Modules for Machine-to-Machine Communication in GPRS

- Case Study, Medical Surveillance -

Master Thesis in
Information and Communication Technology

Submitted to
Agder University College
Faculty of Engineering and Science

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by

Atle Monrad

Grimstad

May 2001

PREFACE

> *"The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn."*
> – Alvin Toffler

I have now, after working more than 13 years with systems for cellular telecommunication, finished a two-year full time graduate study at Agder University College in the field of telecommunications and computing. The ability to seek new knowledge is important, and I would like to thank for this opportunity given to me by Ericsson.

I would also like to bring thanks to Dagfinn Sevik, technical manager at Ericsson, and Arild Haglund, supervisor at Agder University College. Numerous people have also given me additional ideas, comments and motivation. I am grateful for all help and support, but do not find the space to thank everybody by name.

My knowledge about medicine and my ability to express myself in medical terms is limited. For help with medical topics and terminology, I have got much help from MD Lena Bredde, Consultant anaesthesiologist at Aust-Agder Central Hospital and medical supervisor at Norwegian Air Ambulance, Arendal.

In my master thesis, I have tried to use knowledge from both the technical topics and administration and organisation related subjects covered by the curriculum of this graduate study. It has been a goal to be able to combine this without writing a master thesis that does not have the required depth in a key subject area. This is an aspiring goal; the topics are many and changing at an increasing pace. Whether I reached the goal or not, I leave for the readers decision.

Grimstad, 25th of May 2001

Atle Monrad

ABSTRACT

Machine-to-machine communication is estimated to get an exponential growth in the coming years. This will open for new ways to utilise the networks, and is foreseen to be a means to increase business. Increased efficiency and service level can be assumed, and new business opportunities are predicted, in a scenario made possible as creative people notice a technology constantly providing cheaper and smaller devices, the bandwidth increases and the charging fee per bit decreases.

GSM offers ubiquitous coverage and a wide selection of bearer services, and several methods for positioning can be used. The alternative bearers are discussed and evaluated.

The different types of machine-to-machine applications have a vast difference in requirements, and cannot be foreseen solved by one type of module within a short time frame. To realise this diversity, proper classification is proposed.

The continuous technology development improves vital factors like size power demand and cost. This will open for new applications. It is expected that it will be soon be possible to have a complete module on a single chip. This is a strong argument for not suggesting any major change to GSM module architecture.

To illustrate the possibilities in the machine-to-machine scenario, a concept is outlined and discussed. The chosen concept is within medical surveillance. This application is considered to have a large potential, and significant costs in terms of both hospital beds and medical personnel can be saved. The application contains most module aspects. Opportunities are foreseen by the proposed concept.

As the M2M market gets more mature, the current players realise that the margins get smaller. A value chain can be identified, and the different roles in the value chain must be admitted and accepted in order to succeed in the development of M2M applications. In a mature market, each party must focus on dedicated roles in order to get or maintain a leading role. Alliances are considered to be a good solution to offer competitive solutions, and additional value added services may further increase revenues.

TABLE OF CONTENTS

TABLE OF FIGURES

1 INTRODUCTION

1.1 Background

With the current increase in coverage of wireless communication, mobile operators may see an end to increased revenues without looking beyond person-to-person communication. Machine-to-machine (M2M) communication is foreseen to be a means to increase business, both for the current participants and for new players. Creative people are foreseen to increase their efficiency and service level, and even find new business by utilising the opportunities in a scenario made possible as the technology constantly provides cheaper and smaller devices, the bandwidth increases and the charging fee per bit decreases.

Machine-to-machine communication between mobile, portable or stationary devices (clients) and centralised servers is estimated to get an exponential growth in the coming years. This will open for new ways to utilise the networks. To illustrate the possibilities for M2M communication, e.g. devices can be used for remote control, surveillance, tracking, localisation and telemetry. This type of communication device is today often made up of a wireless module, containing the mobile station (e.g. an ordinary mobile station without display and buttons), and additional application specific SW added by a system integrator. The device can then be connected to the equipment that shall be controlled, for example a surveillance camera, the computer within a car or a soft drink machine.

Given a low cost of the communication device, a simple connection to the equipment that should be controlled and the right network technology, M2M has the potential to become an important factor for the wireless communication in the coming years. Modules can be used in all kind of wireless networks, from private networks using Bluetooth, via wireless local area networks to the cellular networks of today and tomorrow.

1.2 Thesis Main Topic

Until now, bearer services for M2M applications in GSM have been short message service and circuit switched connections. The nature of these bearers has not been optimal for the bursty traffic pattern of many M2M applications, due to long set-up times (CS) and slow response (SMS). GPRS now adds packet-based infrastructure to GSM. With this network technology it is possible to stay connected all the time, as charging is based on volume of transferred data. This online availability and the increasing use of Internet, are by many seen as important for further deployment of existing applications as well as creation of new. The ubiquitous coverage that GSM offers today gives M2M communication a huge potential when GPRS is introduced.

The following items will be described, evaluated and concluded in the master thesis:

- Identification and description of application types relevant for M2M communication.
- Identification of generic features of GSM / GPRS modules, to identify a possible module classification in a scenario of increased M2M communication.
- Identification of enablers and obstacles for M2M applications.
- A target M2M application and its technical implementation will be sketched. This concept will be within the area of medical surveillance.
- Evaluation of this application's ability to handle the necessary:
  - technical aspects
  - human factors
  - organising factors
  - introductory aspects
  - strategic value

1.3 Target Application

Medical surveillance can save society a considerable amount of money, if technical remedy can move persons out of e.g. hospital beds and back into their own homes. Persons that manage quite well on their own, but need some assistance, can use advanced communication devices to get in contact with medical personnel under certain situations. Such devices can then be used to collect relevant data, make preliminary diagnosis and track the patient's location.

1.4 Limitations

When data communication is discussed within the cellular market, applications are often classified in horizontal and vertical market segments. This master thesis focuses on a part of the vertical applications, machine-to-machine. M2M applications can also be an acronym for Man-to-machine applications. Such applications, where the human takes a more active part in an interactive application (e.g. mobile office) are not considered.

GSM is the selected technology throughout the document. Alternative technologies as two-way pagers, TETRA, Bluetooth or HiperLAN/2 are not considered. GSM and GPRS in general are not described, as those are assumed known to the reader. However, some key characteristics of most radio bearers available from the very start of GSM and until UMTS are mentioned. This is done to illustrate to what extent GPRS is suitable as a bearer service for the M2M applications. For bit-rates and response times, general considerations are given when relevant or applicable.

Security issues and commercial and legal aspects are not studied in depth. These issues will be a major concern for the proposed application, but were never intended to be included in this study.

1.5 Report Outline and Work

The master thesis seeks to answer each item listed in the thesis main topic. Starting with the next chapter, the report is organised in the following way:

The chapters 2, 3 and 4 describe GPRS in general, relevant bearer services and positioning methods. This is done in order to bring key issues to the reader's attention.

M2M applications are then classified and described in chapter 5. In the following chapter 6, GSM modules are described in brief, aiming to point out possible improvements in order to make such modules more generic. This may improve the production costs, as unnecessary functionality can be removed. Selection of bearer service, the foreseen M2M application segmentation, the need for accurate positioning and the need for application specific SW are key issues in this chapter.

As the wireless business gets more mature, the need for a formal value chain becomes more evident. In chapter 7, the value chain of M2M applications is described, in order to get an understanding of how the different participants perform their role.

In chapter 8, pros and cons of M2M applications in general are discussed.

An M2M application for medical surveillance is outlined in chapter 9. This concept is described as a case study focusing on the application as such. The concept for medical surveillance is discussed in chapter 10.

Conclusions in chapter 11 bring the master thesis to a close.

1.6 Literature Review

The World Wide Web is a fascinating tool with many possibilities. It brings a large amount of information to the computer, and care must be taken in order to sort out both the relevance and the correctness of each piece of information. Nevertheless, WWW is a tool where the majority of the background information is obtained.

When it comes to information about GSM and GPRS, the source of information seems inexhaustible. I have used [9] as a source in this field. Relevant information and a complete set of the specifications can be found on the home page of 3GPP [28]. The scope of 3GPP is referred below, and shows the evaluation path from plain GSM to UMTS.

> *"The Partners have agreed to co-operate in the production of globally applicable Technical Specifications and Technical Reports for a 3rd Generation Mobile System based on evolved GSM core networks and the radio access* technologies that they support ... ...
>
> *The Partners have further agreed to co-operate in the maintenance and development of the Global System for Mobile communication (GSM) Technical Specifications and Technical Reports including evolved radio access technologies (e.g. General Packet Radio Service (GPRS) and ... ...*
>
> *The Project is called the "Third Generation Partnership Project" and may be known by the acronym "3GPP".*"

For general issues about telecommunication, I have used the book [7]. Aspects about radio-related problems, I have found answers to in [8]. For information about EDGE, [13] have been used. The UMTS forum [29] has reports that give valuable information about this 3rd generation system. Issues about positioning in general are found in [1], [31]and [32].

Information about GPRS applications has been found in internal reports [3], [4], [5] and [6], M2M conferences and white papers [21] and [22]. Different classifications of such applications are not precise, to some extent due to that M2M in some reports classify man-to-machine and machine-to-machine together. Within this documentation, some information and considerations of pros and cons for modules are also found.

The architecture modelling of GSM modules is based on knowledge of available chip-sets. Modules from Ericsson [24] and from Xircom [23] are considered in particular.

General methods for application development have been studied in [25], [35] and [40].

The target application is discussed with medical personnel from [41]. Medical information has been found in, [43] and [44].

Note also that some references have been used without being explicitly noted in the text. Such sources are background material only.

For readers that would like to study further, references to internal information, external books and papers as well as companies and organisations I have found interesting are listed in chapter 12.

As a guest to readers not familiar with numerous acronyms, a list covering all acronyms used in the master thesis can be found as the very last chapter

2 GPRS OVERVIEW

2.1 Main Requirements

The need for a packet switched bearer service in GSM was identified. This bearer service could then address packet-based applications where a circuit switched bearer service was not found feasible to use. IP end to end, volume based charging, availability as in a local area network and GSM coverage were wanted. These requirements were met by GPRS, a packet switched bearer service developed as a part of GSM phase 2+ [12]. As GPRS is an add-on to GSM, certain foundational requirements were initially declared.

- GPRS should rapidly get the ubiquitous GSM coverage.
- GPRS should be integrated with GSM; i.e. the TDMA principles and the basic frame structure of GSM should be kept.
- The system should not be too expensive; i.e. BTS upgrades should be possible by SW only[1].
- The system should scale well; i.e. the network subsystem should be cost efficient to expand and not necessarily have a one-to-one physical mapping with the existing network architecture of circuit switched GSM.

2.2 Network Architecture

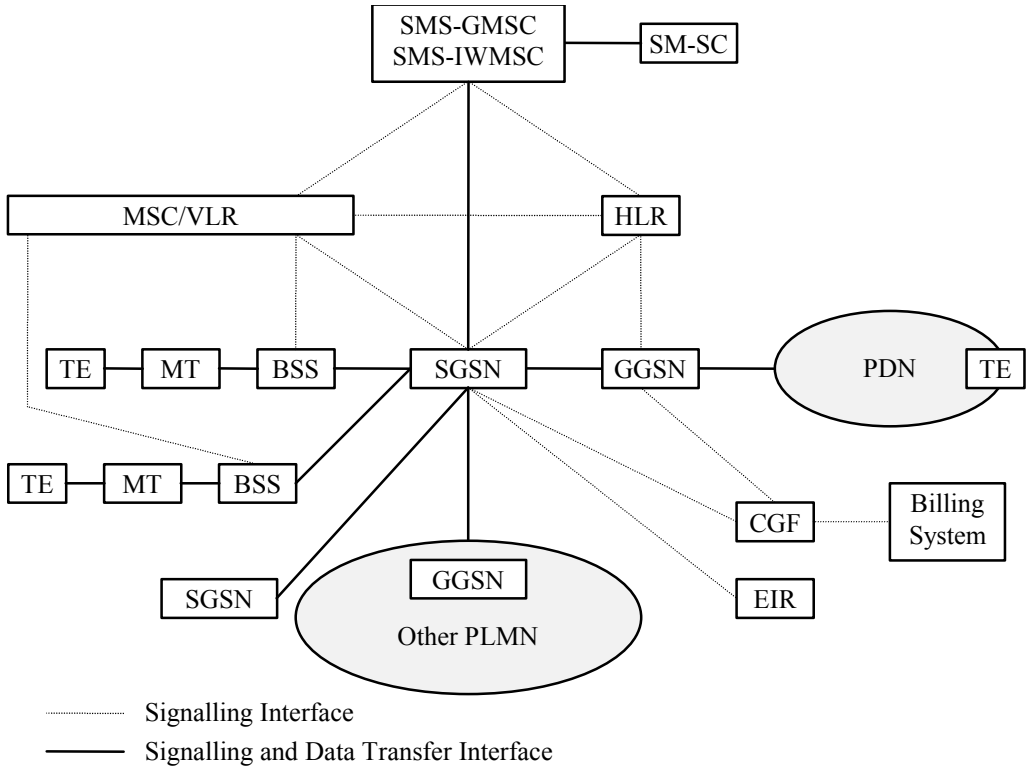


Figure 1 – Overview of the GPRS packet domain logical architecture

[1] A general rule, old equipment may need upgrade.

