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Feasibility study of IP Multimedia Subsystem (IMS) based Push-to-Talk over Cellular (PoC) for Public Safety and Security communications.

This thesis has been submitted for the partial fulfilment of Master of Science in Telecommunication (Radio Communication) degree to Communication Laboratory, Helsinki University of Technology (HUT), Espoo, Finland on 11th of August 2006.

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Instructor: Lic. Tech. Michael Hall

HELSINKI UNIVERSITY OF TECHNOLOGY Abstract of the Master's Thesis

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Abstract:

Feasibility of IMS based PoC over public cellular network, specifically over commercial GPRS network, has been studied for public safety and security communication. Both day-to-day routine work and emergency operation handling capability of the PoC service as well as of the network have been considered. The requirements of PSS communication have been taken as the basis for analysing the technical viability of PoC service for PSS communication. The study is based on publicly available specification documents and related literature. The technical data and factual information have been collected from technical papers, reports and news articles posted into the Internet. The thesis also included a case study comparing over-aged analogue PMR systems and possible PoC service over a nationwide commercial GSM/GPRS network for PSS communication.

The key findings in favour of using PoC over commercial GPRS networks include already existed nation-wide radio coverage and roaming across the nation boarder, ease of use, special group call functionality, advanced IMS based multimedia services. The study has identified some challenges of using PoC for PSS communication, which are mainly due to the inherent latency of GPRS access network and lack of prioritisation of special groups of users in commercial networks. Though the PoC service over commercial network does not fulfil all the requirements strictly but taking into account the suggested measures, it can be a good alternative to PMR networks. Use of PoC for PSS communication requires zero initial as well as less operational expenses for the respective PSS organizations. At the same time PSS sector is a potential revenue generating market segment for the operator as well.

Keywords: PoC, PMR, PSS, GPRS, IMS

Preface

This Master of Science Thesis, Feasibility study of IP Multimedia Subsystem(IMS) based Push to Talk over Cellular (PoC) for Public Safety and Security communications, has been done at Communication Laboratory, Department of Electrical and Communications Engineering, Helsinki University of Technology (HUT), Finland.

I would like to express my deep gratitude to the supervisor of the thesis Professor Sven-Gustav Häggman and to my instructor Lic. Tech. Michael Hall for their valuable comments and guidance's throughout the whole thesis.

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Sanjay Kanti Das

Table of contents **Page no**

LIST OF ABBREVIATIONS

AIE Air Interface Encryption
AMR Adaptive MultiRate
APCO Association of Public-Safety Communications Officials international
ARPU Average Revenue Per User
AT Alphanumeric Terminal
BSC Base Station Controller
BTS Base Transceiver Station
CAPEX CAPtial EXpenses
CDMA Code Division Multiple Access
CS Circuit Switched
DIMRS Digital Integrated Mobile Radio System
DL Down Link
DTCH Dedicated Traffic Channel
ETSI European Telecommunications Standardization Institute
EDGE Enhanced Data rates for GSM Evolution
FDMA Frequency Division Multiple
FM Frequency Modulation
IDRA Integrated Dispatch Radio System
IETF Internet Engineering Task Force
IMS IP Multimedia Sub-System
IP Internet Protocol
IPv4 IP version 4
IPv6 IP version 6
ISDN Integrated Services Digital Network
ISIM IP Multimedia Services Identity Module
GLMS Group and List Management Server
GoS Grade of Service
GSM Global System for Mobile communication
GPRS General Packet Radio Service
HLR Home Location Register
MNO Mobile Network Operator
MS Mobile Subscriber
MSC Mobile Services Switching Centre
MSISDN Mobile Subscriber ISDN
NACC Network Assisted Cell Change
NASTD National Association of State Telecommunications Directors
OMA Open Mobile alliance
OPEX Operating EXpenses
OSS Operation Support Sub-System
PDCH Packet Data Channel
PDP Packet Data Protocol
PDN Packet Data Network
PLMN Public Land Mobile Network
PMR Professional Mobile Radio
PoC Push-to-talk over Cellular
PSS Public Safety and Security
PS Packet Switched
PSTN Public Switched Telephone Network

PTT Push To Talk
QoS Quality of Service
QPSK Quadrature Phase Shift Keying
RAN Radio Access Network
RTP Real Time Transport Protocol
RTCP RTP Control Protocol
SGSN Serving GPRS Support Node
SIP Session Initiation Protocol
SMS Short Message Service
SwMI Switching and Management Infrastructure
TBF Temporary Block Flow
TCH Traffic CHannel
TDMA Time Division Multiple Access
TETRA TErrestrial Trunked mobile Radio
TETRA MoU TETRA Memorandum of Understanding
TIA Telecommunications Industry Association
TRU Transmitter Receiver Unit
VLR Visitor Locations Register
VoIP Voice over Internet Protocol
UDP User Datagram Protocol
UE user Equipment
UMTS Universal Mobile Telecommunication System
UL Up Link
URI Uniform Resource Identifier
USIM Universal Subscriber Identity Module
WCDMA Wide band Code Division Multiple Access
2G 2nd Generation
3G 3rd Generation
3GPP 3rd Generation Partnership Project
3GPP2 3rd Generation Partnership Project2

Chapter 1

Introduction

1.1 Background

Traditionally Public Safety and Security (PSS) services including fire brigades, police, ambulance services, coastguards, etc have been relying on Private Mobile Radio (PMR) systems for safe and reliable communication for long. The PMR networks vary from simple, legacy analogue to most sophisticated digital trunked networks supporting a lot of functions for special groups of users.

Push to Talk over Cellular (PoC) is a half duplex voice service in cellular network environment that allows one-to-one or one-to-many group communication within a service area. Since its introduction into the public cellular network in mid 90's in USA, the Push-to-talk service has gained a huge popularity among different groups of users from amateur groups to various professional user groups. Though the first implementation of the Push-to-talk service in public network was based on Motorola's proprietary technology, later on the standardization of the service has opened the door for other market players for implementation and development of the service.

Until today, most PSS organizations around the world are dependent on analogue PMR networks, which are found to be incapable of keeping pace with increasing demands from PSS organizations for new features and services. Migrating from analogue PMR systems to digital PMR systems involves a large amount of capital investment, spectrum availability and importantly time for the whole process. On the other hand, the use of commercial cellular networks for PSS communication can save capital and operational expenses, and at the same time PSS sectors can be benefited from advanced services offered by modern commercial networks. Therefore, studies have been done in many countries to find out the feasibility of using existing commercial networks for PSS communication. Most efforts were directed towards the question of group call functionality in former commercial networks. Limited group call functionality, known as conference call, is also found in the public GSM network. In case of a conference call, the caller has to call individually each member of the group which takes time and consequently is found inconvenient for PSS communication.

The availability of a PoC type of group call service in commercial networks has gained attention of different public safety user groups around the world to find an alternative to analogue PMR systems as well as modern digital PMR systems for their communication. PoC offers a range of features, especially group call function comparable to those of different digital PMR networks, which naturally have drawn the attention to find the viability of using PoC for PSS communication. The use of PoC over commercial GPRS network for PSS communication can save capital and operational expenses for the respective PSS organizations as well as PSS sectors can be benefited from the development of mainstream technology.

1.2 Objective and Methodology

The objective of this thesis is to find out the feasibility of using IMS based PoC over commercial GPRS network for PSS communication.

A feasibility study of PoC service over commercial cellular networks for PSS communication involves taking into consideration technical and economical issues. Both day-to-day routine work and emergency situation handling capability of the PoC service as well as the network are considered. At the same time, the future evolution of the service as well as the possible integration of new IMS based services over time are also considered as plus points. The limitations of existing over-aged analogue PMR networks are also taken into account while finding the viability of PoC for PSS communication. Both capital and operational expenses are considered in economical analysis.

The thesis includes a case study considering initial investment for a new digital PMR network, which is a big issue. But there are already countrywide commercial GSM/GPRS networks. Bangladesh is taken as an example for the case study.

The study is based on publicly available specification documents and related literature. The technical data and related information have been collected from several sources, such as

- Technical papers, reports and news articles posted in the internet
- Technical specifications from OMA, 3GPP, etc.

1.3 Thesis outline

The rest of the thesis is structured as follows.

Chapter 2 gives an idea of the requirements of Public Safety and Security communication. This chapter also discusses briefly different PMR networks with a more elaborate discussion on TETRA networks to give an idea of a modern digital PMR network.

Chapter 3 describes the PoC network architecture, the technology behind it, key attributes of PoC and some benefits to end-users. The chapter also explains the architecture and motivation of implementing PoC over a commercial GPRS packet data network.

Chapter 4 discusses the challenges of using PoC over GPRS for PSS communication and finds out some improvement proposals to get better performance of the service.

Chapter 5 analyses the feasibility of PoC over a commercial GPRS network satisfying the requirements of PSS communication discussed in Chapter 2. It also provides a case study of possible PoC over GPRS network for PSS communication.

Finally, Chapter 6 concludes the thesis.

Chapter 2

Public Safety and Security Communication

2.1 Introduction

The PSS user groups include Police, Fire Brigades, Public Health service organizations and some other rescue operation teams. Apart from different PSS organizations Public Transport companies, courier services and so on also use different PMR networks. The PSS users' requirements differ significantly from that of most other users' because of the nature of job tasks they perform. In this chapter, the requirements of PSS communication are explained briefly.

The rest of the chapter is organized as; Section 2.2 defines the PSS communication services; Section 2.3 identifies public safety and security communication requirements, Section 2.4 defines the PMR concept and briefly describes different kind of PMR systems, Section 2.5 describes the network architecture of TETRA and some key attributes of it and finally the chapter ends with a summary of the chapter in Section 2.6.

2.2 PSS Communication Service Definition

Voice is the primary means of communication for public safety and security professionals and is treated with the highest regards in the definition of its requirements. With the advancement in technology, PSS users are becoming increasingly dependant on the sharing of data, images and video files etc [20].

In general, PSS communication services can be categorized as follows.

Interactive voice communication

Voice communication where two or more users are involved in an interactive session. Commands, instructions, advice, and information are exchanged that often result in life and death situations for public safety workers, as well as for the public.

Non-interactive voice communication

This type of communication is required when a dispatcher or supervisor alerts members of a group about emergency situations and/or to share information. This includes voice paging or multicast voice broadcast.

Interactive data communication

This is one type of query and response data transfer. PSS field workers require maps, floor plans, video scenes, etc during any rescue or routine operation. Sometimes users could go on an instant chat session where they can share knowledge.

Non-interactive data communication

This is a one-way streaming of data, such as the monitoring of fire fighter biometrics and location, alerting the field worker with text messages etc. This form of communication also makes the command and control requirements easier when the commander is aware of the condition and location of the on-scene personnel.

2.3 PSS User Requirements

The PSS users protect and preserve life and property. Access to communication and information services is crucial so that PSS users can perform their jobs smoothly. High performance, security and robustness as well as specific functions are needed for the PSS users [15].

Due to the nature of their jobs, PSS users work in an environment that demands fast, secure, and versatile communication between individual units, groups and command and control centres. These organizations need instant one-to-one and one-to-many wireless communication using both voice and data supported by the highest levels of security, reliability and availability [12]. In the following, some fundamental requirements for PSS communication systems are discussed.

2.3.1 Call set up time

The average PSS call lasts for a few seconds. Calls are often urgent and require instantaneous set up times. So fast call set up or response time is very important. Typical requirements for the voice call set up time belong to the range from 0.3 to 1 second [36].

2.3.2 Voice Quality

Voice communication is and will remain a top priority compared to all other means of communication for the emergency services. Also, emergency workers work in an excessive noisy environment. So the PSS network should support voice calls with high quality allowing the listener to recognize who is speaking even under excessive background noise.

2.3.3 Specialized group communication functionality

A public safety and security service involves a number of people and often requires significant logistical efforts. The efficient and safe co-ordination of these personnel needs them to be in constant communication with each other and to be continuously aware of actions taken by other staffs in both intra and inter-agency situations. So special group communication functionality is the prime needs for emergency users. Here some group communication features are discussed in brief.

- Push to Talk Functionality: Group communication in PSS networks does not rely on number dialling; instead push to talk button option is used. It is required for quick communication set up with a large group by just pressing a push button. Other group members are able to keep their sets on automatic or manual answering mode allowing them to listen automatically or upon pressing the reception button respectively.
- Group Management: Groups can be predefined or dynamic. Dynamic group formation is needed in some emergency, inter-agency work or on-the-move situations. Both should be supported in PSS networks.
- Late entry into a group: This is needed when a mobile was previously engaged in another job or a mobile enters into a group call area. In this situation the system

should take necessary signalling measures to ensure that the mobile can enter into the group session.

- Presence Information: Task management and decision-making can be easier if the status of other group members is prior known. So status information like busy, idle as well as accept and reject list functionality gives extra benefits.
- Integration with control room or dispatching service: This is essential for managing the organizations' field operations and related communication.

2.3.4 Priority

A priority scheme is needed for calls during the network busy hour or in case of a disaster situation, so that users with high priority can jump the call queue. This includes the following functions to be implemented in the system.

- Priority class definition means to define several priority classes based on the severity of job tasks.
- Pre-emption means to discard low priority calls and to let high priority calls access the network.

In addition to the above priority scheme, emergency-calling options are also important.

2.3.5 Network Resilience

It is a key requirement that the network infrastructure has the maximum resilience with sufficient levels of redundancy such that no single failure will cause a major network outage.

Different means should be taken to make the network resilient or increase the network reliability.

- Use a distributed system so that a single node failure will cause little or no harm to the rest of the system. Redundant nodes also increase the reliability.
- Transmission redundancy can be achieved through alternate routing options.
- Power back-up to ensure service continuity during a natural disaster when central power disruption is common.

- Direct mode operation (set-to-set) to ensure that localized communication continues to be available without the need for any network infrastructure support. This is an important requirement for the emergency services in areas where there is no or limited coverage from the mobile radio network. Direct mode is also ideal for working in a network-overload situation, communicating locally without the involvement of the network and hence decreasing extra load on the network.

2.3.6 Radio Coverage and Mobility

Emergency services require country-wide coverage including offshore, mountainous as well as airborne radio coverage for mobile communication. Disaster scenarios are not location specific. So radio coverage irrespective of the geographical nature of the area is important.

The network should guarantee high radio coverage under normal or any national disaster situations allowing the PSS workers full mobility with a reasonable speed within the area without any interruption of communication.

2.3.7 Capacity

Maintaining a definite Grade of Service (GoS) under normal as well as any incidental or busy hour situation is one of the prime requirements for a PSS network. Call congestion happens during incidental situations. So proper prior means need to be supported by the network by either keeping extra reserve capacity or applying priority and pre-emptive or some other measures.

2.3.8 Security

Confidentiality and secure transfer of information is an important criterion for the selection of professional networks. Interconnected systems result in an increase of the potential for a security breach. The main features related to security are

- Authentication: To protect from unwanted users. The Mobile Station (MS) could authenticate the Base Station (BS) in the same way.

- Air Interface Encryption: Protect against tracing and eavesdropping on the air interface. Encryption and decryption are done at the MS and BS.
- End-to-End Encryption: Encryption and decryption are done at the end points. However, the signaling is not encrypted here.
- Dynamic Keys: Static or dynamic keys are required for encryption and decryption. Encryption with a dynamic key is more secure than with a static key, since keys are always changing.

2.3.9 Data Communication

In addition to voice calls, other types of communication exist where for instance video clips or images also need to be seamlessly integrated into an ongoing session without interrupting the session.

2.3.10 Interworking with other systems

In various situations, emergency users need to communicate with other PSTN, ISDN or PLMN users and at the same time access the Internet. So interworking with these systems is also important.

2.4 Professional Mobile Radio (PMR) systems

PMR is a term used to broadly cover all forms of two-way radio systems that range from a simple community repeater to inter-city radio networks. Early PMR solutions were analogue and even today [24], most police, fire, rescue and border services have their own, often incompatible private radio systems, which are based on vendor specific proprietary technologies. These analogue systems are unable to keep pace with the increasing demand of data applications. Early PMR solutions include single frequency one-way paging systems, two-way simplex radio systems, two-way mobile relay systems, trunked radio systems etc.

