Graz University of Technology

"Institute of Communication Networks and Satellite Communications"
and
"Institute for Navigation and Satellite Geodesy"

MASTER THESIS

"Integrated Navigation and Communication Platform for Disaster Management"

by:
Driton KUÇI, Bachelor of Electrical Engineering

Thesis supervisors:
Univ.-Prof. Dipl.-Ing. Dr.techn. **Otto Koudelka**
Univ.-Prof. Dipl.-Ing. Dr.h.c.mult. Dr.techn. **Bernhard Hofmann-Wellenhof**

Graz, May 2011

Acknowledgments

First I would like to thank my parents, my fiancee Albana and my siblings. I would not have achieved to complete my studies and my master thesis without their help and love. They supported me to work on my dreams in order to make them come true. Special thanks goes to my father for all his contribution and support for my preparation for my studies, specially during the high school when he was my Math teacher.

I sincerely thank the company **"TeleConsult Austria"** GmbH [1], which made it possible for me to implement the practical part of my master thesis and all co-workers for their preparedness to help me anytime with their experience and suggestions.
Special thanks goes to my supervisors: Univ.-Prof. Dipl.-Ing. Dr.techn. Otto **Koudelka** and Univ.-Prof. Dipl.-Ing. Dr.h.c.mult. Dr.techn. Bernhard **Hofmann-Wellenhof** for their scientific and technical advice.

I would like also to thank two institutes of Graz University of Technology, "Institute of Communication Networks and Satellite Communications - IKS" and "Institute for Navigation and Satellite Geodesy - INAS" for their logistics support.

Graz, May 2011 Driton Kuçi

Abstract

This integrated navigation and communication platform will be used in disaster cases in order to manage the rescue operation efficiently. The needs for fast, well organized, effective and synchronized intervention in those disaster cases predefines the requirements of the platform.

The practical part of this master thesis is part of the project "Search And Rescue Optimisation by satellite Navigation Technologies in Alpine Regions - **SARONTAR**" [2], where the company **"TeleConsult Austria"** GmbH and both institutes **INAS** and **IKS** are part of it.

The whole platform (system) consists of three main parts: mobile teams, server and managing center. The platform combines several systems such as: navigation system, satellite communication, Bluetooth technology, etc. The main topic of this master thesis is the application of the mobile teams but the server and managing center applications are also described.

The application of the mobile teams runs in smartphones which support touch-screen, Bluetooth technology, data transfer (GPRS), virtual serial ports, different display orientation (optional), GPS and camera (optional).

Communication between mobile teams and the managing center is realized via the server, thus a direct connection between them is not possible. Mobile teams establish connections with the server either via mobile (cellular) network or via satellite.

The server part consists of the server application and a database where all the communication traffic is stored.

The applications of the managing center and the mobile teams show a digital map of the disaster region. On this digital map search sectors, actual position and tracks of mobile teams, position of any other important objects can be shown.

Zusammenfassung

Die integrierte Navigations- und Kommunikationsplattform "SARONTAR" wird für Einsatzorganisationen als zusätzliches Hilfsmittel in Katastropheneinsätzen weiterentwickelt. Durch dieses Gesamtsystem kann ein schnellerer, koordinierterer und effektiverer Rettungseinsatz der Verunglückten und Vermissten in Katastrophenfällen durchgeführt werden.

Der praktische Teil dieser Masterarbeit ist Teil des Projektes "Search And Rescue Optimisation by Satellite Navigation Technologies in Alpine Regions - **SARONTAR**" [2]. Dieses Projekt wird mit der Firma **"TeleConsult Austria"** GmbH und den Instituten **INAS** und **IKS** der Technischen Universität Graz durchgeführt.

Das Gesamtsystem setzt sich aus drei Hauptteilen zusammen: Mobile Teams, Server und Einsatzzentrale. Für die Realisierung werden unterschiedlichste Technologien, wie Navigationssysteme, Satellitensysteme, Bluetooth-Technologie, Kamera, GPS-Empfänger und die paketbasierte Datenübertragung, miteinander verknüpft.

Als Kommunikationssystem wurde eine Client-Server Struktur verwendet. Dies bedeutet, dass die mobilen Teams mit der Leitzentrale und umgekehrt über einen zentralen Server kommunizieren.

Der Kommunikationsaufbau zwischen mobilen Teams und Server kann mittels Mobilfunknetz oder Satellitennetz erfolgen.

Der Server besteht aus einer Serveranwendung und einer hinterlegten Datenbank, in der der gesamte Kommunikationsverkehr für Einsatznachbesprechungen gespeichert wird.

Die visuelle Darstellung des Katastrophengebietes erfolgt sowohl in der Einsatzzentrale als auch an den mobilen Geräten der Teams mit Hilfe einer digitalen Karte, in der Suchsektoren, aktuelle Positionen und der zurückgelegte Weg der mobilen Teams, sowie andere wichtige Objekte und Punkte dargestellt werden.

Përmbledhje

Kjo platformë e integruar për navigim dhe komunikim do të përdoret në raste të fatkeqësive me qëllim të menagjimit sa më të mirë të operacionit të shpëtimit të personave që ju duhet ndihmë. Kërkesat kryesore të platformës definohen nga nevoja për një intervenim të shpejtë, të organizuar mirë, efektivë dhe të sinkronizuar në raste të fatkeqësive.

Ana praktike e kësaj teme të diplomës është pjesë e projektit "Search And Rescue Optimisation by satellite Navigation Technologies in Alpine Regions - **SARONTAR**" [2], ku pjesëmarrës në këtë projekt janë firma **"TeleConsult Austria"** GmbH dhe dy institutet **INAS** dhe **IKS**.

E tërë platforma, gjegjësisht sistemi, përbëhet nga tri pjesë kryesore: ekipet mobile (lëvizëse), serveri dhe qendra menagjuese. Platforma kombinon disa sisteme si psh.: sistemin për navigim, për komunikime satelitore, teknologjinë Bluetooth e kështu me rradhë. Pjesa kryesore e temës së diplomës është programi (aplikacioni) i ekipeve mobile, por gjithashtu përmban edhe një përshkrim edhe për programet e serverit dhe të qendrës menagjuese.