GPRS introduces new packet data nodes (SGSN and GGSN) in the network. In addition, an upgrade of existing nodes (mainly by SW) is needed to provide a routing path for packet data between the mobile terminal and a gateway node. The gateway node will provide interwork with external packet data networks for access to the Internet and intranets.

This packet switched access technology can provide end to end IP communication, and is foreseen to attract both new applications as well as complete market segments where a wireless connection until now not has been considered as cost-effective. This can be illustrated by e.g. corporate and public Internet access, machine-to-machine and person-to-machine communication.

A major part of the GSM operators are now in the process of updating their networks in order to support GPRS. Commercial service is starting up in the middle of 2001. GPRS is a significant step on the evolution from the second to the third generation of cellular networks. The circuit switched GSM services are often denoted classic GSM.

2.3 GPRS Mobile Station Modes of Operation

The purpose of the GPRS MS Modes of operation[2] is to meet the different needs of the various market segments by MS types with distinct capabilities. A mobile station can be reconfigured, as a result of changes in the user needs.

Three GPRS MS modes of operation are identified:

Class A: The MS is attached to both GPRS and classic GSM. The mobile user can make and/or receive calls on the two services simultaneously.

Class B: The MS is attached to both GPRS and classic GSM, but the MS can only operate one set of services at a time.

Class C: The MS is attached to either GPRS or classic GSM. The MS can only have alternate use of GPRS and classic GSM. If both services (GPRS and classic GSM) are supported then a Class C MS can make and/or receive calls only from the manually or default selected service, i.e., either packet switched (GPRS) or circuit switched (CS) service. The status of the service, which has not been selected, is detached.

For a large number of M2M applications, the class C MS is considered to be sufficient.

A number of applications traditionally considered as M2M can be foreseen to have voice as an integrated feature to be able to communicate with operators. In such cases, at least a class B MS is needed.

Advanced applications will also need simultaneous use of the circuit switched and the packet switched bearer service, thus the applications will need a class A MS.

[2] The GPRS modes of operation were former denoted GPRS MS classes. Both concepts are now used.

3 BEARER SERVICES

3.1 Introduction

Different bearer services available in GSM are discussed in the following subsections. Key capabilities (call set-up times, real-time aspects, capacity and pricing) for each bearer are indicated and evaluated.

Unstructured Supplementary Services Data (USSD) has similarities with SMS since both use the GSM network's signalling path. USSD is session-oriented such that when a user accesses a USSD service, a session is established and the radio connection stays open until released. The text messages used in USSD can be up to 182 characters long. The bearer is not much used[3], and is not discussed further in the thesis.

3.2 Short Message Service (SMS)

The short message service is a store and forward service and provides a "packet like" communication channel from the MS to the remote party. Each message, or packet, consists of maximum 160 characters, and each originating and terminating SMS message is independent[4]. This simple nature of the service makes it not suitable for structured dialogues. The communication is performed on the signalling channel. In the current circuit switched networks, SMS communication have used available excess signalling channel capacity.

Originating and terminating SMS messages are sent via the Short Message Service Centre. The detailed functions of the SC are out of the scope of the GSM specification. It does not exist any quality of service requirements for communication by SMS messages.

Table 1 – Key factors for SMS

Call set-up times	Each SMS message sent on the signalling channel
Real-time aspects	Poor real time capability
Capacity	160 characters (140 octets) maximum per message
Pricing	Price per message

3.3 Circuit Switched Data

Single-slot circuit switched data (CSD) provides a set of services for data communication. Communication can be transparent or non-transparent, and in this way constant bit-rate or error-free communication can be favoured. The normal bit-rates vary from half rate[5] to extended full rate. The service requires a set-up procedure that varies in time, depending on e.g. whether connection via modem to PSTN or connection to ISDN is chosen. When the communication channel is established, the bi-directional path is dedicated to the user.

The different CSD services are optional features in GSM, but most operators support CSD to some extent. Circuit switched data calls are charged as normal calls, based on the duration of each call.

[3] Nokias "FriendsTalk" mobile chat platform is an example where USSD is used. USSD provides the dynamic menu structures that allow the text messages to be managed. USSD acts as a trigger for sending short messages and the phone interacts with the server using USSD as bearer.

[4] Concatenation of SMS messages is possible.

[5] Halfrate not much used.

Table 2 – Key factors for CSD

Call set-up times	Vary from 5 to 20 seconds depending on service
Real-time aspects	Good real-time capabilities in most situations[6] Handover provides a bi-directional path during the call
Capacity	One time-slot occupied: 4,8 kbps, 9,6 kbps and 14,4 kbps
Pricing	Price per time

High Speed Circuit Switched Data (HSCSD) provides a high-speed, multi-slot communication channel to the MS, as several timeslots are used on the air interface to increase throughput. 4 timeslots can be used, giving a maximum capacity of 57,6 kbps. HSCSD is designed for the existing GSM structure, and since it mainly requires software upgrades, it is also a limited investment. Nevertheless, many operators do not support HSCSD in their networks. High Speed circuit switched data calls are charged as normal calls, based on the duration of each call, but charges increase when more than one timeslot is in use. The network dynamically negotiates number of timeslots based on the available capacity in the radio network[7]. Speech is normally given higher priority.

Table 3 – Key factors for HSCSD

Call set-up times	As for CSD
Real-time aspects	As for CSD
Capacity	2 – 4 timeslots[8] occupied: 28,8 – 57,6 kbps
Pricing	In addition to CSD, additional price per time

3.4 General Packet Radio Service (GPRS)

GPRS offers a packet switched connection all the way to the mobile station. This leads to faster connections as the circuit switched call set-up procedure can be eliminated. Instead of the circuit switched connection, the mobile station has a virtual connection established with the network when attached. This is in marketing characterised as ‘always connected’ or ‘always online’.

GPRS provides a packet switched connection over the air interface. By this it is meant that several users can simultaneously share the same timeslot(s). The communication is asymmetric, thus a user can use different number of timeslots in the uplink and the downlink direction and in this way use no more capacity than needed in either direction. GPRS does not require upgrade of the HW in the BTS.

It must be noted that GPRS as a bearer service can be characterised as a “semi-packet switched” bearer. This means that several users can simultaneously share the same timeslot(s), but a simple set-up procedure is needed in order to give a user access to one or more timeslots. As several users are assumed to share the same timeslots, GPRS is not

[6] Problems in the radio network leading to retransmissions are not considered.

[7] No guarantee of number if timeslots is given. The call is reduced to a normal CSD call in case of lack of capacity on the air interface.

[8] Currently no mobiles support more than 3+1 timeslots (3 downlink and 1 uplink) or 2+2 (2 uplink and 2 downlink) for HSCSD.

intended for applications transferring large amount of data, since this occupy timeslots for a longer time and prevent users to have the fundamental ability to share the timeslots.

Service precedence, reliability, throughput and delay are independent parameters that together form the quality of service (QoS) classes available in GPRS. The different applications can then reflect the focus on e.g. service precedence or throughput by selecting different QoS class.

Virtual connections consume a minimum of radio channel capacity, and are assumed kept open without significant cost. Charging is assumed based on amount of data transferred.

Table 4 – Key factors for GPRS

Call set-up times	Less than 1 second
Real-time aspects	Dependant on the QoS level Not as good capabilities as CSD
Capacity	~0 kbps – 171,2 kbps[9]
Pricing	Price per amount of data transferred

3.5 Enhanced Data Rates for GSM Evolution (EDGE)

EDGE will allow operators to use existing GSM radio bands to offer higher bandwidth. Introduction has little technical impact, since it is fully based on GSM, and will require relatively small changes to hardware and software in the core network. No changes to the network structure are needed. EDGE uses the same frame structure, logic channel and carrier bandwidth as today's GSM networks. This makes the technology beneficial to existing operators wanting to offer services where higher bandwidth is needed.

EDGE uses an improved modulation technique and improved link control mechanisms to increase bandwidth. Nine different coding schemes will be available. The theoretical maximum throughput with EDGE is 59 kbps per timeslot, leading to a maximum of 472 kbps.

Upgrade of HW in the BTS is needed.

3.6 Universal Mobile Telephone System (UMTS)

UMTS, a 3rd generation mobile system, operates in a different radio spectrum, and new licences are needed for the operators. In UMTS, a new radio access technology, CDMA, with better characteristics than TDMA is introduced. Due to the changed radio interface, the operators must build completely new access networks. The governments have used auctions or beauty contests to allot the licences. Auctions have led to costly licences in many countries, and many operators have been forced to make extensive investments in spectrum in addition to the investments in infrastructure to get UMTS networks in operation.

Support of multimedia services and world-wide roaming are considered as important factors when promoting UMTS. The maximum bandwidth in UMTS is 2 Mbps and the minimum bandwidth is 144 kbps.

[9] This is only theoretically. Currently no mobile is assumed support more than 4+1 timeslots (4 downlink and 1 uplink). With a network supporting code scheme 2, this will give a maximum of 13,4 * 4 = 53,6 kbps in downlink direction.

3.7 Conclusion

With respect to the real-time capabilities, circuit switched connections have an advantage. A bi-directional bitstream is continuously sent between the radio device and the network server. Seamless handover between radio-channels further ensure that the real-time capabilities are not perceptible when devices are moving. Possible variations in the bitrate for HSCSD can occur if the network negotiates number of available timeslots up or down.

Due to the packet switched nature of GPRS, the real-time capabilities are not as good as for circuit switched connections. When the conditions of a radio channel are not found acceptable anymore, the communication path is terminated, a new channel is selected and the communication is resumed. This cause breaks in the transmission. The length of a break depends mainly on the cell reselection mechanism. The faster a new channel is available for communication, the better real-time capabilities.

The price model currently seems similar for the various operators. All operators offer volume based charging. As GPRS is in an introductory phase, comparison with the time-based charging used for circuit switched data connections that is an established service may lead to wrong conclusions. The prices may change dramatically after the introductory phase of GPRS. Current pricing indicates that transfer of an SMS message by GPRS is much cheaper than using the current excess signalling capacity. On the other hand, a file transfer of 1Mbyte is significantly cheaper when using CSD or HSCSD than when using GPRS.

The perceived capacity of WAP over GPRS is assumed better than the currently available WAP over CSD. In cases where GPRS shall be used for limited downloads, the use of 3 time-slots will give 40,2 kbps downlink. This is equivalent to download of a 2 kbyte WAP-page in less than 0.5 seconds[10]. The concept of sharing time-slots between users is based on users not transferring data continuously. This makes GPRS suitable for applications sending and receiving limited amount of information.

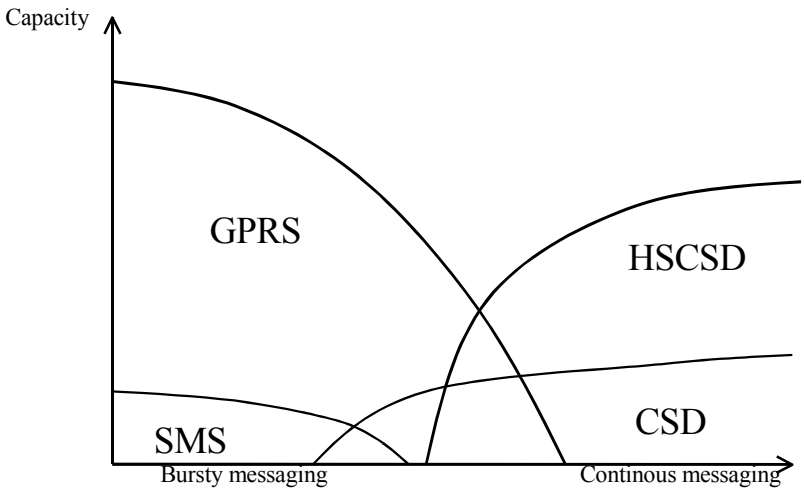


Figure 2 – Capacity versus type of messaging (bursty - continuous)

It can also be noted that the current terminals can receive in maximum 4 time-slots and send on maximum 1 time-slot. This makes GPRS, at the moment, not suitable for transfer of larger amount of data uplink. Increased power consumption and heat dissipertion are arguments against sending larger amount of data uplink. In hand-held devices, such arguments can be seen as valid, but modules as e.g. surveillance cameras may have external power supply. For such applications, with the majority of data transfer in uplink direction, require a transmitter with more time-slots available for uplink traffic.

[10] The procedure of assigning time-slots to the user is not included.

4 POSITIONING METHODS

4.1 Introduction

The Federal Communications Commission (FCC) in the US has put focus to mobile positioning by the U.S. FCC mandate 99-425. This mandate provides requirements for quite accurate positioning of emergency calls[11], and has forced standardisation of location services. This standardisation also provides services for value added commercial applications as local traffic reports, asset tracking and navigation.

Three methods for location based services (LCS) are identified and briefly discussed, and important capabilities (accuracy, coverage, cost) are identified and evaluated. Time of arrival (TOA), a method originally identified by ETSI as relevant for positioning is not discussed separately, as this method seems to have decreasing confidence.