Increasing demands for advanced features and data based services led to the
evolution from old analogue PMR systems to more sophisticated spectrally efficient technologies utilizing digital modulation and in many cases trunking. A major breakthrough has been done in PMR systems since the early nineties. Digital technology

vastly improves the quality and security of communication while enabling greater volumes of information to be carried over the network. Above all, digital technology ensures secure transfer of information with the introduction of powerful encryption algorithms, and the high transport data rates enable many new features, in comparison with the old analogue systems. These technologies are being standardized nationally, regionally and internationally. In the following, different standardized digital PMR systems are discussed briefly.

TErrestrial Trunked Radio (TETRA) System

European Telecommunications Standards Institute (ETSI) has developed the TETRA system based on TDMA trunking technology. TETRA uses 25 kHz of bandwidth that allows packet switched data at a rate up to 28 kbps. The standard provides up to 4 voice or data channel within the 25 kHz bandwidth. The technical specification of TETRA has been developed aiming at the needs of a wide range of professional users from emergency services to commercial and industrial organizations.

TETRA is used by a number of public safety agencies around the world. Because of its special features and high network resilience its market is expanding very rapidly. TETRA is now widely deployed in Europe, the Far East, the Middle East, Africa and South America. The TETRA standard is also used in the People's Republic of China (PRC) [22]. The First TETRA law enforcement communication system was employed in Finland using NOKIA equipment [21].

APCO Project 25

US local Association of Public-Safety Communication Officials international (APCO), National Association of State Telecommunications Directors (NASTD) and federal government users in collaboration with the Telecommunications Industry Association (TIA), has carried out the development of a standard called Project 25 to be used primarily in public safety and government operations.

Project 25 consists of two phases. Phase I is an FDMA system using FM and QPSK modulation at a 12.5 kHz channel spacing. Phase II has added FDMA at a 6.25 kHz channel spacing. Phase II is also addressing TDMA alternatives [22].

Tetrapol

Tetrapol is a digital trunking PMR system, developed by a forum of manufacturers for security and emergency services. Tetrapol uses FDMA technology with carrier spacings of 12.5 kHz and 10 kHz.

More than 50 Tetrapol systems have been in operation worldwide since 1994; among them eight are national networks [22]. In France, Spain, Switzerland, Eastern Europe, South America, Southeast Asia, and the Middle East, Tetrapol networks are in operation.

Integrated Dispatch Radio System (IDRA)

IDRA is a dispatch system developed by the Association of Radio Industries and Businesses (ARIB) in Japan. IDRA is a TDMA system where six voice channels are carried over a 25 kHz radio channel. IDRA uses 16QAM modulation [22].

Digital Integrated Mobile Radio System (DIMRS)

DIMRS, also known as *i*DEN, is one of the systems used in Canada for dispatch services. DIMRS is based on TDMA technology and offers six communication circuits over a single 25 kHz channel [22].

Reference [24] shows that PMR networks around the world are still dominated by analogue technology. With the increasing demand for new features and increase of data usage, the trend is towards different digital networks like TETRA, Tetrapol, APCO Project 25 etc, and during the last few years a lot of new digital PMR networks have been built.

According to the press release by IMS Research [39] on 19th June 2003, the number of Tetrapol and TETRA users is around 500 thousand and 200 thousand, respectively. IMS predicts that by 2008 TETRA will have twice as many users as Tetrapol [38].

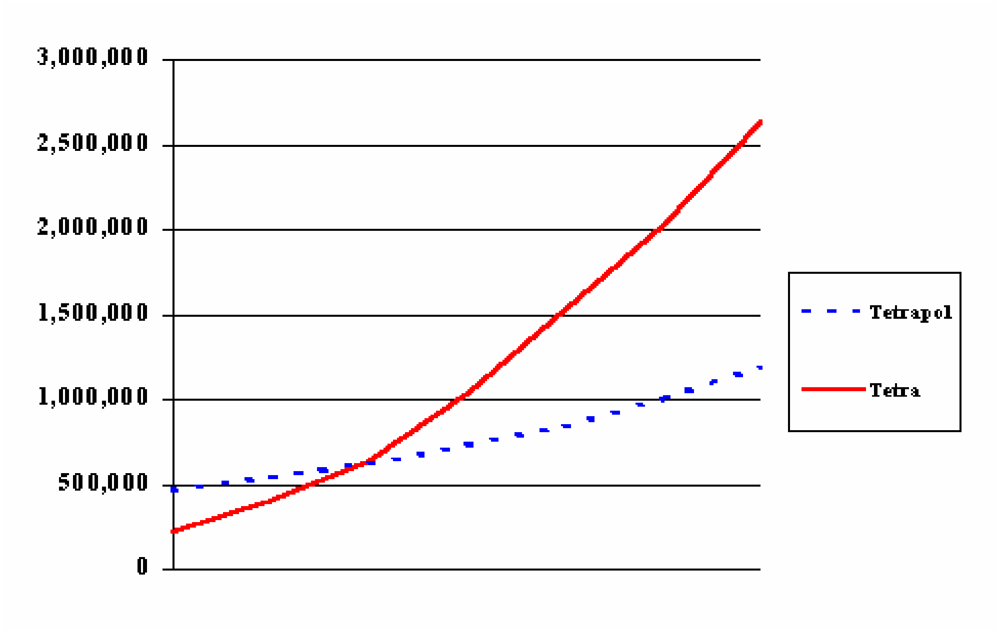


Fig: 2.2 Worldwide TETRA and Tetrapol installed users by technology [38]

TETRA is one of the promising digital PMR systems and its network growth rate is very high compared to other PMR networks [38]. In the following sections, the TETRA network architecture and some important features are briefly described to have an idea of how a digital PMR network is operated in practice.

2.5 Analysis of TETRA Network

2.5.1 Overview

TETRA is the first introduced truly open system standard for digital Professional Mobile Radio developed by the European Telecommunications Standards Institute (ETSI) and has been rapidly adopted on other continents from the Americas to the Far East.

The TETRA standard was developed primarily to bring the benefits of standardization to PMR. It has been developed together with the user organizations to ensure that it offers the best functionality. TETRA is a suite of mobile radio standards that supports trunked and direct mobile-to-mobile communication with a large range of services including voice and various modes of data.

TETRA is a purpose-built technology that offers public safety and security organizations with specialized features and services over conventional radio systems.

2.5.2 Network Architecture

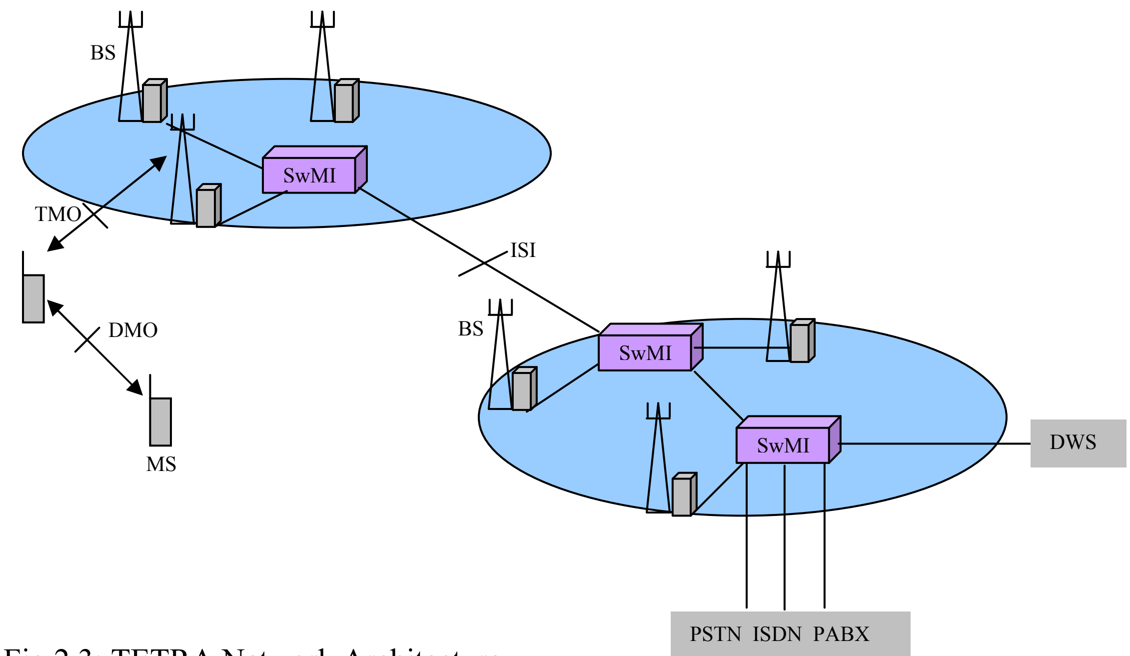


Fig 2.3: TETRA Network Architecture

Abbreviations:

BS-Base Station

DMO-Direct Mode Operation

DWS-Dispatcher Work Station

SwMI-Switching and Management Infrastructure

TMO-Trunked Mode Operation

ISI-Inter System Interface

The SwMI units form the local control part of the TETRA system. Base stations that establish and maintain communication between mobile stations are connected to it. It is connected to the PSTN, ISDN, and PDN through a gateway. SwMI carries out authentication checks and supports the relevant databases such as the Home Data Base and Visited Data Bases. It also handles call charging.

2.5.3 TETRA Radio Interface

Frequency bands: TETRA can operate at frequencies from 60 MHz to over 1000 MHz, with the optimum somewhere around the middle of the range. In Europe the specified ranges are 380-400 MHz for public safety use and 410-430 MHz for civil use.
Carrier spacing: 25 kHz.
Multiple access method: TDMA with 4 time slots/carrier.
Duplex method: FDD
Modulation method: π/4-DQPSK.
Maximum cell coverage: 60 km.

2.5.4 TETRA Services

Teleservices

- Individual Call
- Group Call
- Acknowledged Group Call
- Broadcast Call

Group call is an important feature in the TETRA system. In addition to individual calls, TETRA supports different group calls. A group can be predefined or dynamically created over the air during operations.

A dynamic group is created usually during a rescue operation or inter-organisation operations. Broadcast calls allow broadcasting announcements or commands within a specific area so that the users in that area hear the call.

One of the most popular features of the TETRA system is its ability to transmit data simultaneously together with a voice call, on the same radio channel.

Supplementary Services

The most important feature of TETRA services is that many of the supplementary services are unique. Here some of the supplementary services offered are briefly explained.

- **Dynamic Group Number Assignment:** Allows dynamic creation / modification / deletion of group members.
- **Priority Call**: Calls are assigned with a priority value so that in case of an emergency situation or busy hour only traffic calls with a higher priority value are allowed.
- **Late Entry:** For joining in on an ongoing group call/session.
- **Pre-emptive Priority Calls:** To disrupt ongoing calls in case of network congestion and let the high priority users access the network.
- **Discreet Listening:** For intercepting the ongoing session without alerting the group members. A discrete listening facility allows the control room to monitor the calls.
- **Ambience Listening:** An authorized user may be placed into an ambience listening mode. For example if a vehicle is stolen or hijacked, its TETRA radio can be remotely switched into ambient-listening mode to monitor the verbal exchanges.
- **Area Selection:** The user can define the area to which the call would be routed. Called users outside the area will not be alerted.
- **Call Report:** To inform user B that user A tried to call but user B was not reachable (like miss call information in GSM)
- **List Search Call:** A call is routed to the first reachable address contained in a list of attendants.
- **Transfer of Control:** Allows the originating user to transfer the control of a group call to another user before leaving the call without disconnecting.

2.5.5 Key Attributes of TETRA

Direct Mode Operation (DMO)

Direct Mode (DM) enables direct communication between two or more TETRA DM terminals without the use of network infrastructure, SwMI. The simplest form of DM is the two-way communication between two or more MS terminals, back-to-back. Through the use of a Direct Mode Repeater (DM-REP), it is possible to further extend the area coverage over which these terminals can communicate.

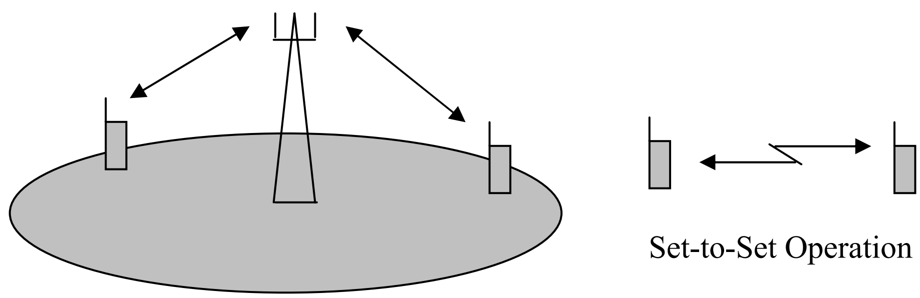


Fig 2.4: Direct Mode Operation

In the Dual-watch mode (DM-DW), the TETRA MS periodically can monitor both calls that are directed to it.

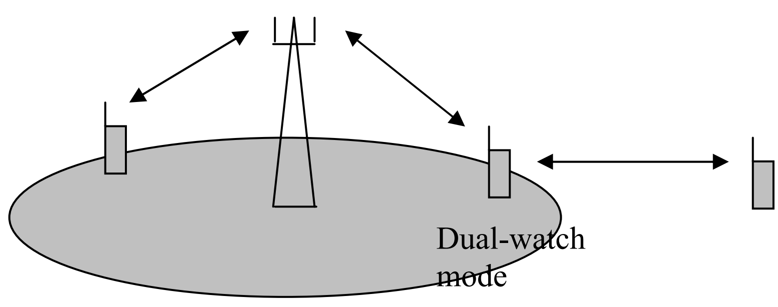


Fig 2.5: Dual-watch mode

Direct Mode terminals may also be contacted by the trunked system by means of a gateway mobile station. The gateway terminal provides coverage extension and communicates with the trunked network.

Trunked Mode Operation (TMO)

Trunking is an effective way to make better use of the spectrum by placing all channels in a common pool and by allocating channels to the users at the beginning of a call. In case of congestion of calls during a busy hour, calling users are placed in a queue and served as soon as channels become free based on the 'First come first served' basis or depending on different priority schemes. The TETRA standard supports three different methods of trunking:

- Message trunking.
- Transmission trunking.
- Quasi-transmission trunking.

The choice of trunking method depends on the network operator or manufacturer, depending on the intention whether to optimize resources usage, minimize access time, minimize call dropping, or some other characteristic. These methods only affect the allocation of traffic channels by the base station. The mobile station does not perceive any difference between the different strategies, but simply carries out the channel change instructions as directed by the infrastructure.

Security

TETRA supports two levels of confidentiality, at the air interface and end-to-end encryption mechanism for secure transfer of user information, along with an authentication mechanism to bar fraudulent access to the system. Certain groups of users require a higher degree of security than is available by just protecting the air interface alone. This is achieved by providing an end-to-end encryption mechanism at all points in the infrastructure.

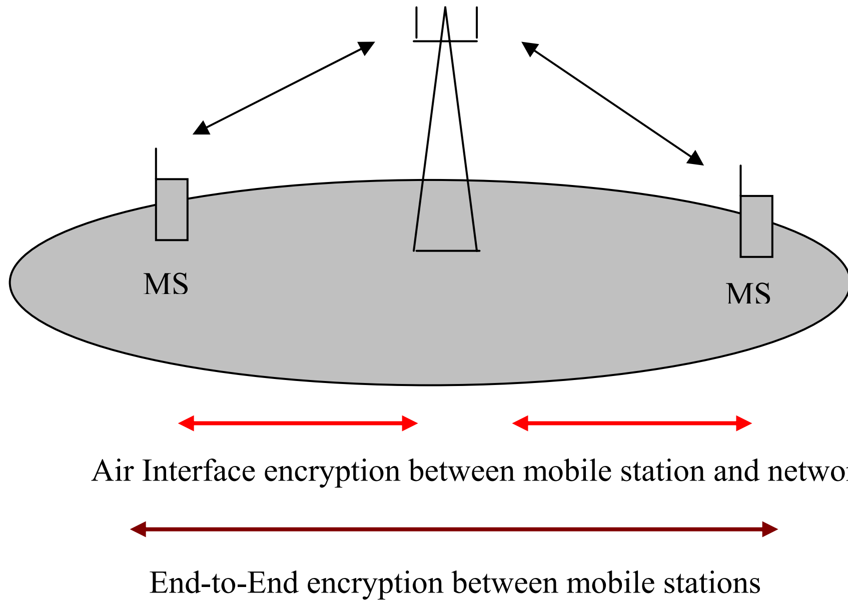


Fig 2.7: End-to-end encryption versus air interface encryption

Base Station Fallback Operation

Base station fallback enables communication within the coverage area of a certain base station if the link between the TETRA base station and TETRA exchange (SwMI) is lost. This in turn increases the resilience of the network.