Programi i ekipeve lëvizëse ekzekutohet në telefona mobil më të përsosur, të ashtuquajtur të menqur (nga fjala smartphone në gjuhën angleze) të cilët mbështesin ekranet e ndjeshme në prekje (touch-screen), teknologjinë Bluetooth, transferim të të dhënave (GPRS), portet virtuale seriale, orientim të ndryshëm të ekranit (opcionale): portret dhe peizazh (portrait, landscape), të cilët gjithashtu janë të pajisur me GPS pranues si dhe me fotoaparat (opcionale).

Komunikimi ndërmjet ekipeve mobile dhe qendrës menagjuese realizohet vetëm përmes serverit dhe jo direkt ndërmjet tyre. Ekipet mobile realizojnë lidhjen me serverin përmes rrjetit mobil (celular) ose përmes satelitit.

Pjesa e serverit përbëhet nga aplikacioni i serverit si dhe baza e të dhënave, në të cilën është i ruajtur i tërë trafiku komunikues ndërmjet ekipeve lëvizëse dhe qendrës menagjuese.

Në të dy programet, si te ai i qendrës menagjuese ashtu edhe te ai i ekipeve mobile përdoren harta digjitale të regjionit ku ka ndodhur fatkeqësia (regjioni ku duhet të zhvillohet operacioni i shpëtimit). Në këtë hartë digjitale mund të paraqiten: sektorët kërkues, pozita aktuale dhe trajektoret e ekipeve mobile, pozita e ndonjë objekti tjetër me rëndësi e kështu me rradhë.

Deutsche Fassung:
Beschluss der Curricula-Kommission für Bachelor-, Master- und Diplomstudien vom 10.11.2008
Genehmigung des Senates am 1.12.2008

EIDESSTATTLICHE ERKLÄRUNG

Ich erkläre an Eides statt, dass ich die vorliegende Arbeit selbstständig verfasst, andere als die angegebenen Quellen/Hilfsmittel nicht benutzt, und die den benutzten Quellen wörtlich und inhaltlich entnommene Stellen als solche kenntlich gemacht habe.

Graz, am 18.04.2011 ....
(Unterschrift)

Englische Fassung:

STATUTORY DECLARATION

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

18.04.2011 ....
date (signature)

Contents

Acknowledgments ii

Abstract iii

Zusammenfassung iv

Përmbledhje v

Acronyms x

1 Introduction 1
- 1.1 Motivation . . . 1
- 1.2 Master Thesis Overview . . . 3

2 Systems and Services used in the Platform 4
- 2.1 Mobile network . . . 4
  - 2.1.1 Cellular concept . . . 4
  - 2.1.2 GSM network . . . 5
  - 2.1.3 GPRS . . . 7
- 2.2 TCP/IP Protocol suite . . . 9
- 2.3 Navigation Communication - NAVCOM . . . 10
  - 2.3.1 Global Positioning System - GPS . . . 10
  - 2.3.2 NMEA Format . . . 11
- 2.4 Bluetooth Technology . . . 12
- 2.5 Satellite Communication - SATCOM . . . 13

3 Platform Requirements and its Structure 16
- 3.1 Platform Requirements . . . 16
- 3.2 Mobile Team . . . 19
- 3.3 Server . . . 24
- 3.4 Managing Center . . . 28

4 Data Format **32**
4.1 Login Message . . . 33
4.2 Position Message . . . 35
4.3 Status Message . . . 36
4.4 Photo Message . . . 38
4.5 Text Message . . . 39
4.6 Point Of Interest Message . . . 39
4.7 Search Sector Message . . . 40
4.8 Termination Message . . . 41

5 Platform Implementation **43**
5.1 Navigation Communication . . . 44
5.2 Connection Establishment . . . 46
5.2.1 Connection between Mobile Team and Server . . . 48
5.2.1.1 Mobile Team Implementation . . . 49
5.2.1.2 Server Implementation . . . 56
5.2.1.3 Connection Establishing . . . 57
5.2.1.4 Connection Release . . . 57
5.2.2 Connection between Managing Center and Server . . . 58
5.2.2.1 Managing Center Implementation . . . 58
5.3 Communication and Data Transmission . . . 59
5.3.1 Position and Status messages sent by the Mobile Team . . . 61
5.3.2 Photo Transmission by a Mobile Team . . . 63
5.3.2.1 Hiding the Message in the Photo . . . 66
5.3.2.2 Extract the Message from the Photo . . . 68
5.3.3 Text Messages sent by the Managing Center . . . 70
5.3.4 Handling the messages in the Server . . . 70
5.4 Digital Maps . . . 75
5.4.1 Digital Maps in the Web Application . . . 76
5.4.2 Digital Maps in the Mobile Team Application . . . 77
5.5 Other Services of the Platform . . . 80

6 Testing the Platform in Terrain **81**
6.1 Simulated Rescue Operation . . . 81

7 Summary and Outlook **87**
7.1 Summary . . . 87
7.2 Outlook . . . 88

A Rescue Operation Report **89**

List of Figures **93**

List of Tables **95**

Bibliography **96**

Acronyms

A

APN	Access Point Name
ASCII	American Standard Code for Information Interchange

C

CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications
CPU	Central Processing Unit
CR	Carriage Return
CS	CheckSum
CSD	Circuit Switched Data

D

DBS	Direct Broadcast Satellite
DGPS	Differential GPS
DHCP	Dynamic Host Configuration Protocol
DoD	Department of Defense
DUN	Dial-Up Network

E

EDGE	Enhanced Data rates for GSM Evolution
EDR	Enhanced Data Rate
EPIRB	Emergency Position Indicating Radio Beacons
ETSI	European Telecommunication Standards Institute

F

FDMA	Frequency Division Multiple Access
FHSS	Frequency Hopping Spread Spectrum
FIFO	First In First Out
FTP	File Transfer Protocol