Angle of arrival (AOA) is a method where antenna arrays are used to compute the location based on the angle of arrival of the radio signal. This method is nor described further, as the method is not considered usable for GSM handsets.

LCS is logically implemented on the GSM infrastructure through the addition of one network node, the Mobile Location Centre (MLC) and the Location Measurement Unit (LMU). A generic LCS logical architecture is shown. Additional information concerning positioning can be found in [16] and [17]. To determine the position of a roaming device is complex and only rough estimates can be given. Cell size, sectorisation and availablilty of multiple cells in case of triangulation are factors that must be considered when accuracy is indicated.

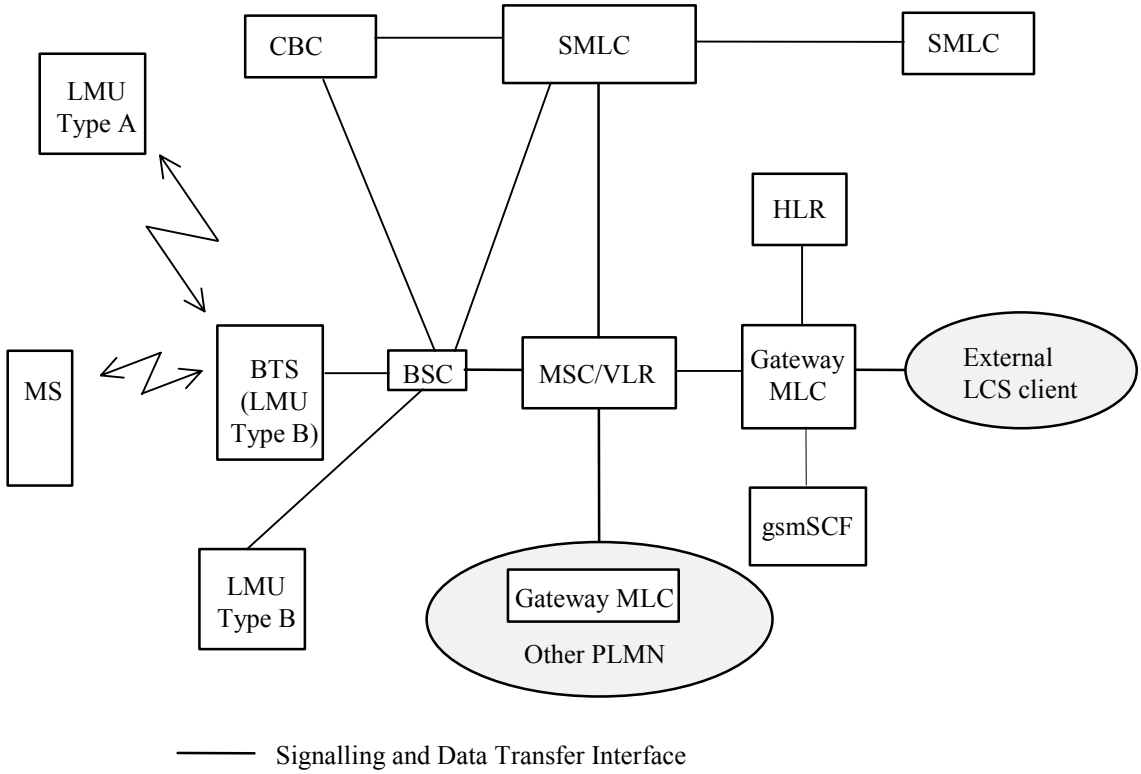


Figure 3 – Overview of the generic LCS logical architecture

[11] Requirements from 99-425 states a horizontal accuracy below 100 m (67 %) for network based positioning methods and 50 m (67 %) for handset based positioning methods.

4.2 Cell ID / Timing Advance

This is a rudimentary location capability, where the GSM cell identity identifies the cell owning the frequency currently used by the mobile unit. Based on this identity, the geographical position of the cell on a map is given by either a circle or a sector depending on the cell planning.

The time a signal uses to travel from sender to receiver is an important factor of the radio path in a TDMA system. This timing advance (TA) is used to adjust for the delay between the sender and the receiver. Adjustment is performed in 63 steps, each step representing 550 metres of signal propagation. By using the timing advanced value, the location of the mobile terminal can be constrained further than the cell identity, as the location of the terminal can be narrowed to a circle or a sector in steps of a 550 metres radius from the BTS.

This method is realised by servers in the network. The cell identity is used together with the timing advance value to provide location information from the BTS serving the terminal. The accuracy of the location information depends on the type of cell, omni-directional or sectored, and the distance from the cell centre to the cell border. This method is cheap to implement, as existing terminals can be located without any changes to the handset. The positioning information is not known in the terminal.

Table 5 – Key capabilities for Cell ID / TA

Accuracy	Limited accuracy Guideline estimate 550 metres
Coverage	Indoor / outdoor: no limitations
Cost of implementing positioning	In network: MLCs In handset: no cost

The accuracy of the positioning depends largely on cell size. In cells that cover a limited geographical area, the accuracy is fairly good, but decrease fast as the distance between the transmitter and receiver increase.

4.3 Enhanced Observed Time Difference (E-OTD)

E-OTD is a method where the handset calculates the position based on triangulation of time-of-arrival measurements from multiple sources. The location is calculated based on the following quantities:

OTD — Observed Time Difference: This is the difference between the reception of signals from two BTSs. The OTD values are measured in the terminal.

RTD — Real Time Difference: This is the timing or synchronisation difference between two BTSs. The RTD values are obtained from LMUs at fixed locations. The RTD values are calculated in the MLC and sent to the terminals.

GTD — Geometric Time Difference: This is the difference in propagation path length between two BTSs.

The calculations are based on the following equation:

$$OTD = RTD + GTD \Rightarrow GTD = OTD - RTD$$

This method cannot be used with old terminals. Additional functionality is needed in the terminals, in order to calculates GTD. SW performs this computation, and additional HW is not needed. In order to perform computation by E-OTD, the terminal must be within the

coverage area of several BTSs. In rural areas this is not always the case. In addition to the MLCs, the network infrastructure must also include LMUs. E-OTD is not dependant on line-of-sight between the BTS and the terminal, and can be used in indoor and outdoor environments.

Table 6 – Key capabilities for E-OTD

Accuracy	Better accuracy than cell ID / TA, but not as good as GPS Guideline estimate 100 metres
Coverage	Indoor / outdoor: no limitations
Cost of implementing positioning	In network: MLCs and LMUs In handset: "no cost" (added SW only)

TOA use much of the same principles as E-OTD. This method requires that multiple BTSs listen to handover access bursts and triangulate the position of the terminal based on this information. TOA can be used together with existing terminals, but the disadvantage is that more infrastructure seems necessary.

4.4 Global Positioning System (GPS)

GPS is based on a constellation of 27 satellites transmitting to the GPS receivers. The satellites have an orbit period of 12 hours, and on average 8 satellites are visible to the receiver. The GPS receiver computes its position based on range measurements to multiple satellites. The basic GPS technology requires line-of-sight between the satellites and the GPS receiver. This makes GPS vulnerable to e.g. weather conditions, indoor use or certain urban areas.

When a GPS receiver is switched on, it does not know precise time, location and orbital data. Thus, it takes some time for the GPS receiver to obtain its position. To overcome the problems with a relatively long period of time to get detailed positioning information in the GPS receiver, the method of network assisted GPS is introduced.

Two different methods using network assistance are outlined, network based GPS and MS based GPS. In the network based GPS method, the terminal acts as a sensor that provides information to the network where the actual position is computed. In the MS based GPS method, the positioning is computed within the terminal. This latter is preferred, and is often referred to as network assisted GPS only.

Via the mobile infrastructure, network assistance can provide relevant information to the terminal to speed up the positioning algorithm, as it is not longer necessary to wait until all information is received from the available satellites. The MLC can inform the terminal about approximate position, actual ephemeris data, actual satellite timing and differential corrections.

Table 7 – Key capabilities for GPS

Accuracy	High accuracy Guideline estimate 10 – 20 metres
Coverage	Indoor: limited coverage Outdoor: some limitations in case line-of-sight cannot be obtained
Cost of implementing positioning	In network: MLCs and LMUs In handset: additional HW

Existing terminals cannot use network assisted GPS, as additional HW is needed, in order to receive and process the GPS signal. The terminal does not need to be within the coverage area of multiple BTSs. Positioning can in fact be performed completely out of GSM coverage. The network infrastructure must include MLCs and LMUs. As the signal from the GPS satellite is weak and e.g. not always penetrate buildings, positioning cannot be achieved in all situations. It must be noted that the company SnapTrack [33] has technology where a server-aided solution [20] claims to solve many of the problems traditionally experienced by GPS in urban and indoor environments.

4.5 Conclusion

As indicated in the tables above, the different methods differ in network investments, complexity and positioning accuracy. Due to this, different services can be realised and priced differently based on service level. The Location Interoperability Forum [32] (founded by Ericsson, Nokia and Motorola) has created three location service categories:

Category 1	Basic Service Level. Provides location of all handsets, including legacy, based on cell or improved cell accuracy. Initial technology choice Cell ID / TA.
Category 2	Enhanced Service Level. Location of new handsets with improved accuracy at a reasonable cost. Initial technology choice E-OTD.
Category 3	Extended Service Level. Location of new handsets with high accuracy and higher (compared to Category 2) cost with customer choice. Initial technology choice network assisted GPS (MS based).

Location service category 2 is the most questionable choice, as several technologies fall into this category.

The U.S. FCC mandate 99-425 may force development of accurate positioning in mobile handsets to a standard function available in all terminals.

Other aspects of location based services are user privacy, security and service authorisation. In applications where positioning is an important factor and huge values or human lives are at stake, legal aspects and liability must be considered to prevent service providers from lawsuits.

5 M2M APPLICATIONS

5.1 Introduction

M2M is an acronym for Man-to-Machine or Machine-to-Machine. In this thesis, focus will be on the latter, on applications where local microcomputers act as clients or sensors, communicating with centrally located servers or controller units. Applications where human intervention play a vital part, Man-to-Machine, is not considered further[12].

Embedded web technologies (EWT) is the application of software developed for the WWW to embedded systems. Embedded systems contain computers, software, input sensors and output actuators dedicated to the control of a specific device. Examples of devices with embedded systems include cars, household appliances and industrial machinery. EWT allows a user to monitor and/or control a remote device with an embedded system over the Internet using an ordinary web-browser.

Classification is made based on logical grouping, and a number of key capabilities are identified for the different application types. Important capabilities are physical size, power consumption, need for positioning, type of messaging (bursty / continuous), data only versus voice and the need for external interfaces. In addition to this, all applications need dedicated SW and distinct amount of memory.

Location based services are not considered a separate type of application, but an important element needed for several types of applications.

The external interfaces that are considered are both serial and parallel interfaces. In several types of applications, Bluetooth can be used as a cable replacement between the sensor part and the GSM part of the module.

5.2 Telemetry

Telemetry is a huge and diversified area, and constitutes classical M2M applications. It spans from unintelligent sensors to advanced devices that measure, compute and store the results until sent to the remote party. Applications for remote control, telematics, are included in this application type.

The application type is normally split into sub-classes reflecting vertical applications.

Telemetry sub-classes:

- Utility meter reading (water / gas / electricity)
- Agriculture (irrigation, fertilising)
- Environment (air quality, acidification, toxic contamination)
- Weather stations (wind force, air humidity, air temperature, precipitation)
- Traffic management (railway crossings, traffic lights, toll-roads)
- Industrial machinery

For most telemetry applications, audio is not fund necessary. Applications like gas meters or industrial machinery are not considered to get features where voice is needed. As modules normally are situated at fixed locations, positioning is considered unnecessary in most situations. Measurement equipment may be moved between geographical positions, but roaming meters are not considered.

[12] Some Man-to-Machine applications are denoted personal telecomputers

The amount of data for telemetry applications is considered modest and normally sent in bursts. This is also typical for most M2M applications. Information can be sent periodically, at certain incidents or on request from the server. The size of modules for telemetry is not considered very important, but in some types of equipment, the power consumption is crucial. For many applications, electricity is anyway needed at the site, but sensors for e.g. agriculture and environmental applications are typical examples of standalone devices where low power consumption can be important. The use of solar power cells as additional energy source may in some situations be an alternative to a power line.

The measurement equipment does not follow certain standards, and the interface towards the module cannot easily be standardised. The reason for this is the diversity in applications, but also the fact that numerous devices are already in place, and the module must adapt to many different existing types of meters. The interface to the meter can be via serial or parallel communication. Telemetry applications can also be part of a larger system where certain modules are connected via Bluetooth to a 'gateway module' performing the GSM communication with the remote server.

5.3 Health Care

Health care is an area with increasing focus. The cost per day for patients at a hospital is vast, and society can save both money and personnel if advanced remote surveillance systems can substitute hospital beds. Non-technical aspects may be issues that impede such applications. The application must be considered secure, in order both to get sufficient confidence from potential users and also not to get juridical problems for the service provider.

Examples of health care applications:

- Surveillance of body functions
- Positioning in emergency situations
- Military first aid systems

The amount of data depends on the application. The characteristics can be comparable to telemetry, but also with surveillance if larger amount of patient data shall be transferred.