Handover Time

TETRA specifies undeclared handover signalling for listening users in a group call. Typical call break time is in the range of 1 second; however, independent measurement reports do not exist [18].

Shifting Group Call Area

The TETRA network offers the 'Shifting group call area' feature which allows incident handling capacity by allocating extra capacity to a particular area during emergency or incidental situations or busy hour. This is very important for emergency users. The reservation of extra capacity to every cell is very expensive and is not possible for economic reasons.

2.6 Chapter Summary

The chapter identified the requirements of public safety and security communication. It started with defining the PSS communication services required by many PSS organizations. The background history of analogue PMR networks and different digital networks are also described briefly in this chapter. The chapter ended with analysing the architecture and key attributes of a TETRA network as an example of a modern digital PMR network.

Chapter 3

IP Multimedia Subsystem (IMS)-Based Push-to-Talk over Cellular (PoC)

3.1 Introduction

Push to Talk over Cellular (PoC) is a half duplex voice communication technique that allows one-to-one or one-to-many group communication within a service area. Different professional groups like public safety and security practitioners around the world have been using similar kinds of services for long. Though they have been available for years, most of these services are based on proprietary solutions and limited to different professional user groups within the Private Mobile Network.

Push-to-talk service over a cellular public network emerged in the mid-90's first in USA. Since then the effort has been going on among different cellular network operators and vendors around the world to standardise this service. Ericsson, Motorola, Nokia and Siemens submitted the technical standard specifications for PoC to the Open Mobile Alliance (OMA) standards body in August 2003. Two specifications, PoC Release 1.0 and PoC Release 2.0 have been completed. Both were passed as input to the OMA for standardization. The specification is based on the 3rd Generation Partnership Project's (3GPP) IMS architecture.

This chapter is structured as follows. Section 3.2 gives an overview of IMS based PoC and describes the architecture, including protocols and interfaces, identification and addressing of PoC users, signaling and media transfer protocols etc. Section 3.3 gives a brief description of PoC features, Section 3.4 an example of the PoC session setup procedure, Sections 3.5-3.7 show how PoC is implemented over a GPRS network and finally the summary of the chapter is given in Section 3.6.

3.2 IMS based PoC architecture

The OMA specified PoC service is based on Voice over Internet Protocol (VoIP) and relies on the IP Multimedia Sub-system (IMS) as a service enabler. The architecture of an IMS-based PoC system and functional entities are described in Figure 3.1.

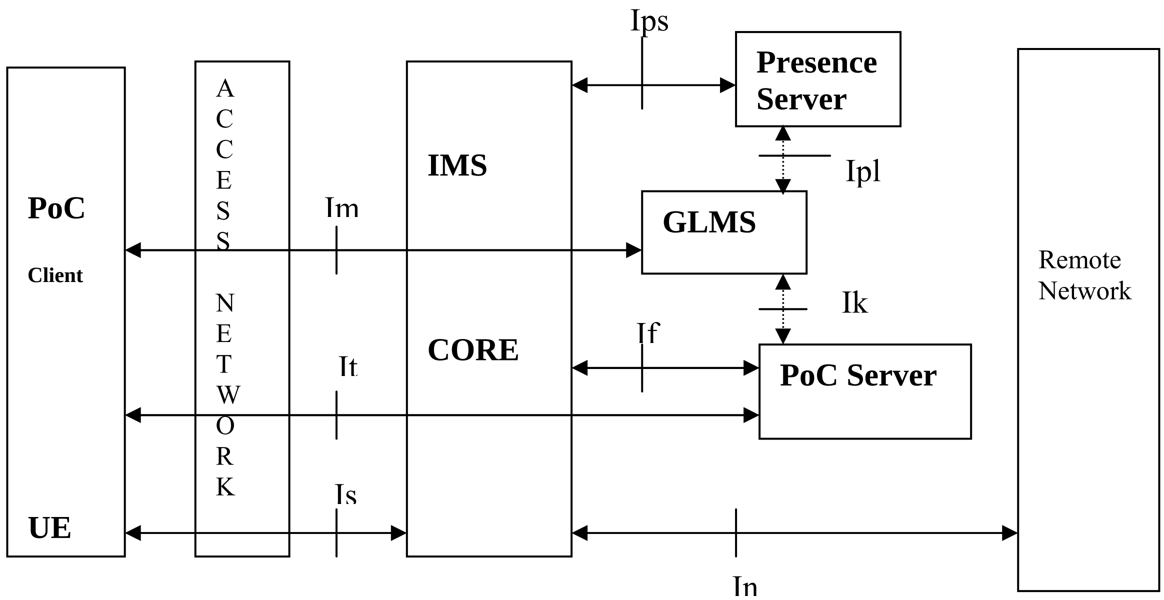


Fig: 3.1 IMS-based PoC Architecture [1]

The User Equipment (UE) that includes the PoC client software communicates with the PoC server over the It interface. The PoC server is responsible for user management like floor control, tearing down the session and media forwarding or replication in case of one-to-one or group communication, respectively. The core network and access network elements provide the required connectivity services between the UE and PoC server. Core network elements in the IMS are also responsible for AAA functions. Group and List Management Server (GLMS) allows users to create and maintain group lists for PoC services. The UE communicates with the GLMS over the Im interface. The IMS obtains presence information from a presence server over the Ips interface. In addition, there are two optional interfaces Ipl and Ik; these are not specified yet.

3.2.1 PoC Network Interfaces

Table 3.1 summarises the interfaces related to PoC.

Table: 3.1 PoC interfaces

Interface	**Network Entity**
Is	UE – IMS Core
If	IMS Core – PoC Server
It	UE – PoC Server
Im	UE – GLMS
Ips	IMS core – Presence Server
Itn	PoC Server – PoC Server
In	IMS Core – IMS Core

3.2.2 PoC Protocol Stack

The protocols used for PoC session set-up, media transfer and session control are IETF specified Session Initiation Protocol (SIP), Real Time Transport Protocol (RTP) and RTP Control Protocol (RTCP), respectively. SIP is used for session set up and RTP and RTCP are used for voice data transfer and floor control, respectively. SIP is a text-based application layer protocol and in PoC applications SIP messages are carried in UDP packets for transmission over IP. RTCP signalling is also transferred in the same way as SIP. The AMR coded voice data is sent in RTP packets, which in turn are carried over UDP over IP.

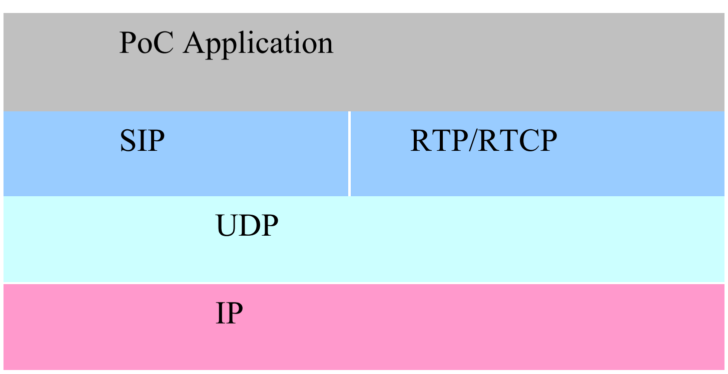


Fig: 3. PoC protocol stack

3.2.3 Identification and Addressing

According to the PoC specification, each user has at least one address of record in the form of a SIP URI (Uniform Resource Identifier) for addressing purposes and optionally a telephone number.

The user part of the SIP URI uniquely identifies the user (i.e. 'abc' in the following example) and the host part (i.e. 'operator' in the following example) the operator. The address of record is used only for PoC and for other SIP based services.abc@operator.net

The Phone number may be in the international E.164 format (e.g. +35840123456) or a local format using a local dialling plan and prefix.

The SIP URI is also used for the addressing of groups. A group with a specific URI can be created and stored in the GLMS.

3.2.4 Packet Data Protocol (PDP) context

There are two options for PDP context activation [1]. One is to use the same PDP context for the transfer of SIP signalling, floor control messages and the media transfer to/from PoC server from/to UE. The other option is to use a primary PDP context for SIP signalling and a separate secondary PDP context for transfer of media and floor control messages, where the Quality of Service (QoS) class is "interactive" for the primary PDP context and "streaming" for the secondary PDP context.

3.3 PoC Services

The OMA PoC specifications outline the following features or connection capabilities of PoC.

3.3.1 One-to-One Communication

This is the basic capability for setting up a voice call between two users. The called subscriber can receive the call automatically or manually.

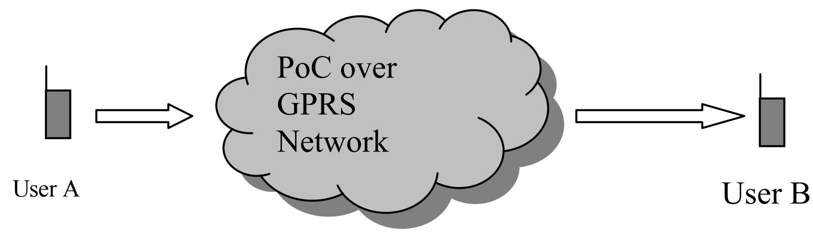


Fig: 3.2 PoC One-to-One communication

3.3.2 One-to-Many communication

This feature enables a subscriber to establish a voice call towards a group of people. One of the group members is the speaker and others are listeners. A participant gets the right to speak through the floor control mechanism. There are three modes of group communication supported by the mentioned version of PoC specifications.

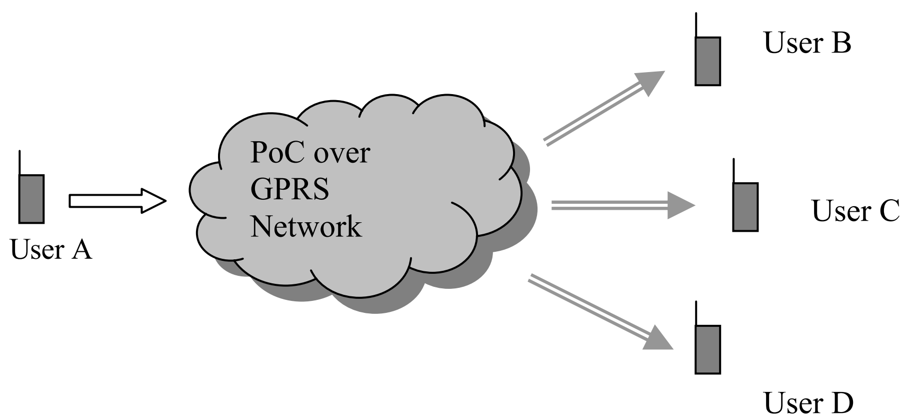


Fig: 3.3 PoC one-to-many communication

- **Ad-hoc:** Ad-hoc group communication is formed when a subscriber selects more than one other subscriber and invites them to join in the talk session. The difference between Ad-hoc Group Talk and Pre-arranged Group Talk is that for the later case a unique identifier has been previously allocated for the instant group.
- **Pre-arranged:** Participants in the session are defined beforehand. The server invites (INVITE) the rest of the participants when a certain member of the existing group invites others in the group session.

A pre-arranged PoC group has a permanent URI by which all the group members can be contacted.

Example: sip:swimming_team@operator.com.

- **Chat:** In a Chat Group Talk, users join and leave an existing chat group as time goes by. The chat group session is established as soon as the first subscriber joins in.

3.4 PoC session setup procedure

PoC users must register with the IMS core before using the PoC service. The UE binds its public user ID (SIP address) to the IP address at registration and the IMS uses this information for routing the call. The INVITE request over the Is interface contains the Accept-contact header with a media feature tag indicating the PoC service. Figure 3.4 illustrates the PoC pre-establishment session set up procedure.

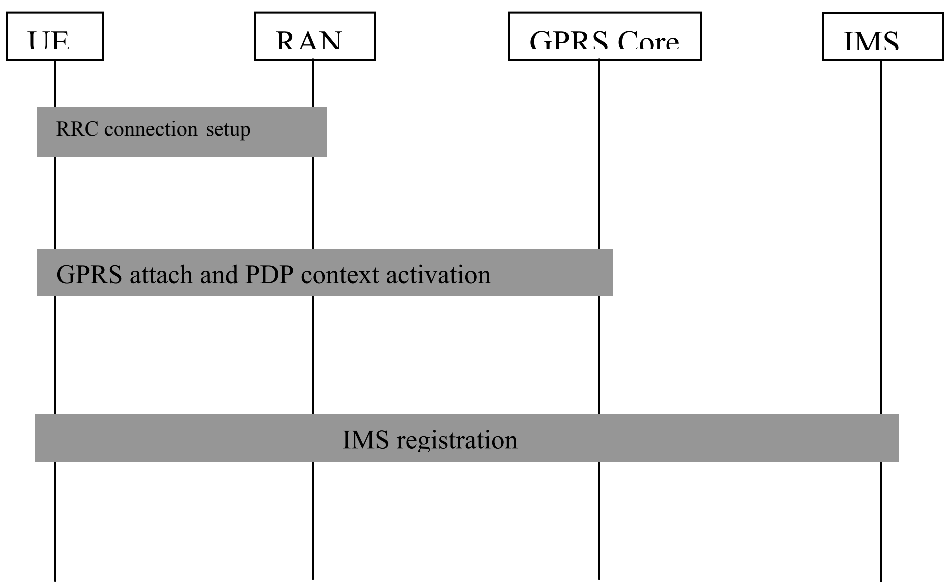


Fig: 3.4 IMS registration signaling

Figure 3.5 shows the SIP and RTCP floor control signaling for an example where user A invites user B sending an invite request message through the PoC server and user B responds afterwards. In this example we assume that user B is in automatic answer mode and thus the early media mode procedure is followed.

For simplicity SIP Trying and SIP Session Progress messages are not shown in the signaling flow chart.

1-7---User A invites user B to a PoC session by pressing his push-to-talk button. This triggers user A to send a SIP INVITE message including the user B's URIs and a media feature tag. The message is routed to PoC server A via IMS core A. The INVITE message is then routed to PoC server B of user B's home network through routing via IMS core A and IMS core B. PoC server B sends this INVITE message to user B.

8- After receiving message #8 (Floor granted), user B sends a Start Talking Indication message to user A. User A can now start talking (message #10) though the end to end media path is not established yet. This is called early media feature. The PoC server must store the voice data until the end-to-end PoC session is established.

11-15—When PoC client B accepts the invitation, an OK message is sent to user A through the SIP core network including PoC server A and PoC server B.

16-17—Controlling PoC server A sends a Floor Taken message to participating PoC server B. This indicates the status of the floor and alerts user B that an incoming talk burst is to be expected.

18-19—PoC talk bursts are transported over the RTP media established between user A and user B through PoC server A and PoC server B.

20-23—When user A stops talking and releases the push-to-talk button, PoC client A sends a Floor Release message to PoC server A to notify user A and user B about the idle status of the floor. This indicates that the floor is free to be taken by user B.

24-28---User B sends a Floor Request message by pressing the push-to-talk button. This message is sent to the controlling PoC server A. The PoC server then send floor status message to user A (Floor Taken message) and user B (Floor Granted message).