G	
GEO	Geostationary Earth Orbit
GIS	Geographic Information System
GLONASS	GLObal NAvigation Satellite System
GmPRS	Geo Mobile Packet Radio Service
GMSK	Gaussian-filtered Minimum Shift Keying
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
H	
HDOP	Horizontal Dilution Of Precision
HEO	Highly Elliptical Orbit
HSDPA	High-Speed Downlink Packet Access
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
I	
IANA	Internet Assigned Numbers Authority
IEEE	Institute of Electrical and Electronics Engineers
IKS	Institut für Kommunikationsnetze und Satellitenkommunikation Institute of Communication Networks and Satellite Communications
IMT2000	International Mobile Telephony
INAS	Institut für Navigation und Satellitengeodäsie Institute for Navigation and Satellite Geodesy
iOS	iPhone OS
IP	Internet Protocol
IPv4	Internet Protocol version four
IPv6	Internet Protocol version six
IrDA	Infrared Data Association
ISDN	Integrated Services Digital Network
ISM	Industrial, Scientific and Medical
ISP	Internet Service Provider
J	
JFIF	JPEG File Interchange Format
JPEG	Joint Photographic Experts Group
L	
LAN	Local Area Network
LEO	Low Earth Orbit
LF	Line Feed
LSB	Least Significant Bit
LOS	Line Of Sight

M

MB	Mega Byte
MC	Managing Center
MEO	Medium Earth Orbit
MFC	Microsoft Foundation Class
MMS	Multimedia Messaging Service
MSB	Most Significant Bit
MT	Mobile Team

N

NAVCOM	NAVigation COMmunication
NAVSTAR	NAVigation Satellite Timing And Ranging
NMEA	National Marine Electronics Association
NNTP	Network News Transfer Protocol

O

OS	Operating System
OSI	Open Systems Interconnection

P

PC	Personal Computer
PDA	Personal Digital Assistent
PHP	Hypertext Preprocessor, original is: Personal Home Page
PIN	Personal Identification Number
PLMN	Public Land Mobile Network
PNG	Portable Network Graphics
POI	Point Of Interest
POP	Post Office Protocol
PSTN	Public Switched Telephone Network
P2P	Point-To-Point

Q

QGIS	Quantum GIS
QPSK	Quadrature Phase Shift Keying

R

RAM	Random Access Memory
Rescue Team	Consists of mobile teams and managing center team
RS232	Recommended Standard 232

S

SARONTAR	Search And Rescue Optimisation by satellite Navigation Technologies in Alpine Regions
SATCOM	SATellite COMmunication
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module or Subscriber Identification Module
SMTP	Simple Mail Transfer Protocol
SQL	Structured Query Language

T

TCA	TeleConsult Austria
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
TFTP	Trivial File Transfer Protocol
Thuraya SG-2520	Handset with satellite, GSM tri-band and GPS functionality

U

UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications System
USA	United States of America
USB	Universal Serial Bus
UTC	Coordinated Universal Time

V

VHF	Very High Frequency

X

XOR	Exclusive OR

W

WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access (Technology)
WGS 84	World Geodetic System 1984
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless LAN
WM	Windows Mobile
WWW	World Wide Web

Number

2D	Two Dimensional
3D	Three Dimensional
3G	Third Generation
3GPP	Third Generation Partnership Project

Chapter 1

Introduction

1.1 Motivation

It was always and it is still a big challenge to provide the right, effective, fast, well-organized help to everyone who needs it, specially in those disaster cases when the life of people is in danger. There have been shown so many reports from all over the world about the disasters where the help "came" too late or the Mobile Teams (MT) did not manage to find the target (injured people) waiting for them because they lost the contact and communication with the Managing Center (MC) and with the other mobile teams in terrain.

This situation holds for Austria too and specially in rescue operations in the Alps after avalanches. Here are cases about avalanches in Austria (actually in Judenburg, Tirol and Salzburg) [3], [4] which unfortunately had a tragic end.

The importance of a fast, effective, well-organized and well-managed rescue operation is shown in Figure 1.1 (original can be found here [5]). It is obvious to see that in short time the probability of survival decreases very fast and there are no minutes to lose. Mobile teams should manage to get to the target as fast as possible, but things would become worse and more complicated if the mobile teams lose the communication with the managing center or with other mobile teams, specially when they need support too.

This platform provides rescue teams an almost permanent communication between mobile teams and managing center (even if there is no mobile network coverage), to observe where are currently the mobile teams in terrain, mark important objects and targets in terrain, split the whole region into small units for each mobile team and some more services which are described in the thesis. The term "almost permanent connection and communication" means that in most of the cases and situations a connection between mobile teams

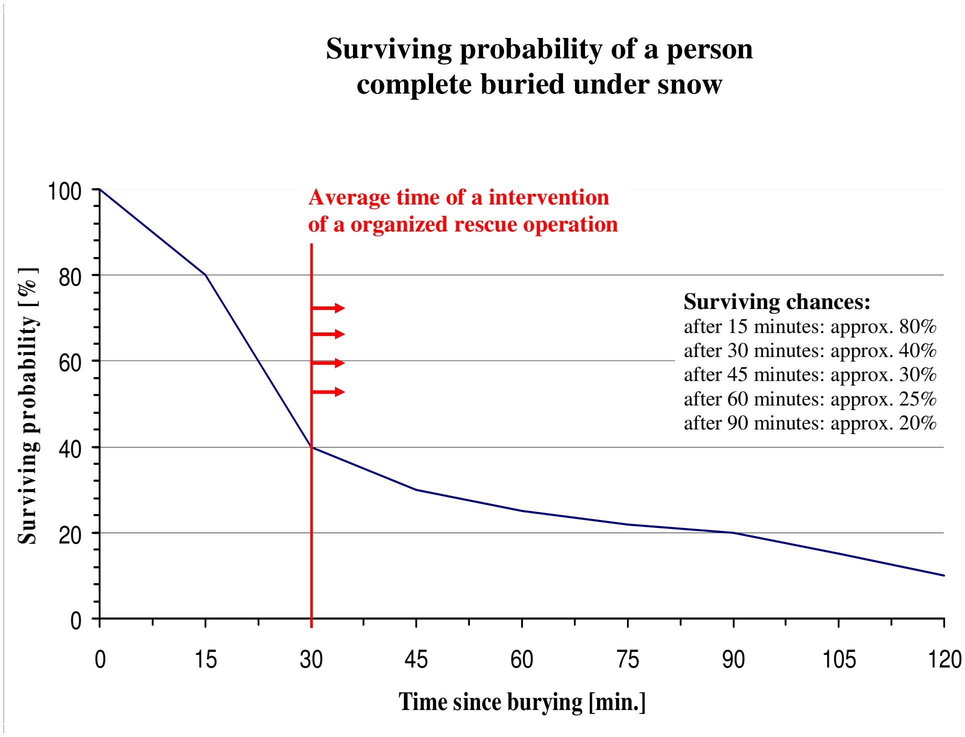


Figure 1.1: Surviving probability

and managing center exists and the communication between them is possible. It is called "almost permanent", because here are also some situations when the connection can be lost. These are described in chapter 5.