The power consumption and size of such a module is considered important, as the device must be small and convenient to wear. The power consumption must be carefully considered, as the power is used for sensors and continuous monitoring in addition to the power needed for the GSM terminal.

No standard has been identified for health care measuring equipment.

An important feature for a health care system is positioning. In case monitoring of bodily functions exceed predefined limits, it must be assumed that action is automatically taken to call for medical assistance. In such a situation, exact positioning is needed, as the person in question may not be able to communicate.

For personal safety alarms, audio is definitely needed, as voice contact is assumed established in case of emergency.

Armed forces always consider new technology to improve own capability. Health care applications can be used to direct medical personnel to correct locations in case of casualties. Monitoring system can also be used to check the physical and mental status of own units before strategic, tactical or operational decisions are taken.

5.4 Fleet Management

Tracking and control of vehicles and freight comprise the application identified as fleet management. Within this area, positioning is a key technology. The requirements for accuracy of the positioning are not unambiguous. While e.g. a car or a railway carriage is large by nature and by default can be assumed located on roads or rails, other items as containers and freight in general can be more difficult to spot. These applications may then need more detailed position technology.

Modest power consumption are not an important factor in cases where the module is intended for installation in cars or railway carriages as power is available. In case the module is intended for freight or containers, the power consumption becomes more important. As the modules are not size-critical, it is possible to achieve substantial additional power by back-up batteries.

Examples of fleet management applications:

- Tracking of trucks / buses
- Control of taxis (dispatch operations)
- Courier companies / freight transportation
- Tracking of goods / containers

5.5 Automotive Applications

The car industry is starting to include modules to offer automotive applications in selected car models. In case of accidents or problems with the car, information can then be given to nearest emergency centre, garage or rescue service. To achieve this, positioning is needed. The accuracy of positioning can be debated. In case of location of the car for example in case of road assistance, the requirements for location can be compared to fleet management, as cars must be assumed located at or near the road. Emergency situations may have requirements for a more detailed positioning.

CAN-bus is the standard for connection of equipment within a car. In addition to this interface, Bluetooth is considered to be used e.g. towards hands-free solutions. Size and modest power consumption are not important factors since power is available from the car.

Modern cars contain a considerably amount of SW, and diagnostics can improve maintenance. Regular communication with the preferred garage can improve service quality and reduce costs. The reason for this is that periodic exchange of parts can be omitted, and substituted by maintenance based on actual wear. This can lead to a personal follow-up making the car owner more confident to the garage.

With a communication device placed in the car, the device can be used for hands-free voice communication, gaming, computer assisted driving and information / push applications. Such applications, infotainment, are considered to have a high degree of human intervention and are thus not discussed further.

Examples of automotive applications:

- Car diagnostics
- Positioning
- Tracking in case of emergency

5.6 Point of Sales (POS)

Fixed and mobile point of sales is a market segment where applications have been available in many years.

Applications in this segment are e.g.:

- Mobile credit card terminals
- Vending machines
- ATM
- Lottery machines

For POS applications, audio is not assumed needed. As for telemetry, positioning is nor found to be of importance, as most machines are situated at fixed locations. Mobile credit card terminals roam by nature, but as the main idea by such terminals is to move money between accounts, positioning is not found needed.

The amount of data for POS as well as size and power consumption can be compared to telemetry applications. Lack of standards for interfaces and numerous devices already in operation makes a uniform module difficult to design.

Bluetooth can be an issue in cases where several machines are located together in for example a penny arcade. In such a concept each lottery machine can have a module using Bluetooth to communicate towards a 'gateway module' operating as a router between multiple lottery machines and the remote server over the GSM network.

Within POS, a module can be used for:

- Credit card payment
- Logistics
- Price updating

5.7 Surveillance

Protection of critical public infrastructure and crime are two important factors that cause private persons, institutes and organisations to use surveillance. By surveillance is meant applications that protect or track humans or their properties. The area covers applications from telemetry-like sensors to surveillance by streaming video. This group is not homogenous, and should be considered split according to e.g. need for bandwidth.

Possible application types:

- Alarms (fire, burglar, smoke detectors)
- Tracking devices (individuals, animals, assets)
- Intelligent homes / clothes
- Surveillance by pictures
- Surveillance by video

For some applications, audio is not necessary, but may in situations be efficient both from surveillance and bandwidth point of view compared to video. Current technologies for compression and picture transmission reduce the demand for bandwidth, but transfer of pictures still consumes significant bandwidth. Other applications consume little bandwidth and can be compared to telemetry applications and its bursty nature.

In most situations, cameras or sensors at fixed and known locations perform surveillance and positioning will not be needed. Such devices are also often considered to have power

available, leading to a limited focus on power consumption. Many such devices will also consume more power, du to a higher amount of uplink transmission. Tracking devices need positioning by their nature. The size and power consumption is considered of importance for such tracking devices.

For e.g. surveillance by video, standards for connection between the camera and the module exists, but in other areas as tracking devices or alarms, no widespread standards have been identified.

Information can be sent from the devices using different technologies, from streaming video to pictures, and like this consume different amount of bandwidth. A possible fundamental difference is that surveillance may require a different configuration of uplink and downlink timeslots. Instead of the configuration of 3 + 1 timeslots introduced in current terminals used for WAP and WWW, the opposite configuration of 1 + 3 timeslots may be more suitable for surveillance.

Examples of areas where surveillance can be employed:

- Tracking services for
- Traffic control
- Weather control
- Surveillance of private properties
- Surveillance in public areas
- Surveillance of particular installations (gas pipes, oil installations, nuclear power plants)

5.8 Conclusion

5.8.1 Overview

Below is a summary of the capabilities for the M2M applications. The different key capabilities are discussed separately after the table. As a general comment, it can be observed that no overall pattern apply to M2M applications. The diversity of applications leads to very different needs of the functionality for a module.

Table 8 – Summary of capabilities for M2M application

	Type of messaging	Positioning req.	External interfaces	Audio needed	Size importance	Low power req.
Telemetry	**B**	**N**	**S / P**	**N**	**Y / N**	**Y / N**
Health care	**B**	**O / G**	**S**	**Y / N**	**Y**	**Y**
Fleet mgmt.	**B**	**O / G**	**S**	**N**	**N**	**Y / N**
Automotive	**B / Cont**	**O / G**	**C / S / B**	**Y**	**N**	**N**
Point of sale	**B**	**N**	**S**	**N**	**N**	**N**
Surveillance	**B / Cont**	**N**	**S / P / B**	**Y / N**	**Y / N**	**N**
Tracking	**B**	**Y**	**None**	**N**	**Y**	**Y**

B	Bursty	G	GPS
Cont	Continuous	S	Serial
N	No	P	Parallel
Y	Yes	B	Bluetooth
O	E-OTD	C	CAN-bus

As stated earlier, M2M applications come in many flavours. Applications are diverse, and to find distinct capabilities and functionality is not easily achieved. Three use cases (UC) are described in order to give examples. The use cases illustrate that the intention for an application from an end user perspective can be very different. The end users span from large companies serving public needs to individuals. UC-1 shows how a supplier of electricity may get a better utilisation of the available infrastructure by investing in an automated system. UC-3 illustrates a situation where a company by a simple business case justifies an investment and buys an application. For UC-2, individuals can see a need and benefit in a personal system.

5.8.2 Messaging Characteristics

> Use case 1 (UC-1)
>
> In an area, the supply of electricity is close to its limit. In order prevent a breakdown of the infrastructure, consumers are stimulated to change their power consumption habits by reducing the prices outside the peak interval. In order to achieve this daily change of price of the electricity, modules are attached to the electricity meter to get on-line metering.

The messaging characteristics are an area where many M2M applications have a similar requirement, the bursty nature of the communication. Hence GPRS is an ideal bearer for a large number of M2M applications. The introduction of GPRS may then open for many new solutions. The number of applications with more complex requirements for bandwidth must not be neglected. The availability of GPRS must not lead to not using CSD or HSCSD in situations where large amounts of data shall be transferred.

In automotive applications, downloading of information like maps and tourist information indicates higher bandwidth than GPRS. However, ordinary CD-ROM may also load such information in advance. I find it important to again point out the difference in characteristics for certain surveillance applications. The fact that such applications often will need the bulk bandwidth in the uplink direction makes such applications special. A configurable radio or a particular radio for such applications may be needed.

Charging of the bearer service may also be an important issue, and is assumed used to direct applications to bearer services that are optimal from the network operator's perspective. Reducing the bearer service to a pipe is foreseen, and an application is assumed to be more charged according to perceived value than the bandwidth it consumes. UC-1 is an example of large amounts of meters that are assumed to be only one subscriber, reducing administrative costs for the operator.

5.8.3 Interfaces

The diversity in applications reflects the multitude of interfaces. 'Standardise the interface' is often pointed as the solution in case of integration problems. In the case of M2M communication, this is considered to have a limited effect. The reason for this is the difference in nature of the equipment interfaces. Many of the interfaces are proprietary, and the vendors may want to have it like this. A number of potential M2M applications are also towards equipment already installed. RS232 is found as the only interface that can be considered to be a 'standardised interface'.

5.8.4 Audio

For a number of applications, audio may become a feature that in a basic situation is not needed, but can give an added value if an application is extended. However, in other applications where margins are small, the additional cost of any unnecessary component may be crucial.

5.8.5 Positioning

Use case 2 (UC-2)

An owner of a summerhouse wants to increase security for his property. An 'intelligent home' is established, and modules for interfacing a burglar alarm, a sensor for water in the basement, a fire alarm and a means to switch heating on is installed. All modules interface respective sensor and communicating via Bluetooth to a centralised GSM unit that performs communication to the remote party. In this way a centralised server all sensors can be controlled and configured via the same interface.

Positioning is an issue for several M2M applications. In certain situations, E-OTD is considered sufficient. As this technology only needs SW in the module, this is a cost-effective alternative if the accuracy can be accepted. As this can be realised by SW in the terminals, this functionality can be included in all modules. In applications where a detailed accuracy is necessary, network assisted GPS will be needed. For automotive applications, E-OTD is in many situations considered to have the needed level of accuracy. Within urban areas or in areas with roads having lanes in two levels, the additional accuracy given by GPS may cause GPS to be the chosen technology.

5.8.6 Power Consumption

Low power consumption is not necessarily synonymous with a small physical size. A complete devices intended for e.g. reporting toxic contamination may be quite large in size because of the physical environment where the device is located. At the same time, the device may be inaccessible due to its location, thus making low power and thereby a long lifetime an important issue.

It must also be noted that the same power source also is used for processing the application SW.

5.8.7 Size

Use case 3 (UC-3)

A company's business is hiring forklifts to contractor companies. The forklifts need periodic maintenance personnel. This service can be improved by introducing a module in each forklift, informing the service personnel when service is needed, instead of stipulating the service intervals. In addition to improve maintenance routines, it is also possible to track a forklift if it is not at the site.

The physical size is not considered very important in most applications. Examples of applications where the size may be important are certain tracking devices. Such devices on e.g. pets must have a limited size and devices for tracking assets as paintings or expensive stereos must be easy to integrate within other items. The current technology now offers chip-sets where the physical size of a GSM module is less than a box of matches.

Further decrease of the module down to a single chip must be assumed in a not too distant future.

6 GSM / GPRS MODULES

6.1 General Description

Below is a general overall description of the main building blocks of a typical GSM module. Only the main internal building blocks are outlined. For modules, the cost / benefit values of the key capabilities are outlined and discussed from the module's perspective.

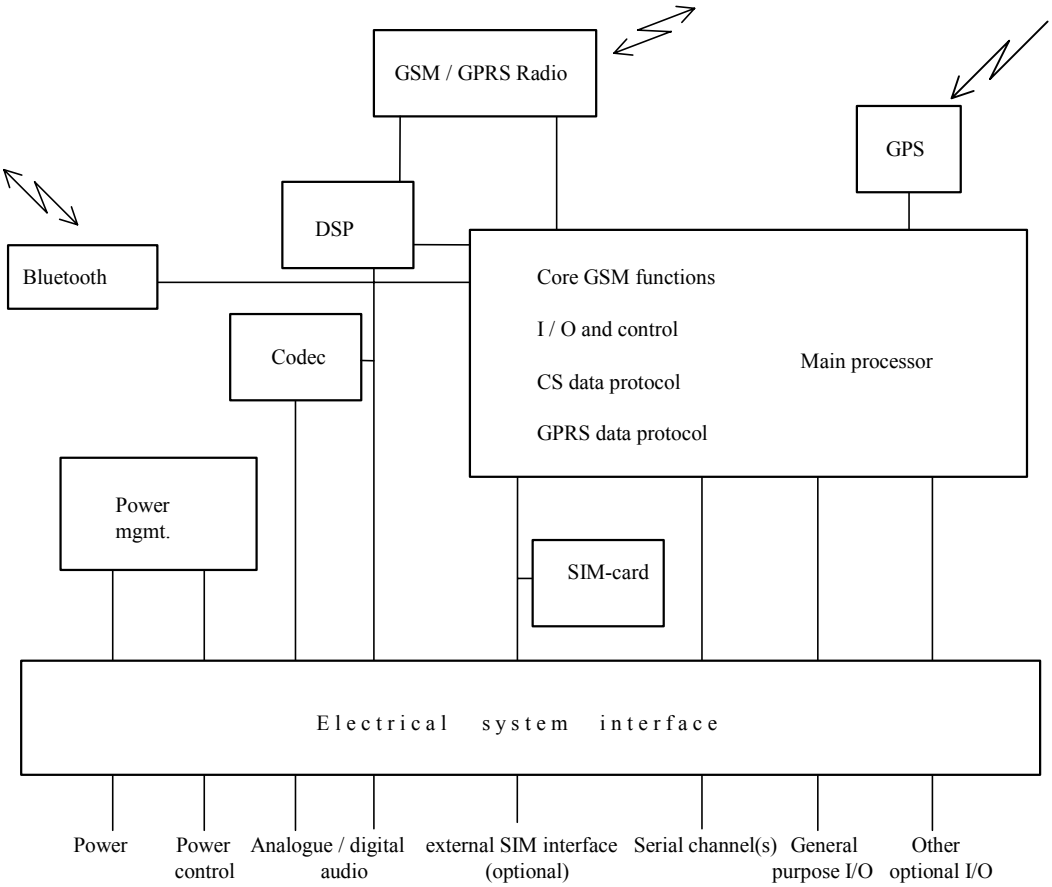


Figure 4 – General module overview

A GSM module consists of few physical circuits. As the module consists of few components, much of the functionality within the module will be default. Functionality that may be made optional, are various system interfaces, Bluetooth, GPS and the voice codec. It must also be noted that the SIM-card may be included in the module or added by system integrators over a possible external SIM-interface.

