R equipment but do manufacture TETRA. Why would they risk their potential TETRA market for their well-established TETRA product by starting a major GSM upgrade program from scratch? Who would fund their development and would they have sufficient resources given their huge investment in 3G?
- Siemens manufacture GSM-R and have also only recently started to manufacture TETRA equipment. Why should they risk damaging the potential market for their TETRA products and risk not recovering their up-front TETRA development costs?
- Ericsson were originally active in the GSM-R development but stopped their development before they got to the manufacturing phase, preferring to concentrate on their relatively basic 'GSM Pro' offering and their proprietary EDACS private mobile radio system. Ericsson are understood to have proposed a GSM/3G solution for the Swedish public safety network. Such a solution would also be constrained by the limitations of GSM and 3G which this report has highlighted.

9.5 Track Record and Risk

In seeking to reduce the implementation risk for any new public safety network, it is extremely desirable that the chosen technology already has a significant installed base elsewhere. Other than the GSM-R networks, that are starting to be rolled out in Europe, there has not yet been any inclusion of the ASCI functionality by the GSM manufacturers in commercial GSM networks.

Therefore, upgrades to existing live GSM commercial networks would require significantly new software and hardware developments. This is risky and would require significant time to eliminate the major bugs even in the controlled environment of a new network. But to implement the proposed upgrade to a live commercial national GSM network (e.g. Telenor have more than 2 million subscribers[15]) will present even more constraints on the implementation and commissioning of a GSM based public safety solution.

9.6 Summary

It is difficult to see the attractiveness of a GSM based solution for public safety users for either the network operators or the manufacturers. Opting for an untried solution, which has yet to be developed, on a commercial GSM network represents a huge risk.

[15] PT Rapport Det norske mobilmarkedet 4. januar 2002

10 Conclusion

This report has considered the suitability of public mobile networks as the basis for a solution for public safety users within Norway. It has looked at the special requirements of the public safety users, particularly in terms of group, priority, fast call set-up, security and control room applications.

Current GSM networks, including external solutions such as GSM-PRO or intelligent networks, cannot satisfy today's public safety functionality.

The inclusion of additional functionality into today's GSM networks, using the ASCI features developed for the railways, has also been considered in some detail. However, it has been shown that the current ASCI functionality is lacking in several areas for public safety use. Whilst some ASCI functionality has been demonstrated in small trial private GSM-R networks, its performance when incorporated into public GSM networks has not.

The applicability of GPRS as an alternative signalling mechanism for high priority calls has been ruled out because it would be slow and have no guarantee of connection of an emergency call.

Third generation networks within Norway will be targeted at centres of population, which are concentrated in relatively small areas. This equates to poor geographical coverage and will fall well short of the wide area geographical coverage required of public safety users. Consequently, third generation networks, whatever their eventual functionality, cannot be considered alone as a viable solution.

Finally, the practical and commercial issues associated with such a major development of GSM networks have been evaluated. Given the relatively small market and the situation of public safety users in other countries, it is difficult to see the attractiveness of developing a GSM based public safety solution for either the network operators or the manufacturers. Opting for an untried solution on a commercial GSM network represents a huge risk.

Consequently, it is concluded that, given the demanding requirements of the public safety users, a mobile communications solution based on a public GSM, GPRS or 3G network will not be practical for Norway, either in technical or commercial terms.