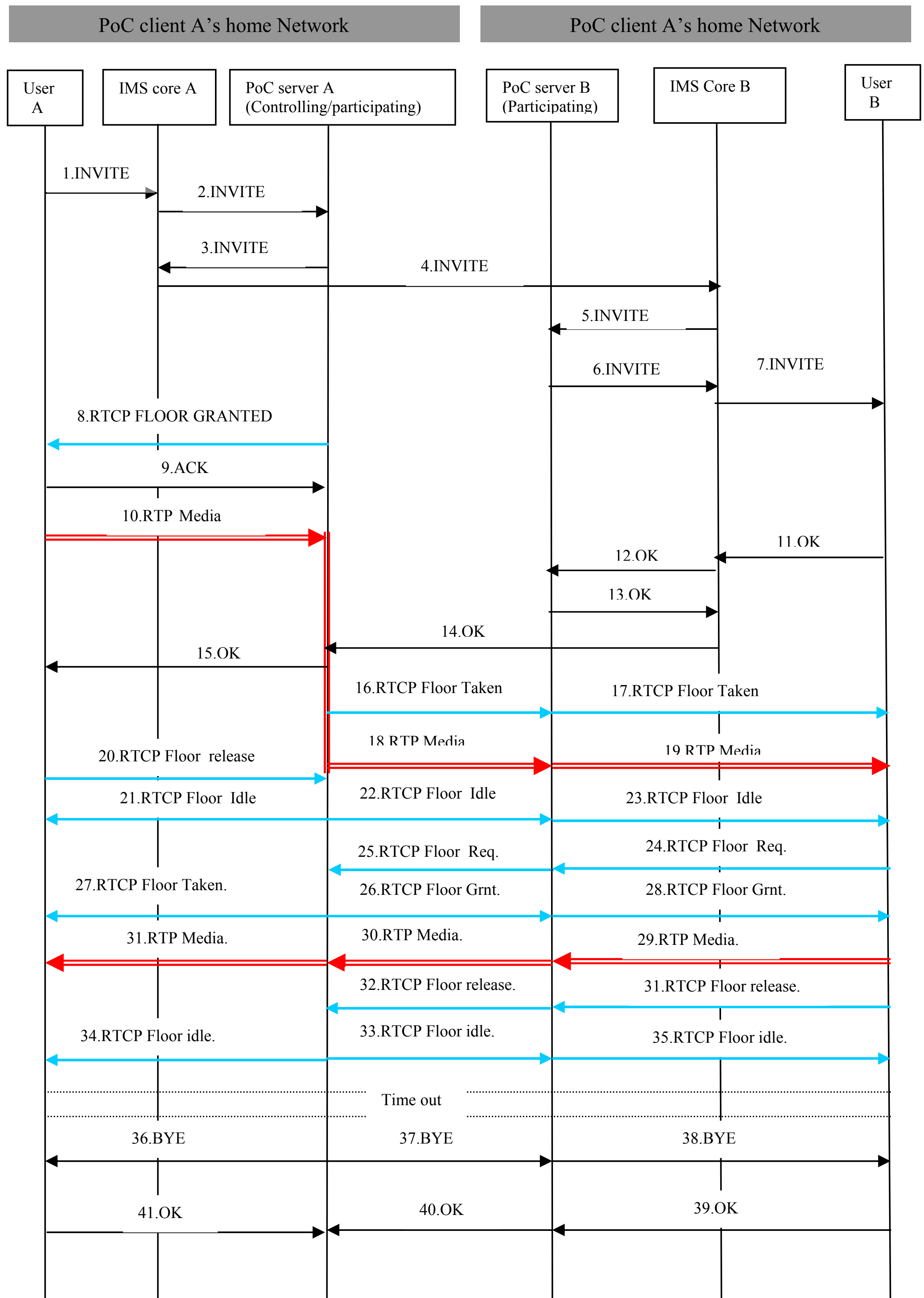


Fig. 3.5 PoC session setup procedure

29-31—User B starts talking and RTP media is transported to user A through PoC servers.

31-35—When user B stops talking, the floor is released and a floor status message is sent to the other users.

36-39—The session release is initiated by the controlling PoC server after a predefined time period has been elapsed.

3.5 PoC implementation requirements

According to the OMA PoC specifications, PoC can be implemented over different packet access networks that deliver a throughput of 7.2 kbps or more [2]. Therefore PoC can be implemented over the following access networks:

- GPRS according to 3GPP Release 97/98,
- EGPRS according to 3GPP Release 99 or later releases,
- UMTS according to Release 99 or later releases.

OMA proposed the use of AMR 5.15 codec for media coding with a frame time of 20 ms. These frames are then encapsulated in RTP as payload and transferred over a UDP/IP connection to the PoC server.Support of IP version 4(IPv4) is mandatory on all PoC interfaces and IPv6 is optional.

3.6 Motivation of using GPRS network

Push to Talk (PTT) service has a proven popularity since its implementation over different PMR networks though its use was limited to certain user groups. Also, its implementation over a cellular circuit-switched network was found neither cost effective nor efficient in terms of resource utilization due to the nature of the PTT service, since typical PTT talk bursts are very short compared to general circuit-switched voice calls and thus reservation of resources for the whole duration of the conversation is very inefficient.

The addition of packet switched GPRS technology in GSM networks from 3GPP release '97 onwards has brought an opportunity for service providers to make the PTT service available to mass market. However, the implementation of Push to Talk over Cellular with the required end-to-end quality and performance over GPRS networks is a challenging task since the GPRS network was mainly designed for non-real-time packet data transfer. But a number of modifications were accomplished in the later releases of GPRS, making the GPRS network suitable for real-time VOIP services [31] [34].

Recently Northstream [16] has done a study on whether the GSM/GPRS network meets the requirements generated by push-to-talk services. The study concludes that the GPRS network, if tuned correctly, meets the PoC technical demands [34].

According to Ericsson Research, their Instant Talk PoC system, based on OMA specifications, shows an equal performance over GPRS, WCDMA and CDMA2000 networks [34]. Other telecom vendors are quoting similar research results [30].

3.7 PoC over GPRS network

The figure below illustrates the OMA standard IMS based PoC implemented over a 3GPP standard GPRS network.

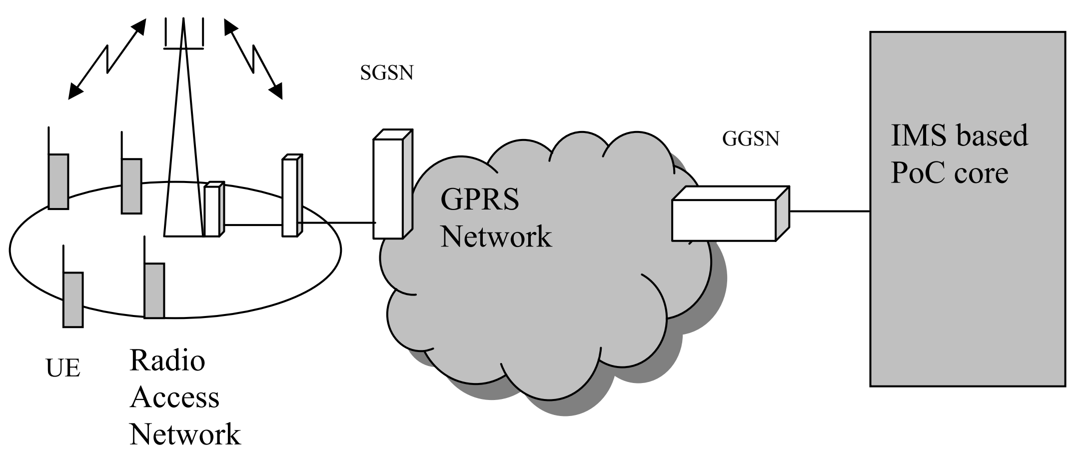


Fig: 3.6 PoC over GPRS Network

In the above figure, the IMS based PoC core includes the IP Multimedia Sub-system, PoC servers, a Presence server, and GLMS. IMS takes care of call routing, interaction with external networks, AAA functions and other generic functions. The PoC server handles session control, floor control etc. The GPRS access network provides an IP based packet transport service between the UE and the service network that hosts the PoC service. Here GPRS access network means a 3GPP release 97/98 (or later) radio access network plus the GPRS core network. UE is a Mobile station with PoC client software.

3.8 Chapter Summery

The chapter started with describing the OMA PoC architecture, functional entities, protocol stacks, as well as PoC features and benefits. A brief overview of the PoC session set up procedure with signalling message flow diagram was given to clarify the role of IMS and PoC server. The last two sections described PoC implementation issues and finally the chapter ended by describing how PoC is implemented over a public GPRS network.

Chapter 4

Performance Analysis of Push-to-Talk over Cellular (PoC) service over GPRS network

4.1 Introduction

PoC has already proved its popularity among different groups of people around the world within a very short period. The service has a large potential for the operators as it can be offered on an existing GPRS network with some modifications and additions in the core network and PoC-equipped handsets. The service offers many features that are comparable to features offered by many professional mobile radio systems. However, in practice the service suffers from some latency-related problems introduced by the GPRS access network.

In this chapter, some challenges of implementing PoC over a GPRS network, when intended to be used for public safety and security communication, are pointed out together with some improvement proposals.

The rest of the chapter is organized as: Section 4.2 identifies challenges of implementing PoC over GPRS network and some limitations of this service if used in PSS communication, Section 4.3 discusses latency issues, Section 4.4 explains the impact of mobility in a GPRS network, Section 4.5 discusses PoC-related QoS and radio resource management strategies to handle congestion and overcome the delay due to contentions for resources, Section 4.6 proposes some improvements to ensure the quality of PoC service over an existing GPRS network and finally the chapter ends with a summary of the chapter in Section 4.7.

4.2 Challenges of PoC over GPRS Network

The implementation of PoC service meeting end-to-end quality and performance requirements over a commercial GPRS network is a challenging task. The Northstream study [34] showed that the successful deployment of PoC mostly depends on tuning the service in an end-to-end perspective. In the following, some challenges which would be faced by the PoC service over current GPRS networks, if intended to be used for mission critical purposes, are briefly discussed.

- **Setup/Response time**

  The PSS network needs call set up times in the sub-second range which is still not possible in a PoC over GPRS network due to the inherent latency in the radio access network and slow text-based SIP signaling. A fast call setup or response time, irrespective of possible congestion in the radio network, is very important for the emergency workers because of the nature of the jobs they perform.

- **Incident/Overload handling**

  In case of an incident, the traffic increases drastically; both the normal subscribers as well as rescuing personnel need to communicate at the same time. Commercial networks are designed with limited capacity and it is not very common to keep extra radio resources reserved beforehand, which is not economical for the operators, in every site for special congestion handling. PoC channel congestion would most likely happen in rural area network sites that are usually built to support a limited number of subscribers. This could pose a severe limitation to the feasibility of the whole service to support emergency communication during major incidents.

- **Impact of mobility in GPRS network**

  Public safety and security workers as well as general subscribers need to move frequently around a certain area for their operation purposes, which imply that support of seamless roaming would be important. As soft or softer handover is not supported in current GPRS networks, cell change or cell reselection is performed, which leads to a service interruption time from 1-2 seconds to several seconds depending on the channel availability and traffic load in the target cell.

- **Delay in Speech**

  Since the voice packets are delivered individually to each talk group member over a ‘best effort’ network, some members could receive the packet earlier and some with a considerable delay depending on the traffic load of the cells. The situation could be worsened when users reside in different cells and one or two of the cells are overloaded. There is a good possibility that listeners in an overloaded cell will get the data packets greatly delayed compared to listeners in non-overloaded cells. This would need the repetition of speech segments and consequently would lead to interruptions in the emergency rescuers operation.

- **Effect of Unicasting**

  Current PoC data transport to individual participants is based on unicasting, which means that the user data is first sent to the PoC server where it is duplicated in case of group communication and then sent to each recipient of the group. One consequence of this unicasting is that many copies of the same data packet are sent over the core and radio access network, which means an inefficient use of the network resources. This would create an extra load on the transport network when the number of PoC users increases. Figure 4.1 illustrates the impact of unicasting on the transport network.

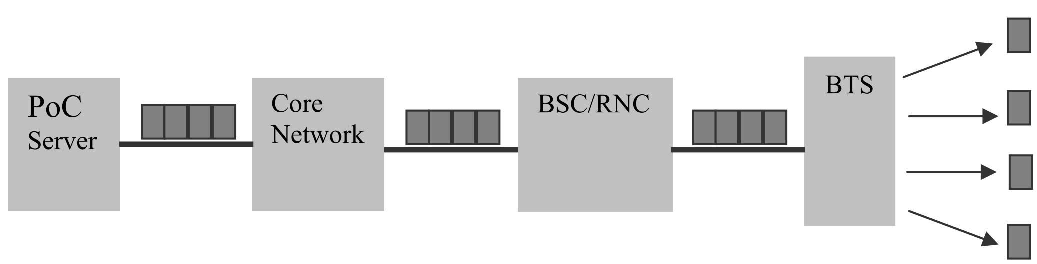


Fig. 4.1 Effect of unicasting on the transport network

- **Voice Quality**

  Since best effort service does not provide any guaranteed bit rate, the voice quality could be deteriorated due to restrictions on the bit rate or delay variation (jitter) in the delivered data packet stream in an overloaded or congested cell. However, as far as emergency operations are concerned, providing good voice quality is important even in a noisy environment so that an emergency user's voice could be recognized easily.

In the following sections, the causes of the above mentioned challenges are investigated and some improvements to fulfil the end user expectations/requirements are pointed out.

4.3 Call Setup Time

As far as public safety and security are concerned, call set up time is a very important factor when selecting a system for public safety and security communication networks. Usually, PSS group talk bursts are very short and in some cases a rapid response is required. The recommended PSS communication call set up time is in the sub-second range (<1 second) [36].

4.3.1 PoC Recommendations for setup and response time

The end-to-end performance of the PoC service involves ensuring end-to-end session setup time, session join-in time, and end-to-end media transfer delay as recommended by the PoC standards. Table 4.1 gives an idea of recommended values for the above mentioned time delay parameters in a PoC network.

Table 4.1: End-to-End delay recommendations [6]

PoC signaling flow		End-to-End delay
Control Plane (SIP signaling)	Session set up (Early media)	2.0 s
	Session set up (Late media)	4.0 s
	Session join-in	4.0 s
Control Plane (RTCP signaling)	Floor request	1.6 s
	Floor release	0.8 s
User Plane (RTP media)	One way media transfer	1.6 s

A session is considered as an exchange of data between associations of participants. The UE must support and operate both in the late media establishment mode and in the early media establishment mode. The UE is unaware of which mode the network selects. Selection of session establishment mode is a PoC server feature.

4.3.2 Set up and Response time in practice

A typical PoC session set up time is more than a second. But some vendors and operators claim that their PoC solutions offer a setup time within a second. A pioneer for PoC over public cellular networks, Nextel, offers a system where the push-to-talk setup time is almost instantaneous. Reference [34] shows that Nextel's Direct Connect service offers call set up times in the range of 0.81 s to 1.10 s with an average value of 0.92 s. Of course, Nextel's Direct Connect service is not based on OMA PoC standards.

Ericsson's Instant Talk system, which is compliant with OMA PoC standards, shows similar figures as Nextel. A Northstream [33] white paper on Push-to-Talk over Cellular shows that Ericsson's Instant Talk over 3GPP Release 99 GPRS network has the performance shown in Table 4.2. The measurements [34] were done both in a laboratory and live network environment and the report has been provided by Ericsson Research to Northstream.

Table 4.2: Ericsson performance figure for One-to-One call with early media set up procedure over a GPRS network [34]

Delay cause	Delay
Push to tone (Initial)	1-2 s
Media delay (Initial)	~1 s
Push to tone (During session)	< 1 s
Media delay (During session)	~1 s

Note: Push to tone is the time required between pushing the button and starting to talk. Media delay is the time between sending the speech at the transmitting side and receiving the speech at the receiving side.

The above measurement reports exclude the paging time. Paging would add another 2-3 seconds to the initial push to tone time. However, the figures are promising.

In Reference [32] Push-to-Talk over Cellular operating over a 3GPP Release '98 GPRS live network was investigated. The Siemens PoC solution is based on IMS and is compliant with OMA PoC standards. Table 4.3 shows the delay results measured for time critical PoC control procedures. All values are average values.

Table 4.3 Delay results for the PoC session and floor control procedures [32]

PoC control procedure		Time in seconds
Registration	IMS/PoC registration	2.6
Session Control	Session set up (Early media)	1.9
	Session set up (Late media)	3.5
	Session join-in	1.9
	Session release	1.5
Floor Control	Floor request	0.7
	Floor release	0.6

4.3.3 Improvement

In Reference [32] it was found out that up to 20-30% of the overall setup delay is caused by establishment of Temporary Block Flow (TBF), 40% by transfer of SIP messages over the established radio link and the remaining 40-30% by transport over the GPRS network including processing in the IMS core and PoC servers.