6.2 Type of Bearer Service

The DSP and the main processor perform communication over SMS, CSD, HSCSD and GPRS. Looking for possibilities of reducing production costs and size, removal of unnecessary functionality will always be an issue. However, customising modules with respect to bearer service is assumed to give marginal decreased costs. The reason for this is the integration of all the protocol stacks within one processor. Some flash and memory can be saved, and the complexity of the processor can be slightly decreased. However, a large number of devices must be produced in order to justify this reduced functionality. No vendors offer modules not supporting voice have been identified.

6.3 Positioning

E-OTD is implemented in SW, and has marginal impact of the cost of a module. Solutions where the requirements for positioning can be met by this technology have a benefit compared to GPS solutions needing additional HW. A consequence is that E-OTD is assumed to be available in all modules as a standard feature, while solutions that need network assisted GPS may use more expensive modules.

6.4 External Interfaces

The interface towards the equipment to be controlled does not follow particular standards. This opens for a diversified interface, both from a physical, an electrical and a bandwidth point of view.

Possible interfaces:

- Serial computer port
- Parallel computer port
- USB
- Bluetooth
- IR
- CAN-bus
- Fieldbus
- I^2C
- SPI

From the above list, it can be seen that many possible interfaces apply. Applications do have different requirements, and multiple interfaces towards the controlled unit are considered necessary also in future applications. It is found difficult to pinpoint interfaces that can be considered standard for all modules. Bluetooth is an interface that may be used in several applications, but the additional cost of this interface is negative from a cost perspective. One or two serial interfaces and a general purpose I/O seem to be common standard interfaces.

6.5 Audio

Audio is definitely not needed in all modules. However, several aspects must be considered before audio is removed.

The fact that audio currently is available from all providers of GSM chip-sets indicates that audio is tight integrated in the design. This makes it difficult to remove. When looking at the general module overview, the codec is the only IC that may be removed. The DSP and the main processor are anyway needed. The tight integration of audio in the chip-sets makes optimality of audio difficult and may lead to a more expensive radio when audio is removed. To have analogue audio as an option may be a solution, to remove the codec.

When looking at **Table 8**, audio is not needed in all applications. E.g. telemetry applications do not need this functionality. Modules intended for telemetry applications are also a type of module that is assumed produced in large series. This may justify a customised GSM chip-set where audio is limited or removed.

6.6 Size

The physical size of a GSM module has reached a level where it less the critical size for most applications. As an example, Xircom offers a GPRS module [Figure 5] with the size 55 mm x 35 mm x 5.6 mm (L x W x H) [23]. The module offers voice, SMS, CSD and GPRS. As the module is intended to be integrated in various types of equipment, the actual size of this item has for many applications a total size substantial larger than the complete device as such. In applications where the size is an important factor, the GSM technology is large, and should be improved. The SIM card alone increases the size substantially, and selection of another form factor of the SIM could further reduce the size. Another factor that influences the physical size, are the external interfaces.

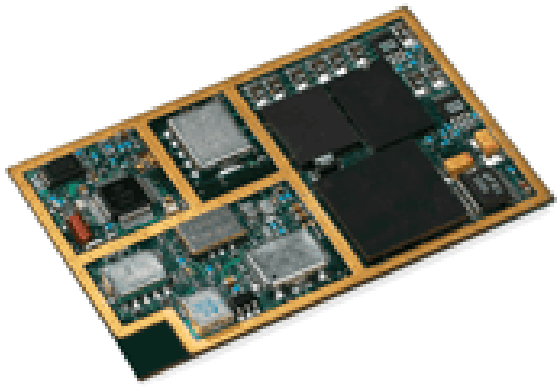


Figure 5 – Core engine, Xircom's GPRS module for integrated solutions

Figure 6 - GM32, Ericsson's GSM module for connection to external devices

Another example of a GSM module is GM32 from Ericsson [Figure 6]. The module can be considered a complete GSM communication device that is ready to connect to external devices. This module has the size 89 mm x 51 mm x 11 mm (L x W x H) [24]. The module offers voice, SMS and USSD.

When considering the size of a module, the SIM is identified as a large part of the total volume. An alternative form factor of the SIM, e.g. by using a form factor of an IC, would be a significant contribution to reduced size.

6.7 Power Consumption

The current power consumption of GSM phones with a normal battery gives a standby time of less than a week. In certain M2M applications, it is a request for a module to have a battery to last for months. The background for this is e.g. industrial applications where it is inconvenient to change or charge a battery on weekly or monthly basis. Meters for gas or tracking devices are other examples of applications where it may be no easy access to re-charge the battery.

In certain situations the reason for selecting a wireless solution is also to remove all cables, power included. It may not help much to make the control communication wireless if cables for power still must be pulled out to each device.

6.8 Memory and Application Specific SW

A module is, when used in GSM systems, an embedded unit that is type approved to meet certain standards. To add SW to this unit can create undesired behaviour in the radio and the signalling part of the module.

Alternatives for room for additional application specific SW:

- Main processor
- SIM card
- Bluetooth chip
- Separate chip dedicated to application specific SW

To add more memory and application SW within the main processor is not seen as feasible due to type approval.

The SIM card may be a beneficial place to put this application SW. As the SIM is operator specific, functionality can follow operator and not the device owner. A service specific SIM can be introduced. The SIM is anyway needed, leading to no increase in physical size of the module. SIM Toolkit may also be used to create simple applications, and KJava and MExE may further open for more possibilities.

Bluetooth may be an optional chip within the module, and hence not the best candidate for localisation of the application specific SW.

A separate circuit for application SW only is a technically feasible solution and will be needed in advanced applications. This will increase the cost of a module.

6.9 Environmental Aspects

The environmental aspect of modules can vary significant. While a meter for reading electricity consumption normally is located indoor, a module intended for automotive applications have an environment that cause problems to cellular electronics as well as the SIM-card. Heat, EMC and corrosion are other environmental aspects that must be considered, and may need particular attention for dedicated applications.

The normal temperature range for modules is -20 to +55°C, the same temperature range as for mobile phones. Within most vertical segments, applications can be identified where this temperature range is too narrow. M2M communication for e.g. automotive applications is an area where the temperature range for the modules in many situations will be outside this normal operating range.

6.10 Conclusion

A module is a communication device, and from a GSM perspective, a module has traditionally been compared to a mobile phone stripped for buttons and display. This approach has been found beneficial in a world market where penetration has been a measurement of success and voice has been the key usage. M2M applications have not had much focus, in spite of the fact that many applications have a communication pattern and data volume that justify SMS as bearer service.

Module vendors must reflect the diversity of M2M applications in the same ways as mobile phones are classified in market segments dedicated to different types of end users. Some modules are intended for applications where margins are large, while other applications have tiny margins and the module cost is decisive. In the same way as the market is segmented,

the offered products must be segmented accordingly. Modules must be seen as a line of products with dedicated focus. To use technology and knowledge from cellular phones as input to GSM module design is valuable, but modules are separate products with a number of particular requirements, as size, interfaces, location services and power management.

A proposed classification is:

- Cost sensitive module
- Standard module
- Enhanced module

The main motive for the classification is saving of HW-costs. A cost sensitive module is typically intended for production in large numbers e.g. for utility meters. Such modules are proposed stripped for GPS and Bluetooth. Functions realised in software is not proposed removed. E-OTD can then be used in case of positioning. The supported bearer services should be at least SMS, CSD and GPRS, on order to have flexibility while designing the application. Solutions where an IC replaces the traditional SIM-card to an IC-SIM-card may be a possibility to reduce costs further. Such a solution makes a tight connection between the network operator and the service provider. The IC / SIM should be considered to have application specific SW. Additional HW from system integrators may give too large HW-cost.

A proposed standard module is intended for most applications. This type of module has voice available. E-OTD is used for positioning, and SMS, CSD, HSCSH and GPRS are supported bearer services. No additional chip for extended memory and application SW is found feasible to include.

An enhanced module has the functionality of a standard module with Bluetooth, GPS and possibly application specific SW as additions.

The technology trend indicates that also modules will be physically smaller and may be assumed integrated on a single chip. When a complete communication device is integrated on a chip, the module classification may be obsolete, and at most two types of modules, are foreseen, a cost sensitive module and an enhanced module.

Voice is not considered feasible to remove. The function is considered too integrated and found necessary in many vertical application types. In case of future additions of an application, voice is also considered to be a candidate in several situations. Even if e.g. an ATM does not have any voice connections now, future machines may have this service to increase convenience or service level.

7 THE VALUE CHAIN FOR M2M APPLICATIONS

7.1 Value Chain overview

As the M2M market gets more mature, the current players realise that the margins get smaller. A value chain can be identified, and the different roles in the value chain must be identified and understood in order to succeed in the development of M2M applications. The module vendor provides a basic building block for the complete solution, and will in some situations provide key technology to realise an application. When it comes to creating the service, the module provider is not considered a significant player. Charging based on perceived value of transmitted data can change current charging methods.

The system integrator interfaces the end customer and provides a solution according to the customers needs. As a part of a solution, the GSM module is used as a wireless communication unit towards remote equipment.

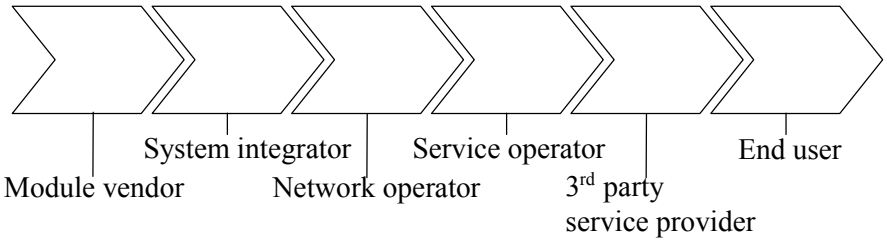


Figure 7 – Value chain for M2M application development

Most existing solutions are targeted towards companies. The size of the companies vary from a small firm with particular needs to control 30 – 50 units by one or two technicians, to large industrial groups that wants millions of units to simplify expensive routines as manual reading of utility meters.

Differences in companies and their reasons to invest in M2M solutions are distinct. The system integrator has main focus towards the solution and can integrate the module with the existing equipment. In **Table 9** an example of roles and participants within the value chain is outlined.

Table 9 – Example of roles and participants in a value chain

Role	Participant
Module vendor	Ericsson
System integrator	Meter manufacturer
Network operator	Netcom
Service operator	Maingate
3rd party service provider	Electric energy provider
End user	Private household

7.2 End User

In pure machine-to-machine applications, the human aspect at the terminal can often be neglected, as the module is assumed connected to a machine. This remove problems with changes in working habits, a generally conservative attitude or fear of new technology, aspects that traditionally is considered as problems when introducing new technology[13].

As machines are not stuck in existing habits, M2M communication is for many applications assumed easier to introduce than applications where human intervention is more important. When e.g. the interface towards a utility meter is identified and data on the communication link is identified, modules can be produced in millions without much concern about guidance for the end user. However guidance may be needed when value added services are introduced. The utility meter may open up for new possibilities, e.g. to provide the user with a better overview of the energy consumption or the ability to turn heaters on and off at certain times.

Applications that do not interfere with end users, e.g. telematics, are considered not to create much negative feedback from end users. Examples of applications with a minor impact for the end user are certain tracking devices, weather stations and point of sales applications.

Another simple application is a general tracking device. A simple button-like device can be foreseen attached to children, bikes, pets or other assets to track its position.

Many applications are foreseen to offer voice as a value added service to increase convenience for the users and convey the impression of personal service.

The end user perspective is diverse.

7.3 3rd Party Service Provider

The role of 3rd party service providers is to own, market, maintain and develop the service. It is considered important to maintain the service in an easy way, In most applications, the end user cannot perform individual configuration. Control and configuration is performed remotely to increase efficiency and have homogenous devices.