The platform brings together mobile (cellular) networks, Bluetooth technology, navigation system and satellite communication. It handles the connections and informs the managing center about the actual position of mobile teams. Thus, the mobile teams do not have to pay so much attention on the platform but can concentrate on the rescue operation.

Helping the rescue teams to make the rescue operation faster, more efficient and almost permanently connected to managing center, indeed will help the people in need, whose life can be in danger.

1.2 Master Thesis Overview

The whole master thesis consists of seven chapters. Chapter 1 gives a brief overview of the actual situation and the need for a platform to help the rescue teams during the interventions, specially the Alpine rescue teams.

Chapter 2 describes the systems, techniques, technologies, protocols and services which would be used in platform, such as: mobile (cellular) networks, GPRS, GPS, Bluetooth technology and satellite communication.

In chapter 3 are defined the platform requirements. Based on these requirements there can be decided about the hardware that is going to be used in platform. Third chapter continues with description of the structure used, topologies and connections. It is more focused on the technical part and specifications of the platform. At the end of this chapter is shown a Figure, 3.9, with a detailed structure of the whole platform.

A description of the messages, such as: types, formats, parameters, lengths and other details, which are used in the platform for communication between teams can be found in chapter 4.

In chapter 5 the implementation of the platform is described: how the connections are established and handled, communication between the managing center and the mobile teams and the database where the whole communication traffic is stored. It is also shown how the synchronization of the shared resources is managed in order to achieve the mutual exclusion. The digital maps used by mobile teams and managing center are explained.

A rescue operation is simulated and it is described in chapter 6. It is supposed that a little child is lost and the mobile teams, organized and managed by the managing center are engaged to find the child. This took place in the district St. Leonhard of the city Graz. Some photos and screenshots of the mobile team application and the web application are presented to make the usage of the platform and the whole rescue operation more understandable.

Chapter 7 provides a summary of the platform and its perspective for the future.

Chapter 2

Systems and Services used in the Platform

In this chapter the systems, techniques, technologies, protocols and services that would be used in platform, such as: mobile (cellular) network, GPRS, GPS, Bluetooth technology and satellite communication will be described.

2.1 Mobile network

2.1.1 Cellular concept

Before the cellular concept has been used, it was a problem to cover a large area with a single antenna (on single frequency). To improve the capacity of mobile systems, the idea is to split the area into small cells and the whole available frequency band into subbands in order to reuse the frequencies. It is necessary to pick such a unit form that does cover the whole area. From Figure 2.1a it is clear to see that the circle cannot be used, because there are left some parts uncovered (marked with red colour). From the other possibilities (triangle 2.1b, hexagonal 2.1c and square 2.1d) the hexagonal form is picked because it has the largest distance from the center to the farthest point in its perimeter (for the same length of the edges) and the hexagon permits easy and manageable analysis. The whole available frequency band from f_{min} to f_{max} is split into subbands, i.e. f_1, f_2, f_3 ... f_m, where `m` is the number of frequency subbands:

$$m = \frac{total\ available\ frequency\ band}{subband\ width} \tag{2.1}$$

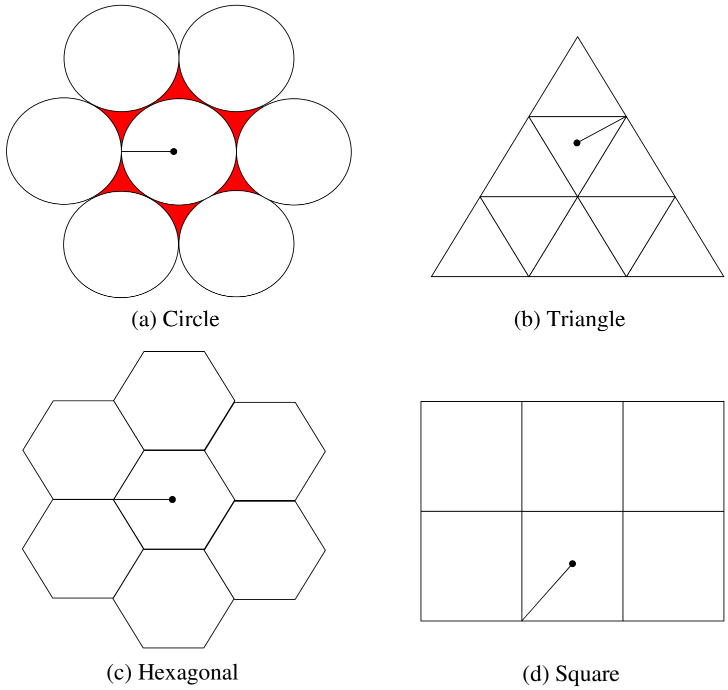


Figure 2.1: Splitting area into units

Each subband is used only once in a cluster (for a single cell). But the good thing is that the cluster can be reused in order to cover larger area (without need of larger frequency band and interferences are much lower) [6]. This is shown in Figure 2.2.

2.1.2 GSM network

GSM stands for "**G**lobal **S**ystem for **M**obile Communication", which in the beginning was known as "**G**roupe **S**pécial **M**obile" formed in 1982 by CEPT (predecessor of ETSI) and its main task was to develop a standard for a mobile telephone system that could be used across Europe. The first GSM network was launched in 1991. Although it was planned only for Europe, nowadays it is active in more than 218 countries. GSM operates in the 900MHz and 1.8GHz bands in Europe and the 1.9GHz and 850MHz bands in USA. It supports voice calls and data transfer speeds of up to 9.6kbit/s [7].