The establishment of TBF is necessary for data transfer. Typical TBF connection delay in the downlink is about 100-230 ms and in the uplink about 150-300 ms [19]. The time taken to establish an active TBF depends on the availability of radio resources and differs for the uplink and downlink directions. If a TBF is currently active then the MS may use it hence minimising the delay. However, if no active TBF is available then the MS and network must exchange signalling messages for establishing a TBF.

If the network supports extended uplink TBF, the delay caused by the re-establishment of TBF can be reduced when transferring signalling messages as well as RTP voice media.

The Extended Uplink TBF extends the time period before an uplink TBF is released and this is set by the network [27]. In the Extended UL TBF mode, the uplink TBF may be maintained during temporary inactive periods, where the mobile station has no RLC information to send. The mobile station must also have explicit support for the extended uplink functionality to operate correctly.

SIP is a slow protocol due to the amount of text-encoded information it transmits during each signalling transaction. Sign Compression (SigComp) is used to reduce the session setup time due to transmission delay. However, this method involves a trade-off between the processing delay and the transmission delay. The compression may shorten the transmission delay but may also lengthen the processing delay depending on the complexity of the compression scheme.

4.4 Impact of Mobility

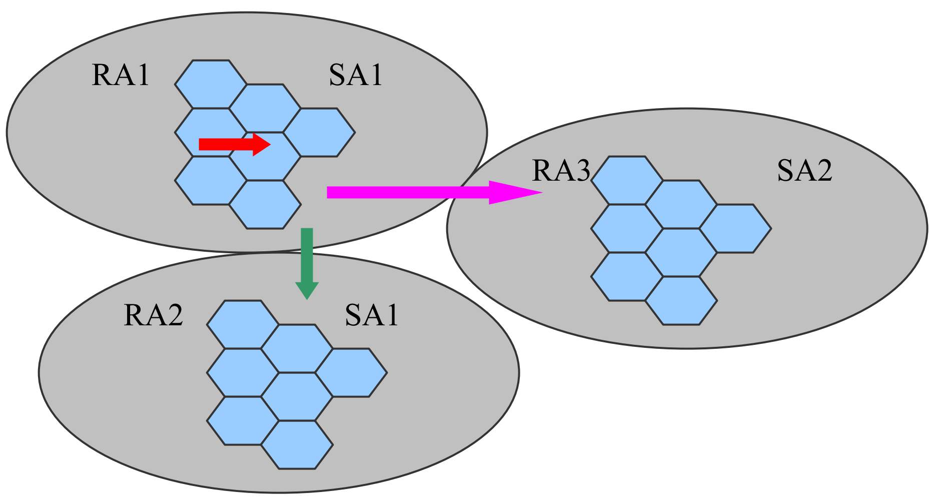
Handover (cell reselection in GPRS) must be performed when a mobile device or user moves from one coverage area to another in the dedicated mode. The length of the cell selection/reselection procedure affects the quality and performance of the PoC session. A long service interruption time causes the loss of IP packets during the cell reselection procedure. In the worst case, this could cause the loss of total talk bursts as PoC talk bursts generally last only for a few seconds (6-10 s) [30].

In the following, the impact of a service break due to the cell selection or reselection procedure is investigated.

4.4.1 Cell Selection/Reselection in a GPRS network

An MS in a GPRS network is not able to camp on more than one cell at the same time. When an MS moves from one cell to another new cell inside the GPRS network serving area, the MS must perform the cell update procedure to inform the network about the current location of the MS. The following three kinds of location management procedures are possible in a GPRS network:

- When a user (MS) moves into a new cell inside the same routing area, a simple cell update procedure is performed.
- When the new cell belongs to a different routing area within the same SGSN serving area, the cell reselection involves more signalling and a routing area update is performed.
- The most complicated case is an inter-SGSN handover when the new cell belongs to a new routing area as well as a new SGSN.



Inter-cell reselection

Inter-routing-area cell reselection

Inter-service-area cell reselection

SA: GPRS Service Area

RA: GPRS Routing Area

Fig 4.2: GPRS cell reselection

An idle MS does not perform any updates and an MS in standby state performs only routing area updates but does not inform the SGSN of its cell changes. However, the SGSN needs to know the exact cell location of an MS that remains in ready state.

Since inter-SGSN cell reselection is not so frequent for PSS operation, it is not included in the following discussion.

4.4.2 Service Interruption time due to Cell Reselection

Cell reselection between cells within the same routing area causes a delay up to several seconds and varies in uplink and downlink. The average service break time due to inter-cell reselection within the same routing area, was found to be in the range of 1.5 seconds (DL) and 1.7 seconds (UL), calculated over a measurement session including 20 cell reselections [19]. Cell reselection can cause service break times up to 10-15 seconds in case of inter-routing-area cell reselection. The measurements done in [19] show that the implementation of the NACC [7] feature in a GPRS network significantly reduces the service interruption times due to cell reselection down to a value in the range of a fraction of a second.

Figure 4.3 illustrates the average service interruption time due to cell reselections with and without the NACC feature.

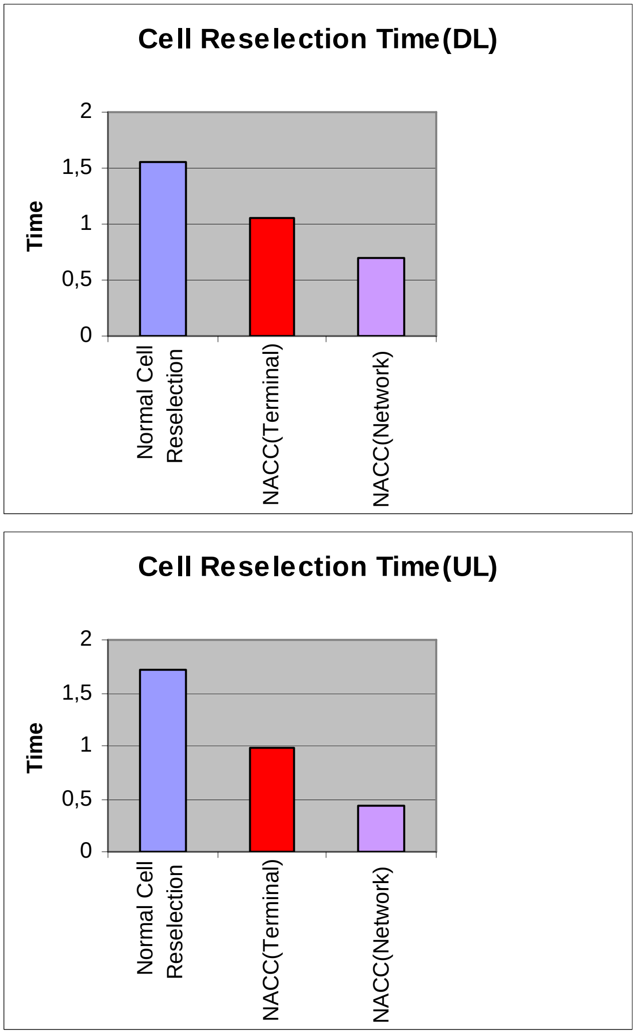


Fig 4.3: Cell reselection time [19]

4.4.3 Improvement

As far as cell reselection delays are concerned, NACC is important. The NACC feature is included in 3GPP Release '99 and Release 4. So it can be obtained for the GPRS network as a network-based upgrade.

4.5 PoC Quality of Service (QoS) Profile

In order to ensure service quality for PoC over a GPRS network, QoS profile parameter values should be carefully selected by the UE during PDP context request. Since a 3GPP Release 97/98 compatible GSM/GPRS network does not support the "streaming" QoS class, the PoC specification [2] proposed the QoS profile parameter values of Table 4.4 to be set during the PDP context activation.

Table 4.4 QoS profile parameter values for PoC over a 3GPP Release 97/98 compliant GSM/GPRS network [2]

Parameter	Proposed value settings	Value Range	Explanation
Delay Class	1	1-4 (Predictive - best effort)	Indicates lowest possible delay
Reliability Class	3	1-5 (Non real time - real time traffic)	Indicates medium level of protections
Precedence Class	2	1-3 (High - low)	Normal precedence is given to PoC traffic
Peak Throughput Class	2	1-9 (8 kbps-2048 kbps)	Up to 16 kbps
Mean Throughput Class	15	1-31 (~ 0.22 b/s-best effort)	For best effort services operator may set value 31.

Most commercial GPRS networks offer best effort service [29]. Since the best effort GPRS network is not able to guarantee any throughput to the UE, the PoC service quality can only be ensured if the radio access network is appropriately dimensioned. Moreover, the standards have not proposed any resource management algorithms that take into account services QoS requirements. This task has been left to the GSM/GPRS network operators.

4.5.1 Radio Resource Management Strategies

In GSM/GPRS cells, both GSM circuit switched traffic and GPRS packet switched traffic share the same radio spectrum. In GSM/GPRS cells GPRS traffic has to compete with GSM voice traffic for channels, so in case of unavailability of channels, this leads to the denial of a new session setup or delays in the data transfer for ongoing sessions. This consequently results in the degradation of the overall performance and quality of GPRS services. The situation becomes worse in overloaded or congested cells. To guarantee a certain capacity for circuit switched traffic and packet switched traffic, channels can be reserved for different kind of traffic.

The implementation of different radio resource management strategies depends on how Mobile Network Operators (MNO) treat circuit switched and packet switched traffic. In the following, different radio resource management strategies are discussed briefly.

Fixed sharing

In fixed sharing, the total number of available channels in a cell is partitioned into two parts - one is for voice and the other for data traffic, which means there are some dedicated time slots (Packet Data CHannel, PDCH) that are always available for GPRS traffic irrespective of GSM voice traffic congestion in the cell.

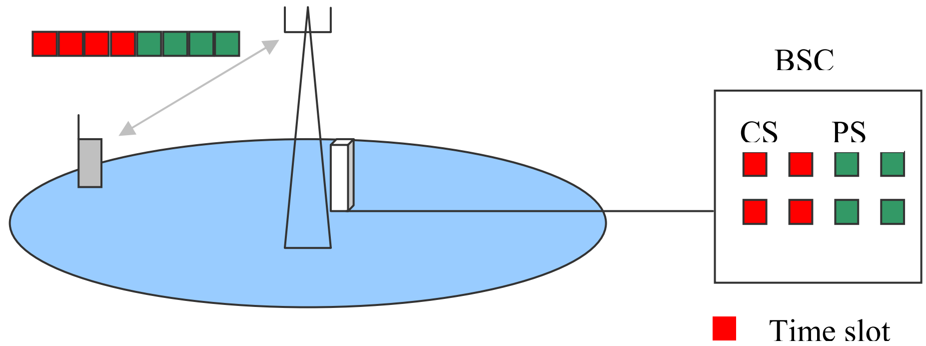


Fig: 4.4 Fixed sharing channel allocation

On Demand Channel allocation

In this channel allocation scheme, a pool of time slots (channels) is available for circuit switched voice and packet switched data. Priority is normally given to GSM voice traffic and in case of congestion, when more channels are needed for voice, data traffic channels (PDCH) are pre-empted.

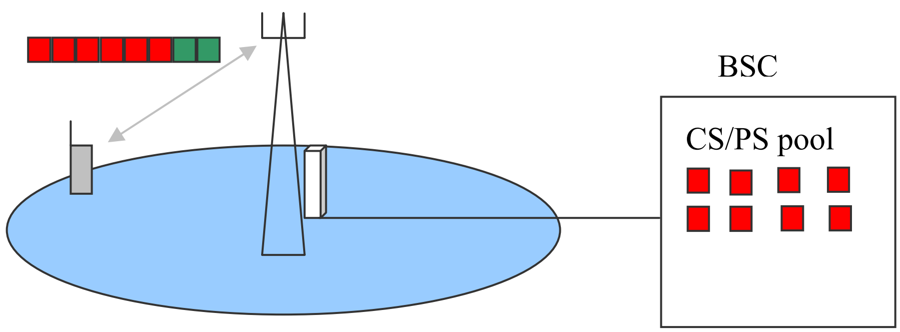


Fig: 4.5 On Demand Channel allocations

The problem of this scheme is that if the cell is overloaded or congested then there will be zero channels available for GPRS traffic. As a result any ongoing GPRS session will be released and a new session attempt is rejected until a channel becomes free.

A combination of the above two channel allocation schemes is possible. A fixed number of channels are reserved for data traffic and the remaining channels are shared by both the GSM circuit-switched voice and GPRS data traffic. Voice traffic has the higher priority over data traffic. Thus in situations when voice traffic needs more channels than available the data channels other than the fixed allocated ones are pre-empted. The advantage of this scheme is that there are some channels always available for data traffic and moreover some extra channels could be used for data traffic in case there is less voice traffic in the cells.

4.5.2 Proposed Radio Resource allocation scheme for handling congestion and delay

In commercial GSM voice traffic dominated networks, usually the priority is given to circuit-switched (CS) voice traffic and thus packet data users are pre-empted in case the channels are needed by the CS users. So if no channels are reserved exclusively for data traffic, it could happen that speech users occupy all available channels. Consequently, packet switched (PS) data users will queue after the CS speech users and wait until the channels become free. Analysis shows that reserving channels exclusively for packet data users has been shown to give a major gain in data user capacity, for a minor blocking of speech users.

Reference [25] investigates the impact of introducing GPRS packet data service into an existing GSM radio network with speech users and different channel allocation strategies for speech and data users in a shared GSM/GPRS cell.

Figures 4.6 and 4.7 show how the spectral capacity changes with different channel reservation strategies, where *d* is the number of data-only channels.

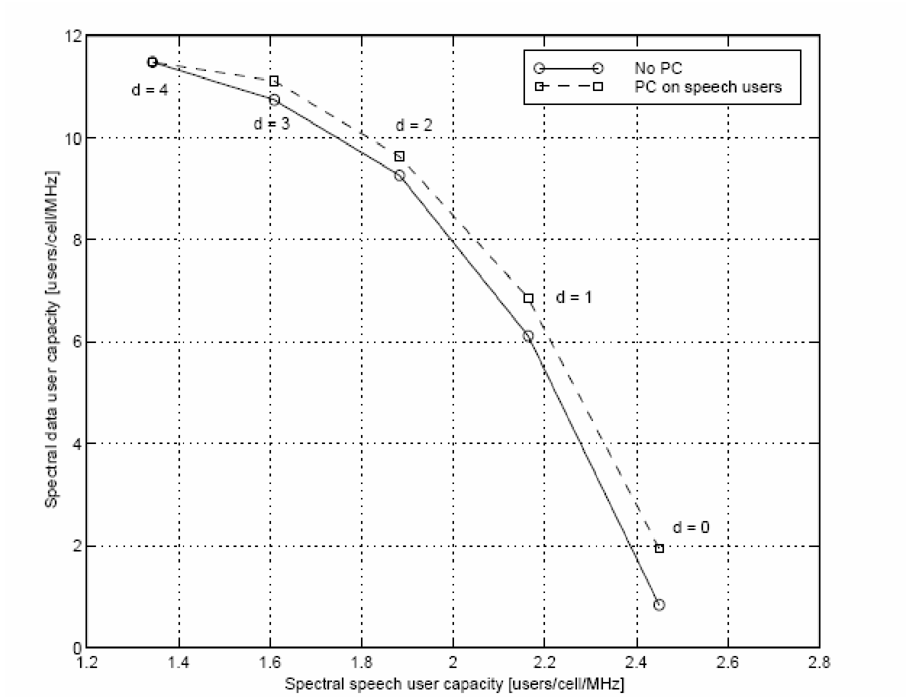


Fig: 4.6 Speech and packet data user spectral capacity for different channel reservation strategies [25].