Charging can be performed according to different models. In e.g. applications for utility meter reading, it must be assumed that all utility meters belonging to a particular company are billed on one bill towards the 3rd party service provider. Fixed fees, if any, then make further billing towards the end users. In other applications, each end user has a different behaviour, and individual charging must be performed. As an example, certain applications for surveillance may have varying and large bandwidth.

Many 3rd party service providers are not familiar with the technology, and must be educated in order to understand the possibilities. IT has got much negative focus lately, and conservative companies must understand and believe in the sketched possibilities.

7.4 Service Operator

The service operators need services and functionality that cannot easily be provided by network operators. A service operator as Maingate, a virtual operator tailor made for machine-to-machine communication, provides solutions for e.g. telemetry, security and automotive applications.

[13] Aspects are valid for man to machine applications, but is not considered having importance in the thesis.

The network operators have traditionally undertaken the role of a service operator. The benefit with dedicated operators for M2M applications, is the ability for such an organisation to keep the focus on M2M applications.

7.5 Network Operator

The network operator provides the communication path towards the end user equipment, and owns the subscription. The network operator gets income from fixed fees and time-based or volume-based charging. As this income is reduced due to increasing competition, the network operators must find new ways to utilise their networks and expand their business to increase revenues.

If time or volume is the basis for charging, it is simple to both understand and perform the charging. In some new applications, charging can also be performed based on the value of the information as such. This type of charging is more complicated. When the value chain gets mature, charging based on perceived value of the information may reduce the network operators to providers of bandwidth.

7.6 System Integrator

The system integrator has an important role that is vital to realise M2M applications. Hands-on experience for connecting boxes and providing added value characterises this role. The system integrator must understand the interface between the module and the device, and implement the application SW. The experience of network and mobility is considered to be less important.

7.7 Module Vendor

The task of the module vendor is to produce the communication unit. It is a limited possibility to increase value in this role, but production is proposed performed according to the identified market segments. It is not considered cost effective to make one generic module for all needs. Customisation for large volumes is possible. As an example of customisation can e.g. be a co-operation with a SIM-card manufacturer and a network operator to make a simple generic device, a service specific SIM, with application specific SW either on the traditional SIM-card or on an IC-SIM-card.

7.8 Conclusion

The traditional participants of mobile telephony services, the handset vendor and the network operator must recognise the other roles in a fragmented value chain. The success of modules depends on the success and co-operation of all participants in the value chain. Each player must focus on its particular role to complete the application, and realise that several payers are needed in order to create cost efficient applications.

The system integrator role is seen as a key factor, and is considered as an important link in the value chain. Applications are created when system integrators and potential customers together find improvements of existing processes or find new business opportunities. While the vendors of GSM modules focus on devices for communication, having a goal to mass-produce cheap units produce units, system integrators interface end customers and can adapt the modules to end user equipment.

One player can grow and take more than one role within the value chain. A network operator can e.g. also take the role of a service operator. It is considered important that this expansion is done by adding a new unit with a dedicated focus on the new role, and not by mixing the different roles. In this way it is ensured that each role is independent has competence in the current area and does not act on behalf of other roles. In many situations it is considered a better solution to build alliances than to expand into new roles.

8 ENABLERS AND OBSTACLES FOR M2M APPLICATIONS

8.1 Expectations of M2M Applications

Around 1990 when telecommunication services for intelligent networks (IN) were introduced, marketing claimed that any feature could be developed, quickly and without much experience; imagination was the limitation. History has shown that IN did not create as many features as predicted.

M2M communication is sometimes given high expectations in a way that can be compared to e.g. Intelligent Network services. Futuristic concepts in an advanced M2M scenario describe wireless communication between toaster, coffee-machine and refrigerator in an intelligent home, or automotive applications where communication between the car, the garage, traffic signs and toll roads ease everyday life for humans.

Such concept may scare people and make M2M communication another dream that does not come true. M2M applications must solve problems or increase revenue for end users within a short time frame. Each application must to some extent be tailor made, and the module must be assumed 'a black box' needed for the solution. In the same way as mobile phones are classified to target dedicated market segments, modules must be categorised and be equipped accordingly.

8.2 Focus on Solutions

In order to create applications that solve problems, it is important to let the solutions be driven by demands and not by technology. M2M applications can be realised by a number of technologies some of them with a multiple of possible bearer services. GSM has a benefit because it offers a large number of bearer services and a wide coverage. Alternative bearers may have some benefits over GSM in certain areas, but the possibilities that can be offered by GSM are larger. The network operators should have enough confidence in the technology to be open for evaluation based on the needs of different types of M2M applications.

The service operators may have better qualifications than the network operators to focus on the solution, since they are a bit more distanced from the network, and does not propose a solution according to e.g. available network capacity or specific network features.

For Internet, an important factor for success has been how TCP/IP have made it possible to create applications easily. Even when the API as such has been proprietary, the portability of the SW has made it possible to improve and develop solutions fast.

8.3 Network Operators

The network operators have several reasons to be a driving force for M2M applications. Three important reasons listed below:

- M2M applications may in many situations be pre-programmed to communicate on off-peek airtime. The burstiness of much M2M communication also offers increased capacity with a minor affect on existing business.
- Network operators will also gain large corporate customers. Such customer will provide large volumes of M2M business. This business may lead to predictable income to the operators.
- M2M communication and subscriptions may provide the network operators with opportunities to bundle the M2M applications with other services to enhance the total offering.

The network operator clearly benefits from the additional revenues from M2M applications. However, network operators are not considered to be an enabler for M2M applications. The network operators must open for co-operation to create services and end user applications. In Sweden, Telia Mobile has co-funded the company Wireless Maingate [39] to ensure that the roles and focus for the network operator and the service operator are clearly separated. In this way the network operator can focus on its main business.

The network operators must be aware of their role. A strong wish to control application developers and an unfavourable pricing can be a serious obstacle to M2M communication.

8.4 System Integrator

The system integrator role is seen as a key factor. This link in the value chain is considered important, and may be helpful for the module vendors in order both to perform an optimal classification, to co-operate with identifying additional functionality within the module and to add the application SW and interfaces relevant for various types of applications.

8.5 Module Vendors

M2M applications have not had much focus yet, in spite of the fact that many applications have a communication pattern and data volume that is considered significant. As an example, 3 million electricity meters each sending an SMS message every 60 minutes leads to over 26 thousand million SMS messages sent per year.

A module is a communication device, and has traditionally been compared to a mobile phone stripped for buttons and display. This makes the module too much of a by-product from the development of mobile phones. The major drawback of this approach is the limited focus this leads to for the requirements of the modules.

A reason for the limited focus on modules from the vendors may be the fast development of new features for GSM and UMTS. It is considered that more focus must be on the modules, and as described in the chapter describing the modules [page 29], modules must be classified and dedicated to market segments in the same way as mobile phones.

Type approval of the modules is an important aspect that until now has been an obstacle for implementation of application specific SW on the main processor where the core GSM functions is located. Future tools may ease this situation.

8.6 Conclusion

I find the approach to see modules as a mobile phone as negative both for module vendors and for target customers. The diversity of M2M applications is bigger than the variety of ordinary mobile phones. Due to this, the development of modules must be given priority. As the penetration of mobile phones in many western countries is over 70 %, machines are a way to increase subscriptions and use of the infrastructure for the network operators. The numbers of utility meters, households and cars are vast, and show the large potential for increased use of the networks. A substantial part of the applications have a predictable communication pattern. This means that it is possible to put a portion of the communication to moments in time where the networks have a low utilisation.

Some applications have very tiny margins, and certain M2M applications may only be justified when the M2M communication open up for added value for the services, either by creating new business opportunities or by combining several applications.

It must be accepted that several players are needed to bring success to M2M applications. New players will be present, and as the market matures, a value chain is assumed to introduce more specialised players, a large number of value added functions and lower price per bit.

The applications must have a charging model that give the service operators and the 3rd party service providers a possibility to earn money. The network operators may hinder the development of new services by introducing charging models where the provider of the communication channel shall have a too large part of the total revenues.

9 MEDICAL SURVEILLANCE, A PROPOSED CONCEPT

9.1 Scenario Snapshots

9.1.1 Today's Situation

A vital 57-year-old lady experiences a myocardial infarction and must undergo an operation. After a successful operation, she is released from hospital. As a result of the incident, she stops working for four months before she resumes her position at work, but is ordered by her doctor to work only part time due to a possible unstable heart condition.

The lady's husband is concerned about his wife's condition and her situation affects his work. He experiences loss of concentration, reduces his social activity and ambition level at work. He decides to spend all his spare time at home in case his wife experiences a relapse.

The atmosphere at home gets tense, and the life quality for the couple drops due to the myocardial infarction.

9.1.2 Tomorrows Situation

A vital 57-year-old lady experiences a myocardial infarction and must undergo an operation. After a successful operation, she is released from hospital. As a result of an unstable heart condition with arrhytmias, she is given a safety bandolier that can communicate with the hospital and detect new irregularities in her heart rhythm. She stops working for two months before she returns to working reduced hours, and due to the availability of comprehensive information about her heart condition, she can work full time after another two-month period.

The lady's husband is concerned of his wife's condition. Due to the safety bandolier he feels more comfortable and her situation does not affect his work. He is more at home than before the incident, but finds time to continue enjoying his social network.

The family situation is surely affected by the myocardial infarction, but the safety bandolier provides a security that minimises the impact her disease has on the couple's social life.

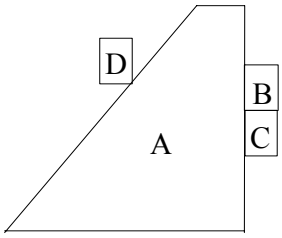
9.2 Feature Description

Medical care and assistance represents a large cost for society. Persons that are at risk of having acquired heart diseases, or people that e.g. have had an operation and feel apprehensive get a decreased quality of life due to their situation. At the same time, the costs of having the persons in hospital are too large. Such patients are also not sick in a sense that in hospital care is needed. These persons and their families can reduce this concern and hereby increase the life quality with the help of a communication device attached to the persons in question. This device possibly consists of a bandolier with relevant sensors attached to it and a GSM unit for continuous communication to supervise selected bodily functions and parameters.

Three possible target groups of patients are considered in the thesis.

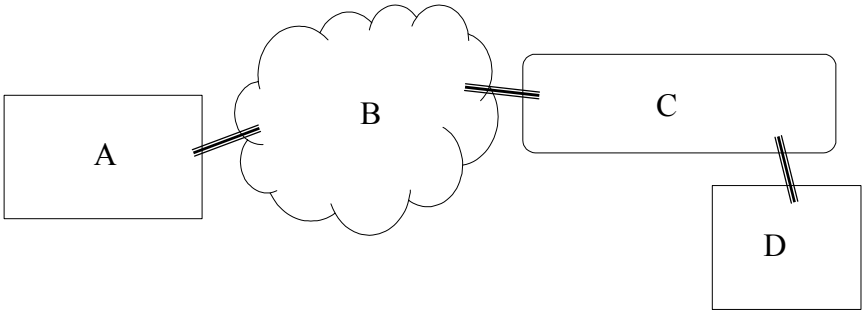
- patients with heart diseases
- patients with lung diseases
- patients with diabetes

By a safety bandolier attached to the body, it is possible to continuously check the electrical activity of the patient's heart. In case of irregularity outside of predefined levels, an alarm is triggered and the medical server at the hospital is noticed by an alert. At the hospital, a diagnosis is made based on the information sent from the safety bandolier. Together with the medical data, information whether the patient is lying or not, and the geographical position is provided from the safety bandolier to the medical server. The doctors at the hospital will decide whether the nearest paramedic will be notified, or if the condition of the patient is satisfactory and no further immediate action is needed. It is also possible that the closest paramedic is notified directly by the safety bandolier to save time. By other sensors[14], it is also possible to measure e.g. tranglutaneous level of carbon dioxide (CO_2), arterial oxygen saturation (SAO_2) and blood glucose level.



A- safety bandolier with sensors
B - battery
C - communication device
D - speaker and microphone

Figure 8 – Sketch of the safety bandolier



A - Safety bandolier
B - GPRS network
C - Secure tunnel through public network
D - Medical server on local network

Figure 9 – Communication path between safety bandolier and medical server

In an emergency situation, it is possible to get continuous Electrocardiogram (ECG) information from the patient. It is also possible to call up the patient to get voice-contact and hereby give or get additional information. By use of automatic voice recognition (AVR), it is possible to make and receive calls for the patient without pressing any buttons. In case of an emergency situation, the patient can also pull a loop in the bandolier to activate the alarm to the emergency centre.

In order to further ensure that the connection between the safety bandolier and the medical server is present, the safety bandolier can do regular polling towards the medical server. In this way, the patient can be alerted in case no contact with the medical server can be achieved.

Local surveillance in the safety bandolier supervises the patient 24 hours a day. This information is stored in a log in the safety bandolier, and can provide medical personnel with selected information from the last day and night. This information can be used to get a better understanding of the clinical situation, and can be accessed on request from the medical server. It is also possible to use this surveillance to get an overview of the patient's condition with respect to medication.