GSM is a cellular network and based on circuit-switching, this means that if two nodes in the system want to communicate with each other they have firstly to establish a channel (circuit) and then send and receive data. The channel (circuit) remains "active" as long

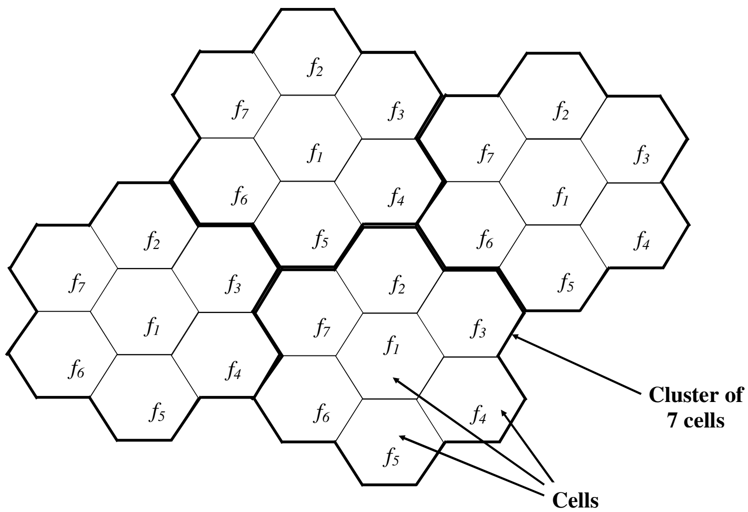


Figure 2.2: Cluster and cells

as any of the nodes wants to drop it and the calling node is charged for the time that the channel was active. According to the GSM specification the longest distance supported in practical use is 35 kilometers.

At the frequency band around 900MHz, GSM uses the band 890-915MHz for uplink and the band 935-960MHz for downlink. Each of these bands (25MHz) is divided into 124 single carrier channels of 200kHz width (the remaining bandwidth of 200kHz is a guardband). GSM uses Gaussian-filtered Minimum Shift Keying (GMSK) as modulation scheme. The GSM multiple access scheme is based on FDMA/TDMA approach [8].

The GSM network architecture consists of four subsystems [9]:

- Mobile Station Subsystem (MSS) - is basically a human-machine interface;
- Base Station Subsystem (BSS) - provides and manages radio access between the MSS and the rest of the GSM network;
- Network and Switching Subsystem (NSS) - is responsible for communication within the same PLMN or with other networks, such as another PLMN, PSTN or ISDN;
- Operation and Support Subsystem (OSS) - provides the means for operation and maintenance of the GSM network, which include monitoring, diagnoses, and troubleshooting.

The GSM services are grouped into three categories [9]:

- TeleServices (TS) - regular telephony, emergency calls and voice messaging;
- Bearer Services (BS) - data services, Short Message Service (SMS), cell broadcast and local features;
- Supplementary Services (SS) - some of these services are: advice of charge, barring of all outgoing, international, roaming calls, call forwarding, call hold, call waiting, call transfer, closed user group, etc.

2.1.3 GPRS

Using GSM to surf in Internet (or to transmit data) is not such a good idea, because it needs to establish a connection which would remain "active" even if no data are sent or received (because GSM is based on circuit-switching). As a solution for this problem came the General Packet Radio Service (GPRS), which is based on packet switching. GPRS has been developed in GSM phase 2+. Packet switching does not require to establish a channel (circuit), but the data to be sent are organized into packets. Each packet has a header, which contains the transmiter and receiver addresses (used for routing packets in the network). The subscribers are charged for the amount of data sent and received and not anymore for the time the channel was active. In order to make GPRS work in the GSM network, there is a need for a new interface in BSS to cooperate with Serving GPRS Support Nodes (SGSNs). For the rest of the GSM network only some small software updates are required [10].

GPRS sends packets, only when they are ready at a rate of up to 115kbit/s, but in practice this rate is up to 40-50kbit/s.

Services offered by GPRS are:

- "Always On" Internet access;
- Multimedia Messaging Service (MMS);
- Instant messaging and presence;
- Internet application for smart devices through Wireless Application Protocol (WAP);
- Point-to-Point (P2P) services: inter-networking with the Internet (IP).

A GPRS subscriber should define an Access Point Name (APN), username and a password (on its device) in order to use GPRS. These three parameters are public to everyone and for every provider (carrier).

Even with the enhancements of the GSM network (GPRS, EDGE) market requirements have been grown, such as: video telephony, TV on subscribers' devices, etc. requiring a new generation of mobile networks called 3G. UMTS is the European member of the 3G. It provides a data rate up to 384 kbit/s. A comparison of data rate provided by GSM, GPRS and UMTS is shown in Figure 2.3 [11].

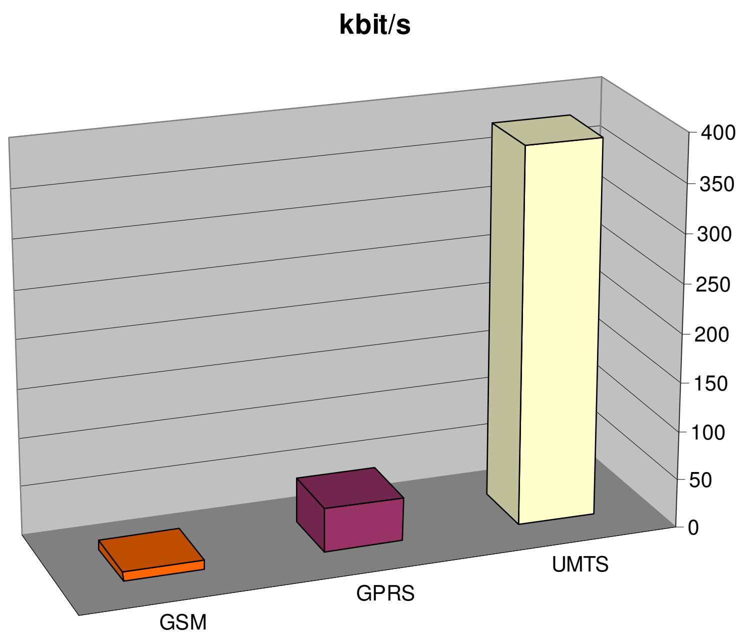


Figure 2.3: Data Rate provided by GSM, GPRS and UMTS (Release 99)

2.2 TCP/IP Protocol suite

There is no official TCP/IP model as there is in the case of Open Systems Interconnection (OSI), but communication task for TCP/IP can be organized in five relatively independent layers, shown in Figure 2.4 [12], where the **Transport Layer** provides