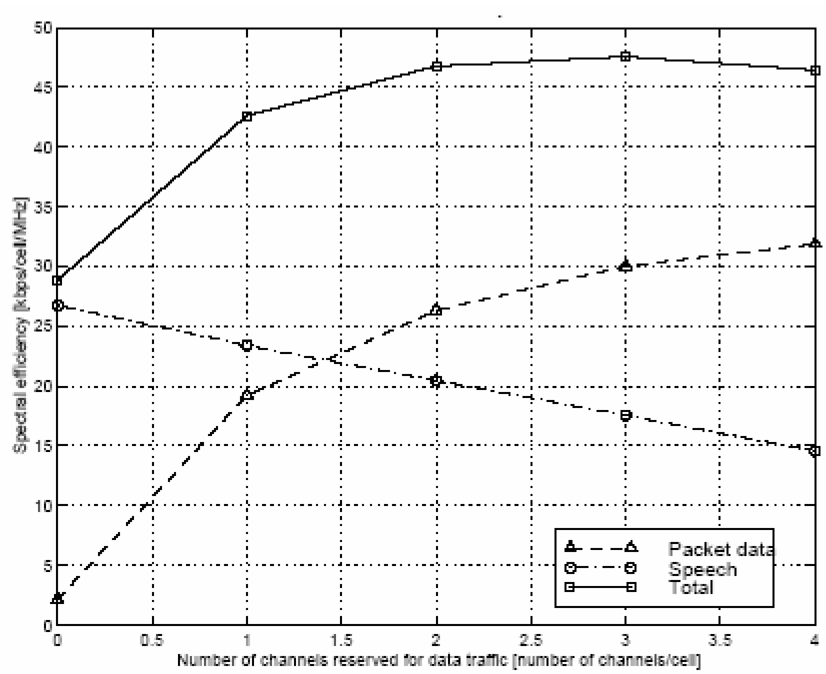


Fig: 4.7 Packet data, speech and total spectral efficiency for different number of data only channels [25].

Reference [28] studies the performance of three different channel sharing schemes to support both circuit switched voice and packet data services in a GSM/GPRS network: **fixed sharing** in which total available channels in a cell are partitioned into two sets - one for circuit-switched (CS) voice traffic and the other for packet switched (PS) data traffic; **partial sharing** in which a few channels are exclusively dedicated for PS data traffic and the remaining channels are shared by voice and data with pre-emptive priority for voice calls; **complete sharing** in which all the channels are kept in a pool and shared by voice and data on demand with pre-emptive priority to CS voice calls.

Figure 4.8 shows the comparison among the different sharing schemes for the particular case of 8 traffic channels available in a cell. For the fixed sharing scheme, the 8 available channels are split into two parts: 4 channels exclusively for CS and the remaining 4 exclusively for PS data traffic. Under the same parameters of the data traffic and voice traffic, it is seen that the complete sharing policy has a voice block rate of 0.3 %, 0.9 % for partial sharing and 14.5 % for fixed sharing. Even though the fixed sharing policy has the smallest mean packet delay, it has a higher CS traffic blocking rate which is not acceptable in a commercial network. On the other hand, the partial-sharing and complete-sharing policies both have quite a small blocking rate less than 1.

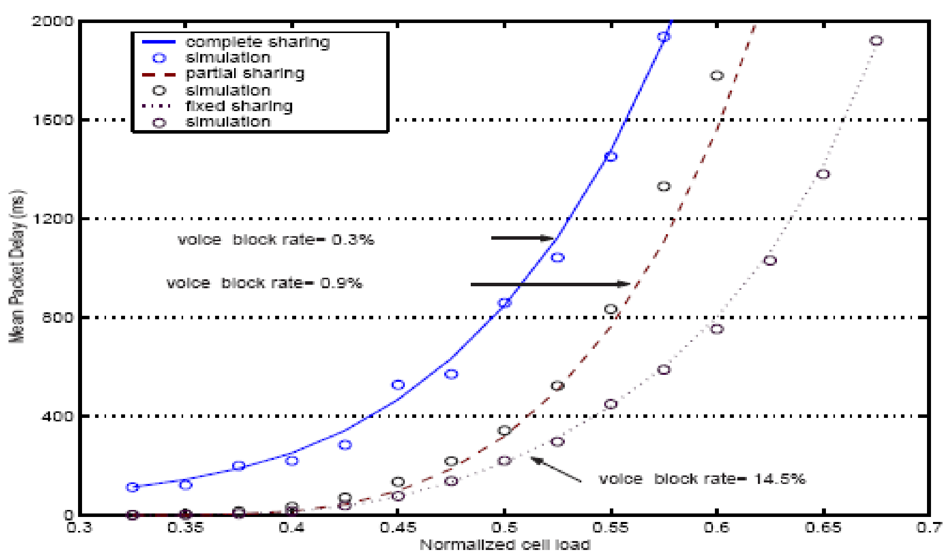


Fig: 4.8 Comparison of mean packet delays for different channel sharing policies [28].

Reserving channels for packet data users has been shown to give better performance in terms of delay [28] and capacity [25] with a minor blocking of CS voice users. The system with no reserved channels for PS data traffic suffers from congestion, which consequently increases the packet transfer delay. However, the optimal choice of channel reservation depends on how the network operators treat PS and CS services.

4.6 Improvement proposals

Since the 'best effort' GPRS network cannot guarantee end-to-end quality of service, the PoC service quality can only be ensured if the radio access network is appropriately dimensioned. Points 1-5 in the following list contain some proposals to improve or maintain the quality of the PoC service over existing GPRS network. It will also be possible to remove some drawbacks of PoC service deployment over GPRS with gradual upgrade of network (points 6-7) or through future evolution to UMTS or EGPRS as more real-time services are going to become available in the near future.

1) Radio resource allocation exclusively to GPRS PS data traffic to avoid pre-emption by GSM CS data flows and at the same time to reduce the delay due to contention for resources.
2) Limiting the number of PoC or packet switched users per PDCH can help to maintain a higher bit rate per user.
3) The UDP/IP header compression may reduce the link capacity needed as well as shorten the transmission delay but may also lengthen the processing delay depending on the complexity of the compression scheme. However, this method involves a trade-off between the processing delay and the transmission delay.
4) A jitter buffer at the receiving side can handle small delay variations or jitter caused by the GPRS access network.
5) Use of early media settings in the network.
6) Extended or delayed TBF can help to keep the TBF active during the PoC session set up signaling as well as transmission of voice bursts and can thus reduce the delay as far as establishing a TBF is concerned.

7) The NACC feature in the PS domain will significantly reduce the service interruption time due to cell reselection.

4.7 Chapter Summary

The chapter analyzed the performance of PoC service over a GPRS network. It started with finding out the challenges of PoC over existing GPRS networks when intended to be used for PSS communication. The causes of the drawbacks due to the GPRS access network are also analyzed and some improvements that are available through proper radio network dimensioning or through network upgrades are suggested.

Chapter 5

Feasibility Analysis of IMS based PoC over GPRS for PSS communication

5.1 Introduction

There has been a tremendous development in the commercial mobile communication sector during the last decade. How can PSS sectors be benefited from this development? Public safety professionals around the world are dependent on various PMR networks, most of which are analogue systems. In many developed countries PMR networks are migrating to narrowband, circuit-switched digital voice technologies with limited support of low-speed data services [10]. On the other hand, commercial wireless networks are already using spectrally efficient, broadband, packet-switched air interfaces supporting a wide variety of real-time, i.e. video conferencing, and non-real-time broadband multimedia applications, i.e. streaming, downloading etc.

Since commercial networks are designed to target a mass market, the use of commercial cellular networks for PSS communication involves some challenges and at the same time existing networks need to be dimensioned properly and modified accordingly.

In this chapter, the feasibility of using PoC over a GPRS network is investigated from different aspects. The chapter also includes a case study considering initial investment for a new digital PMR network, which is a big issue. But there are already countrywide commercial GSM/GPRS networks. Bangladesh is taken as an example for the case study. In Bangladesh different PSS organizations use over-aged analogue PMR networks with limited coverage and capacity for their day-to-day as well as for emergency operations, whereas several commercial cellular operators have countrywide GSM/GPRS network coverage.

The rest of the chapter is organized as follows. Section 5.2 gives an example of modern PSS communication requirements, features and its application using a possible PSS operation scenario, Section 5.3 analyzes the feasibility of PoC over GPRS for public safety and security communication from a technical and shortly economical perspective, Section 5.4 explains a proposal to increase the capacity in a GSM/GPRS cell to handle emergency overload situations, Section 5.5 describes a case study of PoC over GPRS for PSS communication as a substitute of an over-aged low coverage analogue PMR system, and finally the chapter concludes with a summary in Section 5.5.

5.2 Modern PSS operation as an illustrative example: A road accident

PSS usage scenarios as well as the requirements of the PSS professionals have changed a lot over time. In addition to the voice service other types of communication are also required to ease the operation of the PSS professionals in different scenarios. Figure 5.1 illustrates the services required to ease the PSS operation.

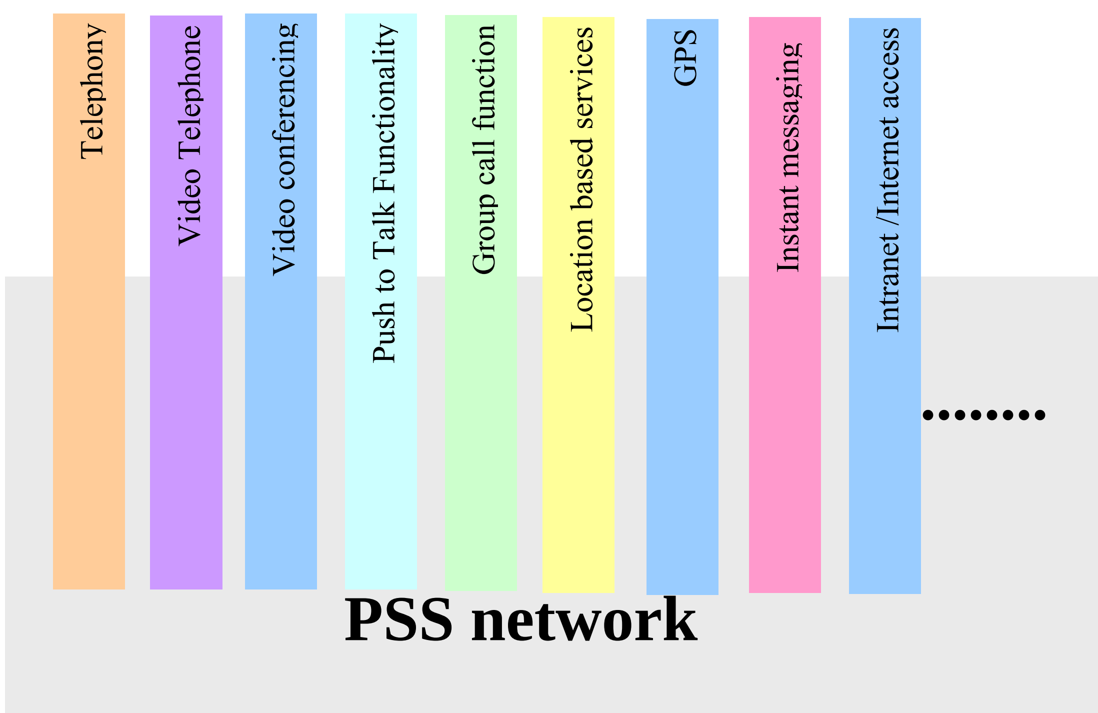


Fig: 5.1 Modern PSS network

A possible PSS operation scenario is described to illustrate how different communication services are used and how these services ease the operation of PSS professionals. It is important to note that all services mentioned in the following example are not available PoC over current GPRS network.

A highway patrol police suddenly notices a severe car accident and the consequent traffic jam on a road. Instantly he informs it to the respective rescue office. The rescue office, without asking any details of the location of the accident, identifies the place using the location service offered by the network. The rescue leader forms an instant group or asks his predefined team member to rush to the accident place by just pressing his PoC push to talk button. Additionally he informs all car drivers moving towards the accident place to avoid that route using the cell broadcast messaging system. All rescue team members, located at different places, start moving towards the accident place and they use a road map guide from the Internet to find the easiest way by accessing the Internet from their GPRS enabled handset. Later, an ambulance team joins the group communication using their PoC terminals. One of the rescue workers enables a videophone and the rescue leader monitors the whole operation through a video-enabled phone set while communicating with all other members.

The medical team rescues the wounded persons and instantly accesses their personal information by accessing a central database through their GPRS enabled PoC terminals and additionally they also ask some medical advice from a superior while heading to the hospital.

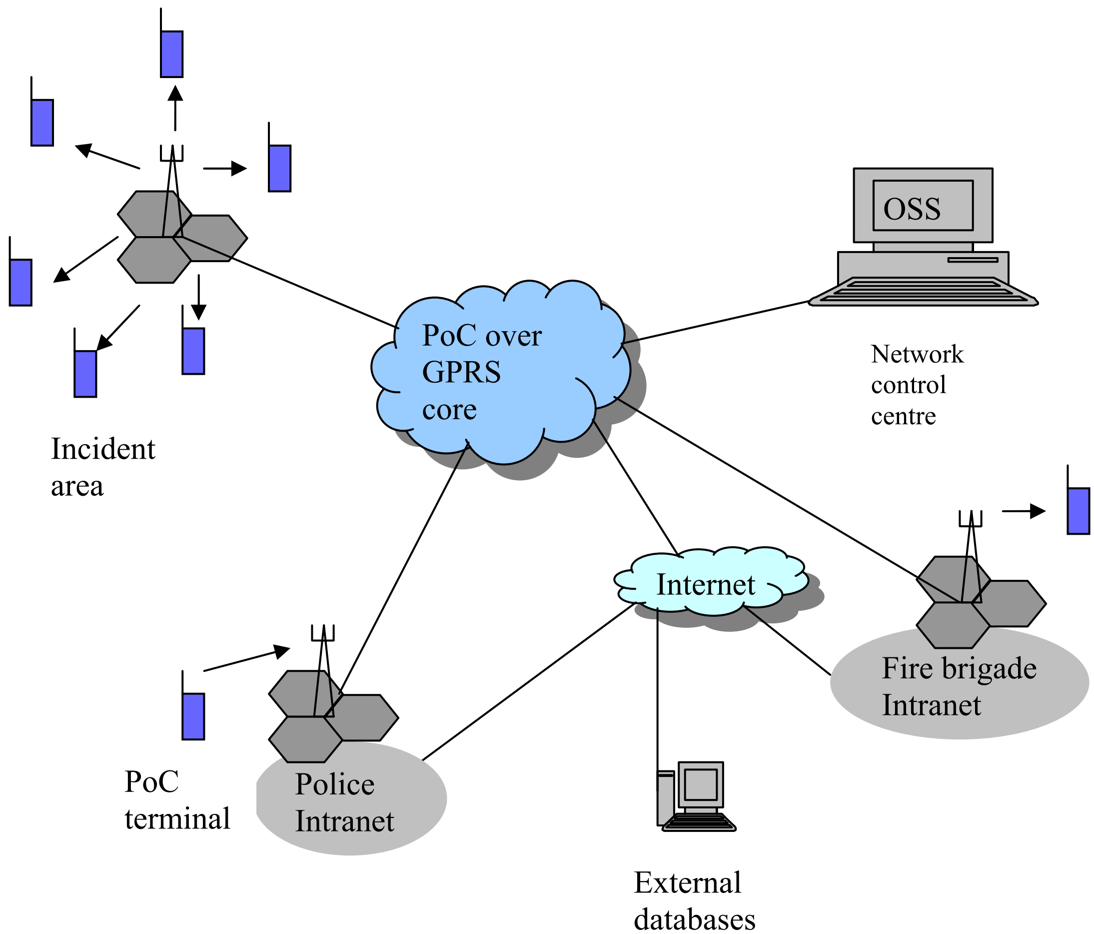


Fig: 5.2 An illustrative example of modern PSS operations.

Everybody in the rescue operation is participating in a PoC group communication session. Sometimes somebody does a database search if needed or makes another call keeping the group communication active, or leaves the group and rejoins the group session later. When the rescue operation is over and the road is cleared, the rescue leader releases the group session and additionally informs all drivers within the area using the cell broadcast message service about the clearing of the traffic jam.

5.3. Feasibility analysis

5.3.1 Approach

Above all, the technical viability of using PoC over a commercial GPRS network for PSS communication, considering different features and network capabilities, is investigated. In addition to day-to-day operation, the emergency situation handling capability of the network is taken into account. The scalability of the solution is also considered in finding the feasibility of the respective service or network so that services and capabilities can be further developed and the range of services and systems can be extended over time in an evolutionary fashion. There are some drawbacks in the PoC service which would be removed automatically in the future as a result of the technology evolution, and more advanced features would be possible to be added in time. These features are also considered. The initial capital investment is a major criterion for many organizations in selecting the appropriate solution for PSS communication.