[14] All the selected sensors are selected to exemplify. No major effort is done to evaluate sensors for medical applications.

At night, samples of the patients ECG are downloaded from the safety bandolier to the medical server at the hospital to complete the picture of the patient's condition.

The patient's doctor can, at the medical server, adjust the threshold values that determine if and when the paramedics are informed. It is also possible to change the application in the medical bandolier by updating the surveillance criteria.

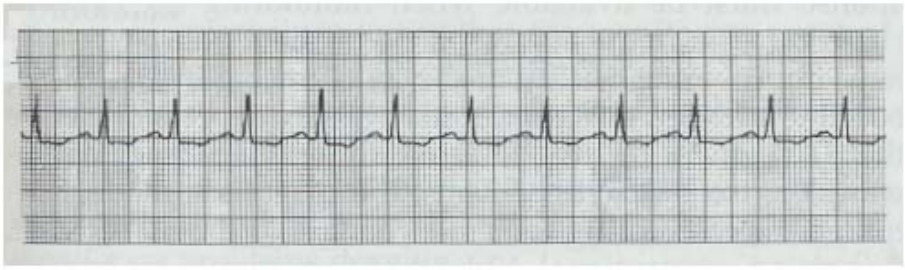


Figure 10 – An example of normal ECG activity

A log is made for all communication between the medical server and the bandolier. The log shows all communication, and is a part of the patient's medical journal.

The communication path between the network operator and the local network where the medical server is located must be secured in order to prevent unwanted access towards the safety bandolier as well as towards the medical server.

Figure 11 – An example of atrial fibrillation

On the bandolier, the sensors are attached to the fabrics, in order not to get out of position or fall off when the patient moves. On the device, the battery can be changed or charged as an ordinary cellular telephone. It is also proposed to get continuous ECG information or the stored information from the 24 hours supervision period from plugs in the device. In this way, the paramedic can attach a monitor to the safety bandolier and get instant ECG information.

9.3 Technical Issues

9.3.1 Measurements and Signal Conditioning

Electrocardiogram is used to measure changes in the electrical activity in the heart. 3 electrodes are attached to the patient's chest. In a sound heart, the activity is shown as a characteristic curve. In case of irregularities in the heart rhythm, the normal characteristic curve is replaced by a curve with another appearance. ECG is proposed sampled 300 times per second with a resolution of 8 bits per sample.

Carbon dioxide is produced in the body's metabolism and is removed from the body through the lungs in the process of ventilation. The level of carbon dioxide is thus a measurement of intact ventilation. CO_2 is proposed sampled 1 time per minute with a resolution of 16 bits per sample.

Arterial level of haemoglobin saturated with oxygen gives an indication of whether the patient has an intact lung-function or not. SAO_2 is proposed sampled 1 time per second with a resolution of 16 bits per sample.

A meticulously controlled level of blood glucose is necessary for good body function and cerebral function. Diabetics need to get artificial insulin in order to control their level of blood glucose, and they may easily drop outside 'normal' values in cases of incorrect doses or intercurrent diseases. Blood glucose level is sampled 1 time per hour with a resolution of 16 bits per sample.

The sensors are based on skin measurements. An analogue measured value is converted to a digital sample, amplified and transferred to the medical server in the network.

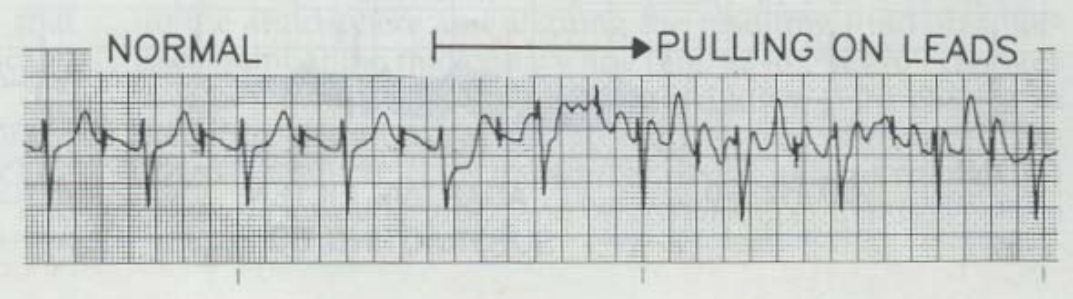


Figure 12 – Motion artefact caused by pulling on an ECG lead

In hospitals, the electrodes can be carefully attached. On a bandolier, the environment can not be controlled or maintained to the same extent. Figure [12] illustrates how the ECG waveform is distorted because the leads are pulled. While persons are in motion, such distortion is assumed one possible source of misleading information that may occur. Figure [13] shows how the ECG can be muted because the electrodes are not properly attached to the skin. Advanced signal conditioning and perfect signal transmission can never be better than the input signal.

The faults introduced by the patients because sensors are not properly attached may be a major source of false alarms. A voice connection from the person at the medical server to the patient is proposed. A conversation is assumed to reduce the number of such false alarms. At the same time, such alarms are time consuming and may be experienced as a major problem for the medical personnel.

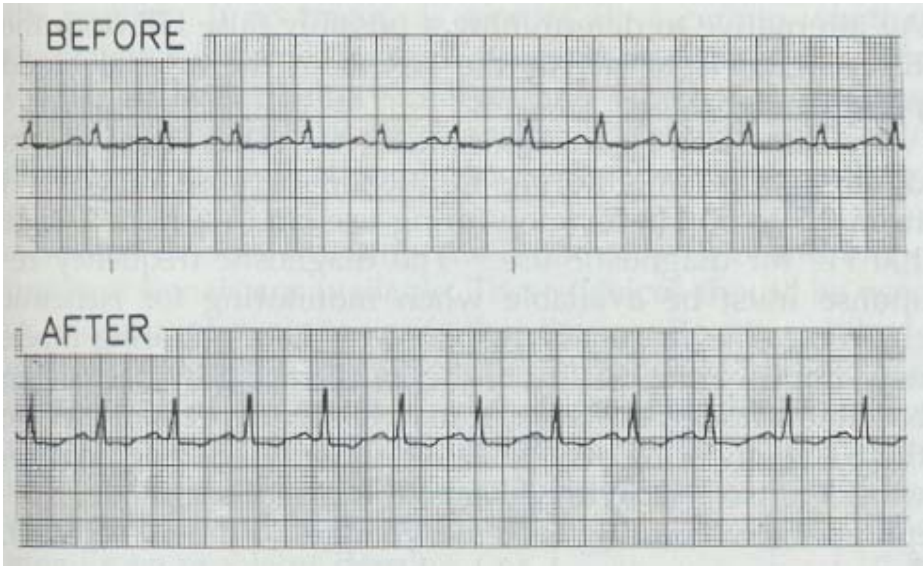


Figure 13 – An ECG waveform before and after proper skin preparation

9.3.2 Set-up and response times

An overview of the network is given in [Figure 9]. As the communication is performed by GPRS, the patient is always attached to the network and has a PDP context activated 24 hours a day. This ensures a fast access to the medical server, as no call set-up is necessary. To illustrate the response times, WAP is used as an example. Tests at Ericsson in Grimstad using Telenors current GPRS network, shows that 3 – 4 seconds are normal response time. This time is measured from the start of sending a request from the terminal and until a reply is completely received in the terminal from the network server. These WAP-pages have a size of approximately 1 kilobyte.

As the application has a normal surveillance-pattern, most data are sent in the uplink direction from safety bandolier to medical server. The current modules have one timeslot only in uplink direction. This will give slower throughput from the safety bandolier to the medical server than provision of information from the network towards a terminal, as 2 or 3 timeslots are available in the downlink direction.

9.3.3 Capacity[15]

To determine a heart condition, a segment of 20 seconds will give sufficient information for medical personnel to determine heart condition. If the ECG is measured over frequencies from 0 – 150 Hz and sampled by 8 bits per sample. This gives a bandwidth of 300 Hz * 8 bits = 2,4 kbps. The 20 seconds segment of ECG will then be 2,4 kbps * 20 seconds = 48 kbits of data. This can be transferred in 3,6 seconds[16]. This brief calculation is performed without any considerations of compression of the data. During a 24 hours period, collected and uncompressed data for an ECG will be 207,4 Mbps. The tranglutaneous level of carbon dioxide, arterial oxygen saturation and blood glucose level will not cause any significant increase in the volume of transferred data.

9.3.4 Priority

An emergency situation must get priority in the radio network to minimise the risk of congestion. The QoS levels in GPRS ensure that possible emergency situations are reported over the GPRS network with a higher priority than ‘normal’ data communication. This is needed, as the extensive use of cellular telephones lead to an increasing experience of congestion. In situations where human lives can be involved, the possibility to provide priority is essential in order to minimise the risk of congestion.

9.3.5 Security Issues

It must not be possible to get information from or change information in the module in the safety bandolier or in the medical server. This means that intruders must not be able to break into the communication path between the medical server and the safety bandolier to access any of the endpoints.

The network that belongs to the network operator, between the safety bandolier and the GGSN, is considered secure. From the GGSN to the local network where the medical server is located, the communication must be tunnelled. Firewalls used to secure the local network where the medical server is located, are considered secure, and are not discussed further.

The module located in the safety bandolier may be seen as a possible object for hackers. As GPRS will provide a virtual connection that makes the module always available, it is a possibility for intruders to connect to the application within the safety bandolier. This possibility is new to hackers, and it is considered a substantial risk that intrusion into mobile telephones

[15] Figures for the calculation are partly based on information found in products from [43]

[16] Assumed GPRS code scheme 2; 13,4 kbps

and modules are found interesting and exciting. The module is proposed equipped with a firewall in order to minimise the risk for such intrusions.

Routines to access the patient files in the medical server have not been considered.

9.3.6 Charging

GPRS provides volume based charging, and together with a fixed fee the network and service operator(s) can charge for the transferred data volume and the subscription, including an increased grade of quality of service that will ensure priority. In this way, the network operator gets revenues.

The service must in most situations be assumed operated by a hospital or a private institution as the 3rd party service provider. From the end user point of view, e.g. a hospital or a private institution is assumed the owner of the service. Without this player, no service can be provided. A model where the revenue is shared between the network operator and this 3rd party service provider must be agreed on. A monthly fee for providing the medical surveillance is the easiest method to ensure income for a 3rd party service provider.

In a situation where a hospital equip patients with electronic devices to save space or medical personnel, the charging may be turned around, and the patient is offered a compensation for not staying in the hospital as many nights as originally predicted.

10 EVALUATION OF THE PROPOSED APPLICATION

10.1 Technical Aspects

The success of a medical application as described in the previous chapter depends on several technical aspects. Three key factors are listed and described below.

- Coverage
- Data transfer
- Security
- Implementation
- Convenience

GSM has today a coverage that in most situations is perceived as 100 % by most people. As the packet switched infrastructure GSM offer to a large extent can be realised by SW updates, GPRS will have coverage in the complete GSM area from now. Some M2M applications have small amount of data to transfer. Such services can from a bandwidth point of view be realised by SMS. The medical application described above needs a bandwidth that only can be solved by a circuit switched or a packet switched connection. Upload of ECG information in case of emergency can be solved by both types of connection. Additional communication as e.g. on-line requests from the medical server or regular polling to ensure a proper connection from the safety bandolier is considered to require a connection with a packet switched characteristics to be efficient. GPRS is considered a key technology that must be available in order to take the proposed application into operation.

As stated earlier, surveillance [page 22] is a type of applications with a communication pattern different from most other application types. The major part of data is sent in uplink direction. As the current focus is on applications with the opposite communication pattern, the availability modules with more than one timeslot for communication in the uplink direction is limited. This is considered to be a problem only in a short time frame. A limited number of vendors with more than one timeslot available for uplink traffic in GPRS telephones and modules are known at the moment. No papers have been found discussing the share of the asymmetric traffic pattern in mobile systems. However, if downloading of information to portable devices will be a major part of mobile data communication, the operators is assumed positive to applications where a major part of the application upload data.

Security aspect is an important issue that must be ensured for the patients. Security at the premises where the medical server is located is assumed taken care of by proper operational procedures, password protected logins and firewalls between the local intranet and the Internet. Current technologies are also available to ensure a secure connection between the local network and the network of the GSM operator. A possible security problem for GPRS as technology may be that frauds attempt to access the application in the module. Such attempts may not be a security problem as such, but accessing the client SW may destruct the application. This medical application may not be as vulnerable as many other applications, as the communication path is secure outside of the network operator.

This application is considered to need an enhanced module [29]. Audio is regarded as necessary as this can cover up for possible problems in case of problems with the ECG or the positioning. Audio may also serve as a back up in case of technical problems that may be experienced, in particular in an introductory phase. The drawback is that audio may be found necessary to use in an emergency situation. In such a situation, transfer of information over the GPRS network may be initiated at the same time. As the voice connection normally performed by a circuit switched call, the simultaneously use of a CS and a PS connection, will require a class A MS alternatively to use voice over IP for the voice connection over the packet switched network.

Positioning will be needed, and as a GPS receiver is included in the enhanced module, E-OTD and GPS can be used in combination in order to have as detailed and robust basis for positioning as possible. As GPS has a weak signal and often require line-of-sight to the satellites, may be a problem both because the patients often will stay indoors and because the receiver is located at the body and clothes may further weaken the signal.