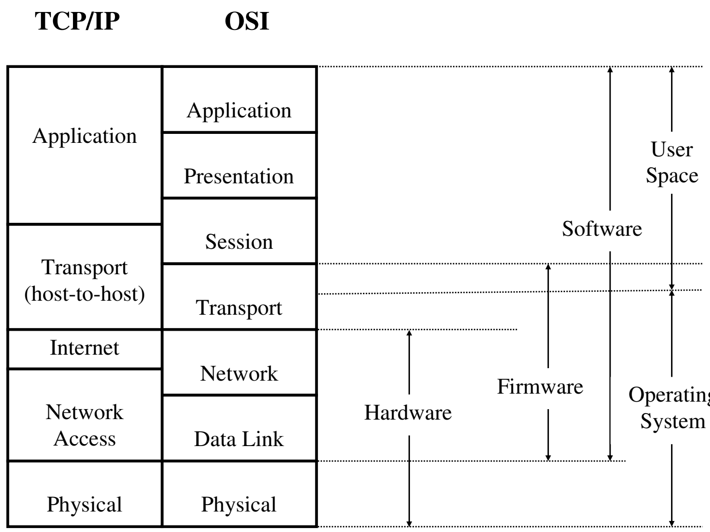


Figure 2.4: TCP/IP and OSI architecture

end-to-end, data-transfer service and the **Internet Layer** is concerned with routing data from source to destination host through one or more networks connected by routers, based on their addresses. As far as the main task of IP is to "find" the destination host in that bunch of networks, TCP provides a reliable end-to-end (bidirectional) byte stream [13]. TCP provides a full duplex P2P connection and not multicasting or broadcasting.

Services offered by TCP are defined in terms of primitives and parameters. A set of primitives used in Berkeley UNIX for TCP is shown in Table 2.1 [13]. These primitives are widely used in network programming. They are used by both end points of the connection (call them server and user) to define the parameters, such as IP address and port of the other part of connection, by using primitives `SOCKET` and `BIND`. Server `LISTENS` for any connection request from the user in order to establish the connection. TCP uses a three-way handshake connection establishment protocol. Then server and user can send and receive data over the connection established until one of them wants to `CLOSE` the connection or if any timeouts occur. These primitives are used as well in platform to establish the connection between mobile teams and server as well as between managing center and server, but this will be described in more details in next chapters.

Table 2.1: Socket primitives for TCP

Primitive	**Meaning**
SOCKET	Create a new communication end point
BIND	Attach a local address to a socket
LISTEN	Announce willingness to accept connections
ACCEPT	Block the caller until a connection attempt arrives
CONNECT	Actively attempt to establish a connection
SEND	Send some data over the connection
RECEIVE	Receive some data from the connection
CLOSE	Release the connection

2.3 Navigation Communication - NAVCOM

2.3.1 Global Positioning System - GPS

GPS is a navigation system based on satellites. In the beginning it was used for military purposes. It was financed and is still under responsibilities of Department of Defense (DoD) of USA and it was known as NAVigation Satellite Timing And Ranging (NAVSTAR). In 1996, a policy directive issued by U.S. President Bill Clinton, declared GPS a system also for civil, commercial and scientific worldwide purposes [14].

GPS consists of three segments:

- Space segment;
- Control segment;
- User segment.

The nominal satellite constellation consists of 24 satellites, which travel at approximately 11.265 km/h, at a distance about 20.200 km from the Earth's surface. Thus, a signal needs between 65 and 68 milliseconds to pass this distance. Each satellite is planned to have a lifetime up to 10 years (they are continually monitored and replaced by DoD). The satellites use solar energy for their power and to charge batteries, which are used when satellite is in the Earth's shadow. The power of the transmited signal from a satellite is about 50 watts or less. The signals used for civil purposes use L1 frequency of 1575.42MHz in the L-band. They pass through glass, clouds and plastic, but most of solid objects, such as buildings, metals, even water are unpassable for them. Each satellite transmits a GPS signal which contains:

- Pseudorandom code - used to identify the satellite that is transmiting;
- Ephemeris data - implies the orbital data, shows the status of the satellite (healthy or unhealthy), date and time;
- Almanac data - tells the GPS receiver where each GPS satellite should be at any time throughout the day.

The GPS receiver computes firstly the travel time of a message from the satellite and then computes the pseudo-distance to the satellite, according to the travel time. Using trilateration method (a method used to determine the intersection of three sphere surfaces when the centers of spheres and their radii are known) the GPS receiver position can be determined. There are three satellites needed, at least, in order to calculate the 2D position (latitude and longitude), but with four or more satellites available it is possible to determine the user's 3D position (latitude, longitude and altitude) [15]. GPS is free of charge and can be used 24 hours a day in any weather conditions from everywhere in the world, except under water, inside the buildings or inside the caves. Thus, GPS is very usefull to determine any location in the world (when there is Line Of Sight - LOS) and the velocity of any object.

Other global navigation systems based on satellites which are under development phases or are in use, are: **GALILEO** (European system), **GLONASS** (Russian system) and **COMPASS** (Chinese system).

2.3.2 NMEA Format

The National Marine Electronics Association (NMEA) is a non-profit association of manufacturers, distributors, dealers, educational institutions, and others interested in peripheral marine electronics occupations. NMEA proposed a standard (NMEA-0183) which defines an electrical interface and data protocol for communications between (marine) devices, such as: echo sounder, sonars, anemometer, autopilot, GPS receivers, etc. The standard is intended to support one-way serial data transmission by a single talker to one or more listeners and this data are transmited in American Standard Code for Information Interchange (ASCII) form and may include information such as position, speed, depth, frequency allocation, etc [16].

Data transmitted are organized in units called sentences with a maximal number of characters of 82. Every sentence starts with sign "$" and ends with Carriage Return (CR) and Line Feed (LF). There are three basic types of sentences [16]:

- Talker sentences - after "$" sign, the address field comes. It consists of five characters. The first two characters are `talker identifier` and the other three are `sentence identifier`. The address field is followed by a number of data fields separated by comma. Before the CR an optional checksum can be used. The checksum field consists of an asterisk symbol "*" and two hexadecimal characters, which represent XOR of all characters excluding "$" and "*";
- Proprietary sentences - used by manufactures to define their own sentences;
- Query sentences - used by the listeners to send requests to talker.

2.4 Bluetooth Technology

Bluetooth has been designed to make it possible to connect devices, in short ranges, without cables and even if there is no LOS between them. Bluetooth is also considered a replacement of Infrared Data Association (IrDA), which requires LOS for connecting two devices. Bluetooth is named after Harald Blaatand (Bluetooth) II (940-981), a Viking king. It has been standardized under the standard IEEE 802.15.1.