5.3.2 Technical feasibility analysis

Evaluation parameters

Public safety and security users' requirements significantly differ from those of general users. In evaluating the feasibility of PoC over a commercial cellular network for PSS communication, considerations are given to the following factors:

- Resilience of the network - Maximum resilience with a sufficient level of redundancy such that no single failure will cause a major network outage.
- Radio coverage - Radio coverage irrespective of geographical nature, i.e. mountainous area or sparsely populated area.
- Continuity of operation - Minimum service interruption time due to moving around the service area.
- Security and privacy - Level of inherent security and privacy of the service.
- Group call functionalities - This includes the maximum size of the group, group formation, late entry into an ongoing group session, etc.
- Priority and pre-emption - Service is accessible on demand irrespective of the traffic situation in the network.

- Call setup time - Fast call setup time.
- Voice quality - Good voice quality that is identifiable even in a noisy environment.
- Availability of end user terminals.
- Ease of use - Ease of use including formation of talk groups, addressing and dialling options.
- Integration with control/dispatch room.
- Range of data services supported.
- Interworking with PSTN, ISDN or PLMN.
- Roaming across the nation border.

Technical feasibility analysis of IMS based PoC

PoC is a supplementary service in a GSM/GPRS network. PoC functionality is integrated into GSM/GPRS end user terminals. In the following discussion, the GSM/GPRS network capabilities and features are considered together with the PoC services while investigating the network capabilities and functionality.

Resilience of the network

Resilience is a measure of robustness of the network and how the network behaves in an adverse situation. High resilience with very high availability is a pre-requisite for PSS communication. There are several criteria like decentralized or localized operation, transmission redundancy and power failure backup etc. that can be applied for measuring the resilience of a network.

The commercial GSM/GPRS network architecture is extremely centralized. All calls go via the central exchange or MSC. So a failure in the MSC or a communication failure with the MSC means disruption of all kinds of services. In contrast, a modern digital PMR system like TETRA supports some localized functionalities, for example direct mode operation, base station fall back operation, etc. This kind of localized operation increases the resilience of the network allowing continuity of operation in case of central exchange failure or lack of radio coverage – for example inside a tunnel.

Transmission redundancy does not depend on the specific solutions. An alternate transmission link is essential to ensure the undisrupted service. Power back-up is also not solution specific. The operator can increase the resilience of the network by taking into account the above-mentioned measures. Of course this involves some extra expenditure.

Radio coverage

Commercial GSM networks have very good radio coverage in highly populated areas not only outside but also inside the buildings. But in densely populated areas like coastal, mountainous areas, etc. commercial networks have low coverage for economical reasons. Disaster or any kind of incident scenarios are not location specific. So radio coverage irrespective of the geographical nature of the area is important for smooth operation of the PSS organizations.

In order to meet the PSS organizations requirements, commercial GSM/GPRS networks need to be tuned and optimized to provide seamless nationwide coverage.

Priority and pre-emption

Priority and pre-emption mechanisms allow withdrawing the resources used by low prioritized users and reallocating them to a highly prioritized user in case of a congested situation. Priority without pre-emption means allocating resources based on prioritization.

PoC is a packet switched data service and in a GSM/GPRS network normally priority is given to circuit-switched calls. If fixed time slots are not allocated exclusively for packet switched traffic, PoC calls can be pre-empted by the CS voice calls. Providing priority and pre-emption as required for PSS communication in a PoC over GPRS service means prioritization of packet switched PoC traffic over CS voice traffic, which is a very unusual scenario in commercial GSM/GPRS networks.

PoC supports prioritization of talk burst requests in a group session level. The following priority levels are defined for PoC group calls:

- Pre-emptive priority
- High priority
- Normal priority
- Listen-only

Handover/ cell reselection time

The length of the cell selection/reselection procedure affects the quality and performance of a PoC session. As discussed in Chapter 4 Section 4.4, reference [19] showed that implementation of the NACC feature in a GPRS network significantly reduces the service interruption times due to cell reselection down to a value in the range of a fraction of a second. The NACC feature is included in 3GPP Release 99 and Release 4.

Security and privacy

The PoC client is authenticated prior to accessing the PoC service. The SIP/IP core ensures during registration that the registered PoC address is allocated to the correct user in order to prevent spoofing attacks.

The PoC server relies on the security mechanisms provided by the underlying IMS core for securing the service environment, e.g. by authenticating the users of the service. Mutual authentication is done when the SIP/IP core is 3GPP/3GPP2 IMS compliant and the User Equipment contains a USIM/ISIM.

The PoC user data is protected between the PoC client and PoC server using the existing 3GPP GPRS or 3GPP2 PDN security mechanism.

Call setup time

Fast call setup or response time, irrespective of congestions in the radio network, is very important for the emergency workers because of the nature of the jobs they perform. The recommended call setup time for PSS communication is in the sub-second range, which is not yet possible for PoC due to the inherent latency in the GPRS network.

As discussed in Chapter 4 Section 4.3, the call set up time for push-to-talk over a GPRS network is longer than one second, which does not meet the PSS communication requirements. Reference [34] found that Ericsson's Instant Talk over a 3GPP Release '99 GPRS network for a One-to-One PoC call using the early media set up procedure is in the range of 1-2 seconds. Again, reference [32] showed that the session setup time for Push-to-Talk over Cellular operated over a 3GPP Release '98 GPRS live network in early media settings is around 1.9 seconds.

Voice quality

Under normal operating conditions the voice quality of PoC over a best effort GPRS network is expected to be good, but problems arise in overload or congestion situations. Since the best effort service does not provide any guaranteed bit rate, the voice quality can be deteriorated due to the low bit rate or delay variation (jitter) in delivered data packets in an overloaded or congested cell.

Group call functionality

PoC as specified by OMA supports three kinds of group sessions: Ad-hoc group, pre-arranged group and instant chat group talk. The users can create and manage groups using a terminal or a web page. A PoC Group is identified with a PoC Group Identity and is normally given a name, and can be easily called using this group name.

The subscriber that creates the group member list is the group owner for that group, and other members cannot change this member list, unless modification permissions are given to those members. Changes to group status are propagated to the PoC participants, for example when a new user joins a group or when an existing user leaves a group.

PoC supports the actions Rejoin, Late entry and Addition of a new user into the ongoing group session during a group talk, when performed by an authorized active group member.

Size of group

The maximum number of members in a PoC group and maximum number of PoC groups that can be created and managed by a PoC subscriber is configurable by the PoC service provider.

Availability of end user terminal

Rugged, easy to use handsets with enough functionality are required for PSS professionals. Due to the lack of competition in the PMR sector there are not many options when choosing handsets, and usually these handsets are quite expensive. On the other hand, Because of a tough competition among different manufacturers there are a lot of options to choose from and usually these handsets are much cheaper than PMR handsets.

Commercial PoC enabled handsets are not distinguishable from normal mobile handsets. So for PSS professionals who do not want to disclose their identity to the general populace, a commercial PoC enabled handset is a good option.

Integration with control/dispatch room

Such a kind of application is not available in the PoC over GPRS service.

Ease of use

Setting up a call is easy, with the press of a button a connection is made, and most importantly there is no need to keep track of frequency assignments, channels and so forth while roaming, as is required in PMR systems.

Users can also set their preferences for receiving an incoming call either in auto answer mode or manual answer mode. This eases the emergency operation while the emergency personnel are busy with other jobs.

Interworking with PSTN, ISDN or PLMN

A GSM/GPRS network interworks with other types of PSTN, ISDN or other PLMN networks. So calling from one network to another is possible.

Roaming

A PoC user can roam in a visited network if a GPRS roaming agreement between the visited and home network exists. This adds an extra benefit for PSS professionals in case of cross-border PSS operations.

Advanced features in an IMS based network

PoC as specified by OMA is based on the 3GPP specified IMS. IMS is designed to provide a number of key functions required for enabling new IP based services through mobile networks. IMS adds an extra benefit to the PSS operation in some respects.

IMS uses the SIP for session negotiation as well as session management. IMS enables any type of media session i.e. voice, video, text etc. to be established. It also allows combining circuit-switched and packet-switched services in the same session, i.e. adding a video component to an existing voice conversation. This capability opens up a number of new and innovative user-to-user and multi-user services such as enhanced voice services, video telephony, chat, PoC and multimedia conferencing, all of which are based on the concept of a multimedia session.

So implementing IMS based PoC means that operators are getting the opportunity to offer a number of multimedia services to the subscriber. Therefore, from the operator's point of view, it is a step forward to provide the subscriber with multimedia services in addition to the PoC service offerings. Two examples of IMS based services which enhance the PoC service a step up are briefly described below.

Multisession

IMS based PoC supports several simultaneous sessions if the radio resources requirements are fulfilled [6]. It allows participating in multiple groups at the same time and making / receiving 1-to-1 calls while in a group session.

Presence Service

IMS based PoC offers the presence service through a presence server over the Is and Ips interfaces [1]. The basic idea is that a PoC user publishes the presence information to the presence server and the presence server forwards the information to all authorized and subscribed users. The service eases the users' operation, and if used in PSS communication, the caller may decide whom to call knowing the availability of the called person.

Summary of Technical feasibility analysis

It has been observed from the above analysis that some of the critical requirements like short call setup time and priority and pre-emption options etc. are not at an acceptable level. On the other hand PoC over GPRS offers some advanced features like presence information, roaming and advanced data services that are very attractive for the PSS operation. The features and functions investigated above are summarized in Table 5.1.

In Table 5.1 the terms ok, acceptable and not ok are used with the following meaning

OK - The feature/function meets the respective organization's requirements.

Acceptable - The feature/function partially meets the respective organization's requirements or with minor modification the requirements are fulfilled.

Not OK - The feature/function does not meet the respective organization's requirements or the network does not support that feature/function.

Table 5.1 Summary of technical analysis

Features		**PoC over GSM/GPRS network**
Resilience of the network	Localized operation	Not ok
	Set-to-Set operation	Not ok
	Transmission redundancy	Acceptable
	Battery backup	Acceptable
Radio coverage		Acceptable
Continuity of operation		Acceptable
Security and privacy		Acceptable
Priority and pre-emption		Not ok
Call setup time		Not ok
Voice quality		Acceptable
Group call functionality	Ease of group formation	Ok
	Late entry	Ok
	Rejoin	Ok
	Maximum group size	Service provider configurable
	Presence information	Ok
Integration with control/dispatch room		Not ok
Ease of use		Ok
Availability of end user terminals		Acceptable
Data services		Ok
Interworking with PSTN, ISDN or PLMN		Ok
Roaming		Ok. Subject to inter-operator roaming agreements

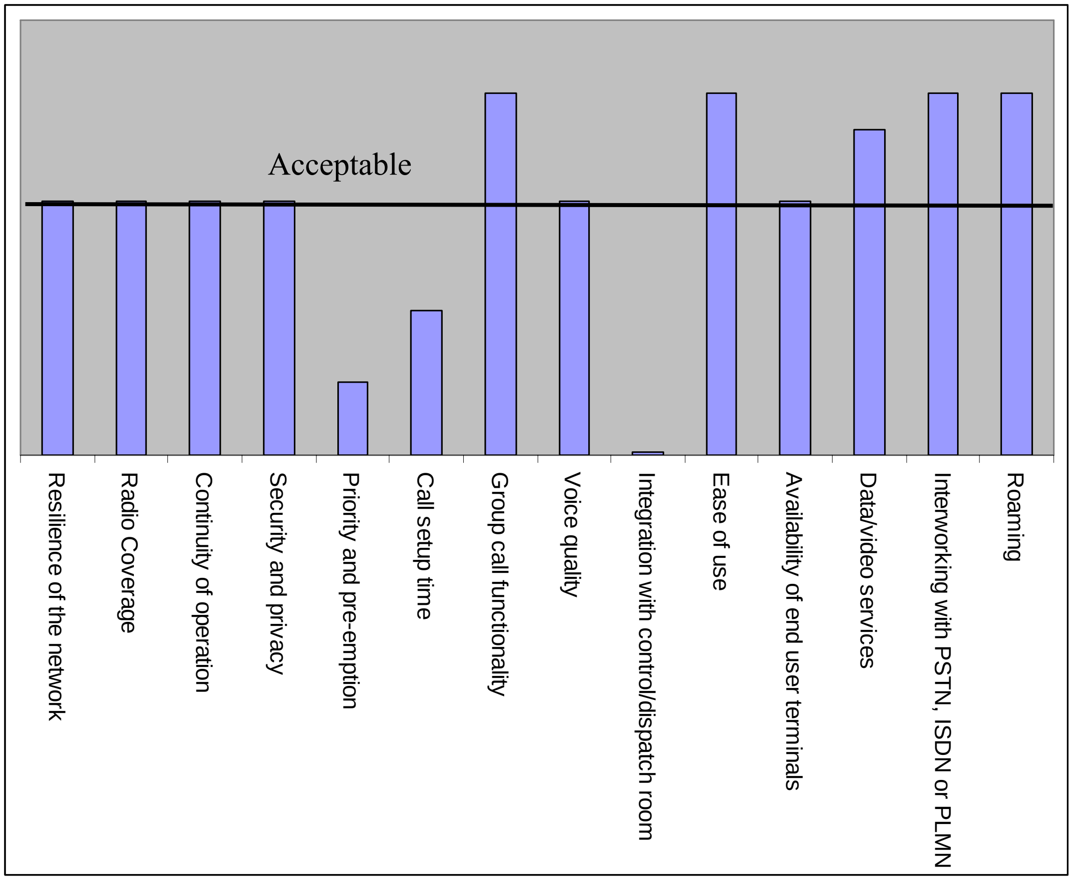


Fig. 5.3 Summary of technical analysis

To optimize the commercial network for public safety and security purposes the following measures should be taken into account:

- Tune the network in order to ensure seamless coverage and extend the network coverage into low populated mountainous and coastal areas.
- Ensure an alternate link to increase the resilience of the network.
- Radio resource allocation exclusively to GPRS PS data traffic to avoid pre-emption by GSM CS data flows at the same time, to reduce delay due to contention for resources.
- Emergency capacity increase agreement with the network operator as described in Section 5.4.
- Ensure the end-to-end QoS in the GPRS network by decreasing the end-to-end transfer delay and by guaranteeing a constant bit rate.

- Upgrade the GPRS network in order to get the benefit of NACC features for reducing cell reselection time.

5.3.3 Economical feasibility

Economical feasibility is an important factor when selecting a PMR solution. But when comparing the financing sources for a PSS network and a commercial public cellular network, it is very difficult to make a comparison of expenditures for both cases. PSS networks are generally financed by the state, on the other hand commercial networks are owned by private or public companies. There are a number of factors like capacity, coverage, resilience of the network and even specific vendor solutions which should be considered when calculating the cost. In the case when existing commercial networks are used for PSS communication, this involves zero initial investment for the PSS organizations. So an exact comparison of investment for both cases is not possible. In the following, cost issues for PMR and commercial cellular networks related to the PSS service are discussed briefly.

Network infrastructure cost:

CAPEX for building a new PSS network infrastructure starting from scratch involves the costs of the following network nodes and functions:

- Base stations
- Radio links
- Exchanges
- Dispatch stations
- Sites

OPEX includes costs related to

- Operation and maintenance
- Upgrade of the network
- Monthly or yearly service charges for the organizations

On the other hand, providing PoC service over the existing 2.5G cellular networks involves costs for the following core network equipment and functionality

- IP Multimedia Subsystem (IMS)
- PoC server
- Group and List Management Server (GLMS)
- Presence server

IMS is designed to provide a number of key functions required to enable new IP based services through mobile networks. So the introduction of IMS into a GSM/GPRS network means the network is able to provide various multimedia services to the end users. The public safety and security sector is not the only target group for PoC service. So the cost and risks involved when implementing PoC is distributed to all other market segments as well.

When the network is to be tuned and optimized for public safety and security purposes, special considerations should be taken into account that incur an extra cost for the operator. For example

- Increase the resilience of the network

  Provide power failure backup through batteries or generators.

  Add alternative radio links so that failure of one link does not hamper the operation.
- Coverage

  Extend the coverage to low populated areas like hilly/mountainous regions and fill up the black holes.
- Extra capacity in some important sites

  Increase the number of Transmitter Receiver Units (TRUs) in some important sites and keep some channels (timeslots) reserved at each site only for packet data traffic.