A separate processor is needed where the medical client application is running and the 24 hours log is stored. Together with the processor and memory, a number of external interfaces to sensors and medical surveillance equipment are also needed.

The physical size of the device is not considered to be critical, as the module is reasonably small. The size and convenience of the sensors as such may be a bigger concern in this matter. The battery capacity may be found too small, ~ 100 hours standby time and ~ 4 hours of speech indicates that a recharged battery may be replaced 2 – 3 times every week. The normal temperature range of modules is -20 to +55°C. As people with a slightly reduced general condition intend to use the device, this is considered sufficient.

Interference on the ECG or on an pacemaker from the GSM radio communication, or interferrence is a potential problem. This has not been studied, but with sensors attached to the patient's chest and a transmitter / receiver in the armpit, this may be a problem.

10.2 Human Factors

The feeling of increased safety is an important factor for people. To get a serious disease is a chock both for the person that is directly affected and for the family. Means that ease the situation for such persons will in many situations be met by a positive attitude. A remedy that many people will find inconvenient may be found helpful and acceptable by people with particular needs. The safety bandolier is, due to this, considered acceptable. An example of a similar bandolier has not been found and prototyping is required to ensure both convenience and adequate connection of the sensors.

The development of society has also changed the attitude of people with diseases. People are not supposed to stay at home in case of a disease. The activity level of people has increased, and the proposed application will be helpful also in such situations. The possibility to continue with the social activity is considered important in order to have a good quality of life.

The nature of the service makes it impossible to be anonymous, but the patients must feel confident that this kind of sensitive information is not given to outsiders. The communication between the medical server and the safety bandolier must be considered a part of the patient's medical journal.

Some people may think the 'science fiction' factor of such an application makes it unrealistic. Most people today own a GSM telephone, and even if the penetration of mobile phones is not so big among older people, it is not assumed found deterrent. In many situations where an older person may be a bit reluctant to such a modern device, the patient's family may convince the person needing such a safety device about the benefits.

10.3 Organising factors

How an organisation is affected by the proposed application, depends on the context the medical surveillance is performed by. If the surveillance is performed by the medical personnel a hospital, it is assumed that the reason for performing remote surveillance is to get patients out of the hospital faster. The medical personnel will get new patients to treat, and it is questionable whether spare time can be assumed for the medical personnel to handle the remote patients. More resources may then be needed to take care of these remote patients.

Such resources can be organised as a separate unit, or the patient can be kept on the department the belonged to at the hospital. This remote surveillance is assumed to have some characteristics different from the routines at a hospital. Irregularities in the measurements can e.g. be due to individual routines or different interpretation of the sensors in an environment less controlled than the hospital. It may be beneficial to let a dedicated department take care of the surveillance, as these persons have more time to get familiar with the remote patients. A separate unit can also have a clear focus on such patients. The benefit with using the regular departments is that the medical personnel know the patients better and have larger in-depth knowledge of the disease.

An alternative to use the organisation at the hospital to take care of medical surveillance is to buy the service from an independent company or organisation. In this way, this post-medical care is not directly coupled to a certain hospital and one unit can serve more than one hospital or medical institution. In case the medical surveillance is intended for older persons without a need for treatment at a hospital, this will be a better organisation. The potential to provide a successful surveillance service is larger in case the service is not coupled to the last part of a hospital stay.

10.4 Introductory Aspects

Technical problems in an introductory phase are always a risk. For a medical application, such problems are a large risk that can cancel the service. Most people experience GSM today as a system with a good coverage. This is a benefit for the medical application, as potential patients and their family must perceive good coverage. It must be realised that this perceived coverage is based on the fact that calls can be made when persons want to call. No study has been found that chart how long time during the day persons are out of radio contact with the GSM system. This is essential, as the perceived ubiquitous GSM coverage must be confirmed by measurements. This is a fundamental issue that must be discussed before the service is introduced.

False alarms because of technical problems with the bandolier and the sensors are also a possible major introductory problem. Voice contact between the medical personnel and the patient may in many situations confirm whether this is a false alarm or not. How the medical personnel shall react on possible false alarms must be decided, as some persons may claim it is no problem even if the sensors can indicate this. The patients' confidence in the application will also be reduced in case too many false alarms are indicated.

To what extent the sensors will measure correct values over long time with varying condition between the bandolier and the body is also not studied. The previous figures (Figure [12] and [13]) show that for example the ECG electrodes will measure faulty values in case the electrodes are not properly secured.

10.5 Strategic Value[17]

Initially, the idea was to equip patients with devices in order to get patients faster out of hospital and introduce a post-hospital period where the patients was under medical observation without physically occupying hospital beds. As the costs per day for having a patient in a hospital bed is large, the benefit of the service and the willingness to invest in the service was considered substantial.

[17] Security and legal aspects of such bodily surveillance, and the possibility that information is passed to people not entitled to it is an important issue. However, this issue has not been discussed, and is no major issue in the thesis.

During my work with the thesis, I have found this to be only the most evident possibility. Health care and safety are areas where many people are willing to spend money. In case the application is intended for patients in a post-hospital period, it will be a part of public health care. The application will reduce the expenses, but will not open for medical surveillance of people that want to get this type of surveillance without medical considerations. In countries with a public health care system it may be found difficult to earn money on medical surveillance.

Private organisations or medical centres may find opportunities to earn money by medical surveillance. Examples on such organisations can be private medical centres, Norwegian Air Ambulance [41] or Falken [42]. One possibility is to let e.g. organisations perform the post-hospital surveillance. This will remove the patients totally from the hospital. The organisations may in this way find additional business.

In addition to perform surveillance of patients coming from hospitals, such organisations can offer surveillance of people that are in e.g. a risk group for myocardial infarction. People can in this way organise surveillance of themselves. People can by this technology then collect information of their body functions. This information can then be used as input to the medical personnel at a hospital in case a disease is discovered.

Persons with certain diseases, as diabetes, can be better controlled by an application offering medical surveillance. Diabetics need to get artificial insulin in order to control their level of blood glucose, and certain information can be accessed by the diabetics to control this level and confirm that e.g. their current diet is satisfactory.

Consulting services can further be considered. Persons can analyse results and perform advisory services to customers. Such advisory services can be to diabetics or other diseases where a proper diet affect bodily functions that is measured and reported to the consultant.

An interactive dialogue between the patient and the medical personnel can be established based on possible findings during the surveillance. This can create a good relation, and fast responses may give an increased feeling of security. For many people, this feeling may be of major importance.

11 CONCLUSION

11.1 Technical Aspects of Modules

Modules are intended for applications with very different needs. Requirements for bandwidth, size, power consumption, external interfaces, audio and positioning cannot be precisely defined. This vast diversity must be considered when modules are developed. To realise this diversity, classify modules according to main requirements and make products according to the classification is considered important.

The classification in a cost sensitive module, a standard module and an enhanced module is proposed, and the main motive for the classification is functionality versus requirements for the different application types.

Voice, is not needed in many applications. This makes it a candidate for being removed. It is not found feasible to remove voice, as it is heavily integrated in current chipsets, and e.g. the DSP is anyway needed for other purposes.

The continuous technology development improves vital factors like size power demand and cost. This will open for new applications. It is expected that it will be soon be possible to have a complete module on a single chip. This is a strong argument for not suggesting any major change to GSM module architecture.

Positioning may be heavily influenced by the U.S. FCC mandate 99-425. This mandate may force development of accurate positioning in mobile handsets to a standard function available in all terminals.

Alternative form factor to the SIM-card should be considered. Such alternatives may be cheaper and is proposed to include application specific SW. A drawback with such modules is that they will have a more tight integration with the network operator, but service specific SIM-cards may open for new possibilities.

A firewall included in the terminals should be further studied. The packet switched technology often use IP as a bearer for the application SW, and certain implementations of the TCP/IP protocol is vulnerable to intruders. People interfering in the SW of mobile devices may create problems. Modules, often connected to external machinery may be more exposed to this than mobile telephones.

Charging based on perceived value of the transmitted data instead of the duration or the volume of the transaction may also give increased income to the 3rd party service operator. Charging based on perceived value of transmitted data can change current charging methods.

11.2 Aspects of the Medical Concept

The concept as such has been discussed with medical personnel and found attractive. Hospital beds as well as medical personnel can be better utilised by using modern technology. The application may also help people that get nervous and do not continue their social life because they fear a relapse.

The activity level and the trust on and knowledge about technology is considered to reduce the ‘science fiction’ factor of such an application, and make people believe in the benefits such an application can offer.

The information given by the safety bandolier is assumed included in the patient’s medical record. This will improve the record and strengthen the basis for the diagnosis. The security aspects of this increased use of electronic medical record accessible from various sources must be considered carefully.

To let the post-medical care be performed by a separate organisation is considered beneficial. The competence of particular issues of the medical surveillance may be better in a dedicated organisation. The potential to provide a successful surveillance service is larger in case the service is not coupled to the last part of a hospital stay.

It is important that the patients understand the limitations of the application. A safety bandolier may assist a doctor in giving the patient correct medication or ensure a fast call for assistance in case of an emergency situation. However, the bandolier is not an active helping device, and has limitations with respect to e.g. coverage.

False alarms may be a problem. To reduce possible false alarms, the safety bandolier is assumed equipped with a cellular telephone to be able to communicate with the patient. Too many false alarms will reduce the patient's confidence in the application.

Value added services will open for increased revenues or entirely new business. Such applications can be introduced by e.g. private organisations or consulting services. By using the M2M communication in an interactive session, functionality outside of the original scope can be offered. In many situations, an application is not found cost-effective as stand-alone. The compound of several applications may be necessary to justify the costs of the equipment.

11.3 Suggestions for Further Work

Studies to consider the need for inclusion of a firewall in the module should be performed.

SIM-card manufacturers and network operators should evaluate the possibilities for service specific SIM-cards for simple applications.

Possible interference between the GSM signalling and medical equipment as ECG and pacemaker must be studied.

The medical concept should be further studied and evaluated. It is proposed to let Ericsson and Ortivus cooperate with aspects of the module, the medical sensors and the medical application. To realise the network services, Netcom as network operator and Maingate as service operator are proposed, as the companies already have signed an agreement to be partners in Norway. Norwegian Air Ambulance is a candidate for acting as a 3rd party service provider towards a Norwegian hospital acting as an end user. By combining knowledge, the different players may create a medical application as proposed in the scenario.

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13 ABBREVIATIONS

AOA	Angle Of Arrival
ATM	Automated Teller Machine
AVR	Automatic Voice Recognition
bps	bit per second
BTS	Base Transceiver Station
BSC	Base Station Controller
BSS	Base Station System
CAN-bus	Controller Area Network - bus
CBC	Cell Broadcast Centre
CDMA	Code Division Multiple Access
CGF	Common Gateway Functions
CS	Circuit Switched
CSD	Circuit Switched Data
DSP	Digital Signal Processor
EDGE	Enhanced Data rates for GSM evolution
EIR	Equipment Identity Register
EMC	ElectroMagnetic Compatibility
ETSI	European Telecommunications Standards Institute
EWT	Embedded Web Technologies
E-OTD	Enhanced Observed Time Difference
FCC	Federal Communications Commission
GPS	Global Positioning System
GGSN	Gateway GPRS Switching Node
GPRS	General Packet Radio Service
GSM	Global System for Mobile communication
gsmSCF	GSM Service Control Function
GTD	Geometric Time Difference
HLR	Home Location Register
IC	Integrated Circuit
IC-SIM	Integrated Circuit Subscriber Identity Module
IN	Intelligent Network
IR	Infra Red
ISDN	Integrated Services Digital Network
I^2C-bus	Inter IC bus
I/O	Input / Output

HSCSD	High Speed Circuit Switched Data
HW	HardWare
kbps	kilo (10^3) bit per second
LCS	Location based Services
LMU	Location Measurement Unit
Mbps	Mega (10^6) bit per second
MExE	Mobile Execution Environment.
MLC	Mobile Location Centre
MS	Mobile Station
MSC	Mobile services Switching Centre
MT	Mobile Termination
M2M	Machine to Machine
OTD	Observed Time Difference
PDN	Packet Domain Network
PLMN	Public Land Mobile Network
POS	Point Of Sales
PSTN	Public Switched Telephone Network
RTD	Real Time Difference
QoS	Quality of Service
SGSN	Serving GPRS Switching Node
SIM	Subscriber Identity Module
SMLC	Serving Mobile Location Centre
SMS	Short Message Service
SM-SC	Short Message Service Centre
SMS-GMSC	Short Message Service Gateway Mobile services Switching Centre
SMS-IWMSC	Short Message Service InterWorking Mobile services Switching Centre
SPI	Serial Peripheral Interface
SW	SoftWare
TDMA	Time Division Multiple Access
TE	Terminal Equipment
TETRA	Trans-European Trunked Radio
TOA	Time Of Arrival
UART	Universal Asynchronous Receiver / Transmitter
UMTS	Universal Mobile Telecommunications System
USSD	Unstructured Supplementary Services Data
USB	Universal Serial Bus

VLR	Visitor Location Register
WAP	Wireless Application Protocol
WWW	World Wide Web
3GPP	3rd Generation Partnership Project