Although there are so many different vendors of Bluetooth enabled devices, Bluetooth makes it possible to connect these devices to each other, exchange data, files, calendar entries, address books, etc. Bluetooth enables also the use of the mobile phones (smartphones too) as gateway for external devices like PCs, laptops, PDAs to connect to the Internet. This service will be used in platform as well when the satellite handheld will be used as gateway for the mobile team to connect (via satellite) to the server. Bluetooth also supports speech transmission between a mobile phone and a headset (specially used while driving).

The data rate of the Bluetooth transmission channel (divided into timeslots of 625 microseconds) is shared between devices that communicate directly with each other. Bluetooth version 1.2 achieves a data rate of maximal 780 kbit/s. With Version 2.0 + Enhanced

Data Rate (EDR) it is up to 2.178 Mbit/s. Bluetooth uses the 2.4GHz ISM band (2.4 - 2.4835 GHz), divided into 79 channels each of 1MHz. It uses the Frequency Hopping Spread Spectrum (FHSS) technology (with 1600 hops/sec) because the ISM band is also shared with other networks. Thus, Bluetooth devices switches between these channels after each packet has been sent [11].

There are three different classes of Bluetooth transmitters:

- Class 1 - outputs 100 mW for maximum range (approx. 100 m);
- Class 2 - outputs 2.4 mW at maximum (approx. 10 m);
- Class 3 - nominal output is 1 mW (1 m).

2.5 Satellite Communication - SATCOM

In cases where terrestrial connection is not possible for any reasons, such as: rough terrain, long distances, high costs or if any known wireless technologies (2G, 3G, WiMAX) can not be used to establish a connection then a communication via satellite would be the solution, even if the costs are high. The first satellite was launched in 1957 and it was called SPUTNIK 1. It transmitted telemetry information for 21 days. The first communication satellite, Telstar, was launched in July 1962.

Nowadays services provided by satellite networks include a wide range, such as: military, weather, radio and TV, telephony, Internet, mobile communication, navigation and positioning, tele-medicine, tele-education, etc.

The following satellite orbits are relevant:

- Low Earth Orbit (LEO): distance from Earth's surface 800 - 1.700 km;
- Medium Earth Orbit (MEO): distance from Earth's surface 6.000 - 20.000 km;
- Geostationary Earth Orbit (GEO): distance from Earth's surface approx. 36.000 km;
- Highly Elliptical Orbit (HEO): distance from Earth's surface up to 40.000 km.

With the distance of 20.200 km from Earth's surface, GPS belongs to MEO Orbit, as well as GALILEO (approx. 23.222 km, until now only two test satellites have been launched) and GLONASS (approx. 19.100 km). The GEO orbit is in the equatorial plane, thus it has an inclination angle of 0°. GEO Satellites have the same rotation period as the Earth, i.e. by observing satellites from the Earth's surface they appear always at the same position in the sky and there is no need for antenna tracking.

The frequency bands used by satellites depend on the services provided by them. These bands are shown in Table 2.2 [13].

Table 2.2: Frequency bands for satellites

Band	**Downlink**	**Uplink**	**Bandwidth**	**Problems**
L	1,5 GHz	1,6 GHz	15 MHz	Low bandwidth; crowded
S	1,9 GHz	2,2 GHz	70 MHz	Low bandwidth; crowded
C	4,0 GHz	6,0 GHz	500 MHz	Terrestrial interference
Ku	11 GHz	14 GHz	500 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain, equipment cost

There are groups of satellites that form constellations, which provide voice, video and data services to their users. Some of these networks are:

- **Thuraya** - has been designed to support dual-mode allowing user to use Thuraya network or any other GSM networks. The satellite THURAYA-1, launched in October 20, 2000 is located 44° East and covers an area between 20° West to 100° East longitude and 60° North to 2° South latitude. Thuraya uses FDMA/TDMA multiple access scheme and QPSK for signal modulation. Some of the supported services are: voice communications, short messages, data transmission, fax, Geo Mobile Packet Radio Service (GmPRS), navigations service (GPS) [17];

- **Iridium** - provides telecommunication services, such as: voice, data, paging, fax and navigation services by using handheld devices that communicate directly to Iridium satellites. Its network consists of 66 LEO satellites (in six orbital planes). Iridium is the single network that covers the entire Earth, even the South and North Pole [18];

- **Globalstar** - provides satellite telephony and low speed data communication. Its second-generation constellation will consist of 32 LEO satellites [19];

- **Inmarsat** - is a British satellite telecommunication company providing seamless mobile voice and data communications worldwide. Its satellite constellation consists of 11 satellites, which are placed in GEO orbit [20].

The main goal of using satellite communication in platform is to have the possibility to connect to the server even if the mobile team is in an area where no GSM/3G network is available. GmPRS service [21] is used to achieve this goal, which enables a continuous "always on" Internet connectivity and sets the handheld as gateway for the external devices. Through this service connection to the server will be established. Later on, if this integrated platform will be used in any regions which are not covered by Thuraya then as alternative can be used any of other satellite services mentioned before.

Chapter 3

Platform Requirements and its Structure

This chapter consists of four sections. The first one describes the platform requirements. In the next three sections the structure, components, connections and services of the applications of the mobile teams, server and managing center are discussed. These sections contain the technical part and specifications of the platform.

3.1 Platform Requirements

Before defining all the platform requirements one by one, an intervention of a rescue team will be briefly described, to explain the usage of the platform. The rescue team consists of mobile teams (which are active in terrain) and a team at the managing center (which communicates with the mobile teams and manages the rescue operation). The platform should be used just after receiving the alarm that a new rescue operation has to be started. The mobile teams should have an almost permanent connection with managing center in order to communicate with it and get new information about the rescue operation, such as: actual position of all teams, any important object found by other teams, etc. This connection between mobile teams and managing center should be established through a server and not as a direct connection between them. The server must contain (except its application) a database where the whole communication traffic between mobile teams and managing center should be stored. Mobile teams should be able to communicate with the managing center by sending and receiving different messages. They can send any of predefined messages (like "Call for Help" or "Point Of Interest") or write a new one. Mobile teams should also have the possibility to take any photos from terrain and send them to the managing center, with some text describing the photo. Each mobile team should send its actual position to the managing center. The platform should support and show a digital map of the intervention region for mobile teams and managing center. The whole intervention region can be split by managing center into sectors (called search sector). One search sector is dedicated only to one mobile team, which has to search only inside of it and inform the managing center for any found object.