End user equipment cost

Handsets or radio terminals comprise a significant part of the initial investment for a PSS organization. This expenditure depends on the size of the organization and availability of the required handsets. Traditional PMR handsets are expensive compared to commercial standard handsets. Reference [11] identifies that PMR handsets are 10-50 times more expensive then commercial PoC enabled handsets. The costs of Motorola's ASTRO® and Spectra® radios vary from US$ 4000–5000 each whereas the price of commercial PTT handsets currently ranges from below US$ 100 to as high as US$ 350 [11]. This is due to the lack of competition in the private sector. For example, considering an organization size of 300 professionals, the handsets cost in the case of commercial and PMR networks can be predicted from Table 5.2.

Table 5.2 An example of handsets cost of an organization.

Network used	Size of the organization	Cost per handset	Total handsets cost
PMR	300	US $ 4000–5000	US $ 1200,000-1500,000
Commercial PoC	300	US $ 100-350	US $ 30,000-105,000

So it is seen that there is a big difference between the cost of PMR and commercial PoC enabled handsets, which could be a deciding factor when selecting the appropriate solutions.

A significant amount of expenditures when using a commercial network is incurred from the monthly charges. Since PoC is based on IP, this service is not expensive. Commercial operators normally charge subscribers a fixed amount for fixed minutes of CS calls plus unlimited PoC calls. In some cases a special billing package is also possible. So monthly charges mostly depend on the operators' policy how they offer the service. On the other hand, if an organization uses a private PMR network, there is some O&M cost.

5.4 Emergency capacity increase in GSM/GPRS cell: a case study

In case of an incident, the traffic increases drastically in a particular area. Commercial networks are designed with limited capacity and it is very uncommon to keep extra radio resources reserved beforehand, which is very uneconomical for the operators, in every site for special congestion handling.

The solution of this kind of overload handling in a commercial network could be to increase the system capacity within a short time with minimum interruption of the PSS operation.

How is this possible?

Configuration of cells is normally done from the Operation Support Sub-system (OSS).

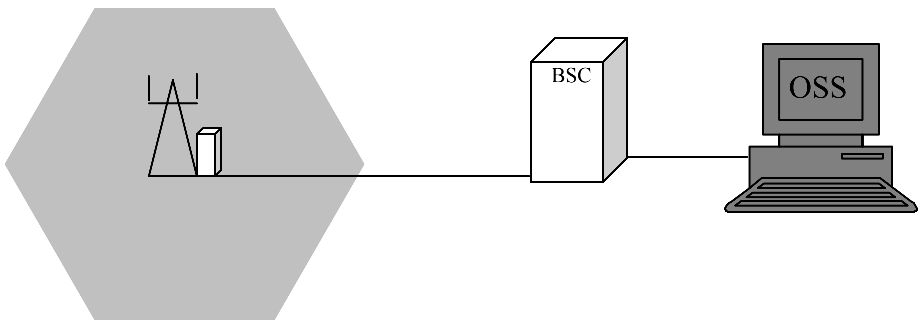


Fig 5.4: Emergency capacity increase

What is the impact of this to the network?

The possible impact of changing the configuration means allocating more channels or time slots to the packet switched domain during congestion in respect to circuit-switched voice calls.

How much time is required for the changing?

Changing the configuration of time slots or channels (from CSD to PSD or vice versa) in a GSM/GPRS cell is usually done from the OSS or a BSC Alphanumeric Terminal (AT) terminal with a command. So the time taken to change the configuration is the execution time of the command plus the time it takes for the information to reach the right person.

What is needed for this operation?

Agreement between the respective organization and the PoC service provider/network operator can be signed beforehand to handle emergency situations.

5.5 PoC over GPRS vs. analogue PMR: a case study

Until today, most PSS users around the world use over-aged analogue PMR systems. A study in June '01 by one market research company, IMS Research, estimated the total number of PMR users around the world to be 33.1 million and a breakdown region-wise is shown in Table 5.3 [24].

Table 5.3 PMR users around the world [24]

Region	Total no of users (million)
Americas	18.9
Asia	7.3
Europe	6.2
Middle East and Africa	0.8

In terms of technology, approximately 77% of current users rely on analogue systems and the remaining 23% on digital technologies. Figure 5.4 shows the detailed breakdown. [24]

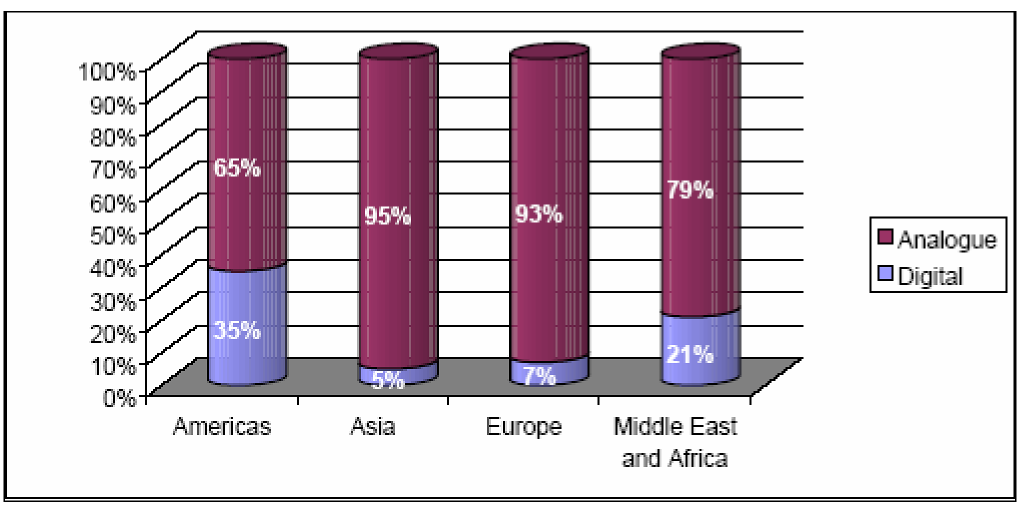


Fig: 5.5 Breakdown of PMR users by technology. Source: IMS, 2001. [24]

Typically, these systems have local coverage and communication among different organizations is very difficult, sometimes even not possible. These systems do not work with other systems like PSTN, PLMN or ISDN. One major bottleneck of these systems is the very low data rate supported.

As mentioned earlier in the introduction, Bangladesh is taken as a type example, and the present situation of PMR networks and commercial mobile networks is discussed briefly in the following.

In Bangladesh different PSS organizations like police, fire brigade, etc. use over-aged analogue radio communication systems for their day-to-day usage as well as handling emergency situations. Coverage of these systems is limited to small areas around different police stations and wide area coverage is available only in district cities. This means that radio coverage as well as seamless roaming around the whole country is not available.

On the other hand, there are 6 (six) mobile phone operators named GrameenPhone, Telekom Malaysia International Bangladesh (TMIB), Banglalink, WaridTelecom, Pacific Telecom (City cell) and a government owned operator Bangladesh Telephone and Telegraph Board (BTTB) in Bangladesh. Out of these six, the first five operators have countrywide networks that cover even remote places. Four operators offer GPRS services and the biggest operator GrameenPhone offers GPRS plus EDGE service.

To get an idea of coverage, the areas that are covered by one of the operators, GrameenPhone, is taken as an example. GrameenPhone is the largest mobile phone operator in Bangladesh and has more then seven million subscribers as of April 2006 [43]. The total coverage area covered more than 88% of the country’s area.

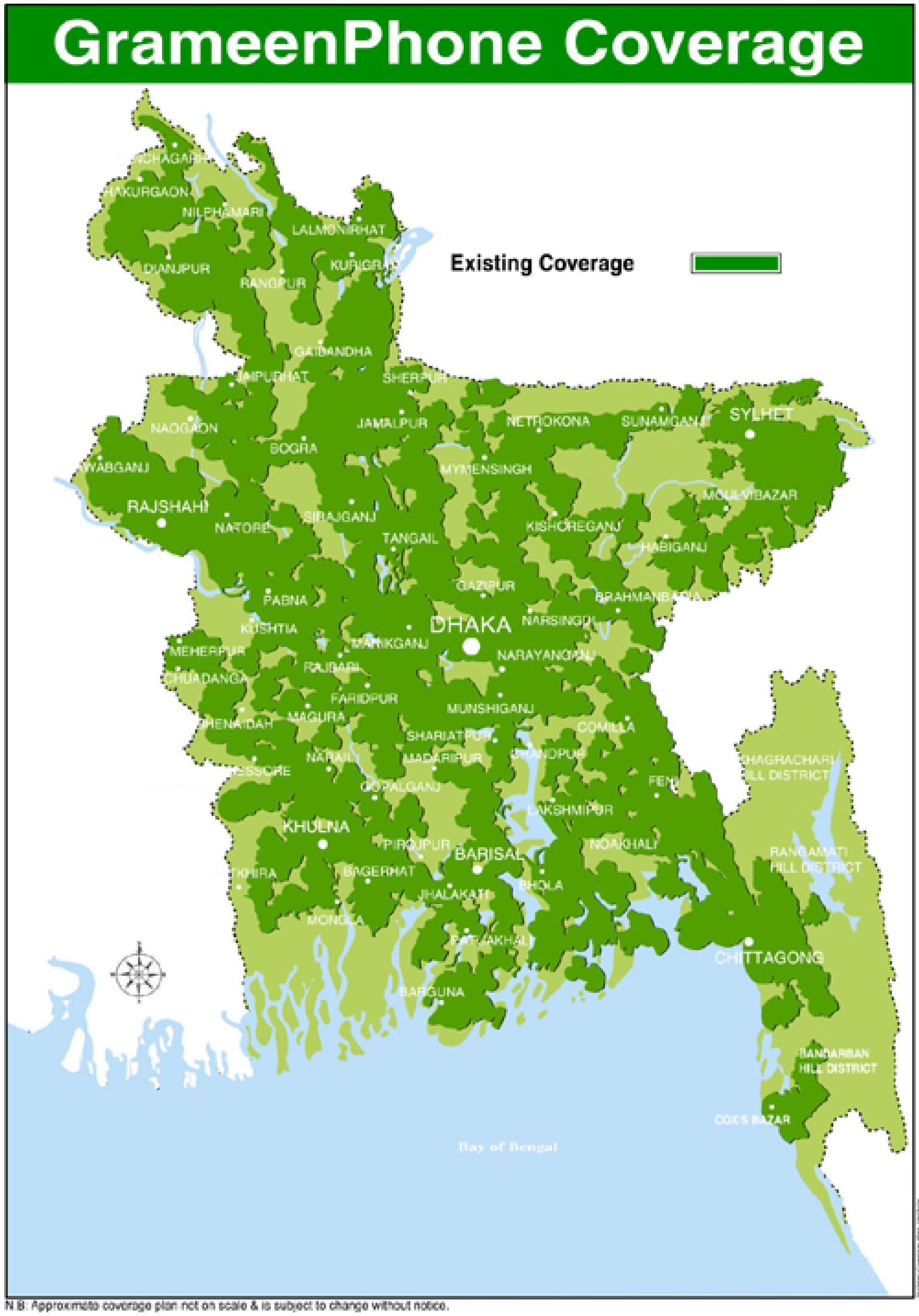


Fig: 5.6 GrameePhone coverage [42]

Benefit to the operators

Introduction of data services alongside traditional voice services has been an excellent addition for those wireless network operators searching for new revenue generating service offerings. The rate of subscriber growth has slowed down and Average Revenue Per User (ARPU) continues to drop. With the advent of the high speed packet data service, operators are trying to recapture the subscriber attention again and it has been projected that data services will offset the annual drop in voice service ARPU within the next few years. Operators and analysts around the world are seeing PoC as a potential revenue generating packet switched service. A market investigation by IMS Research [39] reveals that worldwide revenues generated by PTT services offered to business users and consumers are shown to demonstrate sustained high rates of growth, exceeding $ 50 billion in 2008 [40].

In Bangladesh, voice calls and limited data services (SMS, wireless Internet access) are still the market driving force for the operators. But it seems that the market for voice services is going to be saturated in the near future. The trends towards which the operators are moving show that they are also going to place emphasis on various data based services. For example, four operators have implemented the GPRS service over their 2G GSM networks. Most of the operators have started searching for new data service offerings (news update, sports news etc.) and in some cases these offerings got a very good response from the operators.

For the operators in Bangladesh, PoC over GPRS can be a new revenue generating service offering as it has already showed its popularity in some markets around the world, especially in USA. The possible target group for operators in Bangladesh could be different public safety and security organizations (Police, Fire brigade etc.), transport companies, different tourism companies, private organizations and teens, young adults and families.

PoC is not a substitute for the existing voice service, rather a differentiated voice service which gives the operator an opportunity to develop a new service without any changes in the conventional services. Moreover, PoC offers features and functions comparable to existing push-to-talk services offered by many PMR networks, which means PoC offers an opportunity to expand services to different PMR user groups in addition to existing subscribers as well as increase in revenue.

5.6 Chapter Summary

PoC over a GPRS as well as GSM/GPRS network is not a proven technology for public safety and security communication. There is no practical experience in how a network will react if normal and high priority traffic will reach their peak simultaneously, as this may be the case in major accidents and catastrophes. So there is a hidden fear/risk of implementing PoC over GPRS for public safety and security communication applications.

In this chapter, the feasibility of PoC over a GPRS network is analyzed from different aspects. The technical feasibility is analyzed keeping in mind the requirements of PSS operation. In order to use this solution for PSS communication, the network needs some changes which are suggested in the summary of technical analysis, explaining one possible emergency capacity increase procedure for data traffic at the GSM/GPRS cell level. The chapter ended with a case study comparing over-aged low-coverage and capacity analogue PMR systems and commercial GSM/GPRS networks.

Taking into account the measures suggested in the summary of the technical section of this chapter and in Section 4.6 in Chapter 4, PoC over a GPRS as well as GSM/GPRS network could be a good alternative over a low-coverage and capacity analogue PMR system.

Chapter 6

Summary and Conclusions

6.1 Summary

The feasibility of PoC service over commercial GSM/GPRS networks for PSS communication has been studied in this thesis. The feasibility was analyzed both from technical and economical point of view. From the initial investment and operating cost point of view, PoC over commercial network is found to be more economical than using a separate PMR network. The technical viability was investigated considering different features and network capabilities. Use of PoC service for PSS communication involves proper dimensioning of the network as well as, in some cases, upgrading of the GPRS network to ensure end to end quality and performance of the service.

6.2 Conclusions

The challenges of PoC over a GPRS network, identified in this study include a long call setup time, service interruption due to cell change, delay in speech in congested cells, absence of measures i.e. priority / pre-emption to handle overload cell situations, etc. It has been seen that most of the challenges are caused by the GPRS access network. Some improvements that are available through proper radio network dimensioning or through network upgrades are also suggested such as reservation of radio resources exclusively for packet data traffic and limiting the number of PoC or packet switched users per PDCH, the emergency capacity increase procedure discussed in Chapter 5 to handle extra PoC traffic load in a cell and GPRS network upgrade to get the advantages of NACC and Extended TBF features to reduce the time for cell change and time for session setup respectively, etc. Key findings in favour of PoC over GPRS include spectral efficiency, existing nation-wide radio coverage of commercial GSM/GPRS networks, a range of data services, a number of group call functions, interworking with other PLMN, PSTN or ISDN networks and above all ease of use. The thesis includes a case study comparing over-aged low-coverage and capacity analogue PMR systems and possible PoC service over nation-wide commercial GSM/GPRS networks for PSS communication.

Finally, it is concluded that, given the demanding requirements for public safety and security users, PoC over commercial GSM/GPRS networks needs proper dimensioning and tuning of access network and some modification in the core network part. It does not fulfil strictly all the requirements of PSS communication. However, taking into account the suggested measures, PoC over a public network is a good alternative to a legacy analogue PMR network.

The source of investment of commercial and PMR networks made it difficult to compare these networks with each other. Moreover, the PoC over commercial GSM/GPRS network is not a proven technology for PSS communication. Therefore, no practical information is available regarding handling of emergency PSS operations.

6.3 Further work

Most of the challenges/limitations identified in this study are caused by the GPRS radio access network. Reserving radio resources specifically, timeslots per cell for packet data traffic separates packet switched traffic from circuit switched traffic and avoids pre-emption by GSM CS data flows and at the same time reduces the delay due to contention for resources. Again prioritization of PoC traffic over other packet switched traffic could enable network operators to optimize the service, which would consequently improve the quality of user experiences.

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