The main requirement of the platform is to provide an almost permanent connection between mobile teams in terrain and managing center (through the server), in order to manage, organize and synchronize the rescue operation. Each mobile team uses a mobile device (where the mobile team application must be installed and executed) and a satellite handheld. The MT's application should attempt to establish the connection to the managing center via the GSM network. If it does not achieve that for some predefined time, in both devices of the mobile team, the Bluetooth interface should be turned on and the satellite handheld would be used as a gateway for the mobile device in order to establish the connection. Thus, it should not matter where are the MTs, in mountains, rocks, rough terrains, canyons, jungle, or which mobile network providers are being used by the MTs, as long as the data transfer is supported. If connection is established via satellite, the MT's application should search all the time for a GSM network in order to switch the connection to it because of higher costs of communication via satellite.
After connection is established, mobile teams and managing center can communicate with each other at any time. If connection is lost for any reason, messages must not be lost. They must be sent later when the connection is re-established. It should be possible for mobile teams to send photos taken from terrain with some text describing the photo in more details, i.e. the mobile device should be equipped with a camera. Photos should be sent only when the connection is realized via GSM network.

MT's application must run in mobile devices that are equipped with a GPS receiver. The application must inform the MC about the actual position of the MT. In order to observe the position, track, search sector of MTs and any other important object, the platform should be able to load and show a digital map of the intervention region.

The platform should also support parameters changing, such as IP addresses and ports, mobile network providers, MT's name and ID. Some of these parameters should be changeable without needing to restart the platform. As well, mobile device should be touch-screen enabled.

The server should make the communication between mobile teams and managing center possible, as well it should store the whole communication traffic between them in a database.

The application of the managing center should be a web application running in a web browser. It should be able to establish a connection with the server (through the Internet) and communicate with mobile teams in order to manage the rescue operation. Managing center should have the possibility to move, be a mobile managing center, and due to this it should be equipped with a GPS receiver in order to inform mobile teams about its actual position.

According to all these requirements defined above, a general overview of the whole platform is shown in Figure 3.1. It shows that the direct connection between mobile teams and managing center is not possible (red line) but only through the server (green lines).

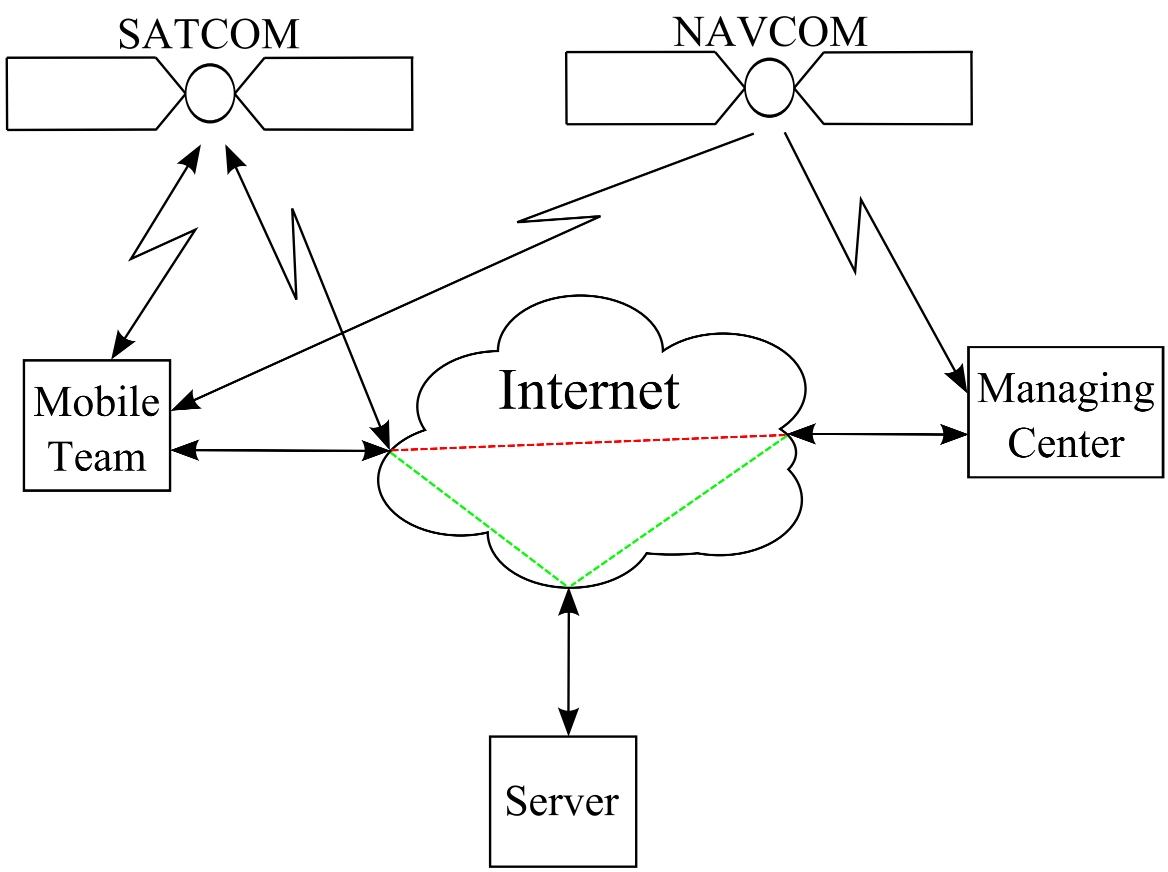


Figure 3.1: General overview of the platform

3.2 Mobile Team

After definition of requirements the first thing to do is determining the devices that provide the required services and are equipped with the necessary hardware the platform needs.

The mobile team application must be installed and run in any mobile device that supports Bluetooth technology, data transfer (GPRS), virtual serial ports, touch-screen, different display orientation (optional): landscape and portrait, GPS receiver and camera (optional). There are also some other factors to be taken in consideration, such as: mobile team should not waste time with (dis)connecting devices but it should concentrate on rescue operation. Mobile devices should not be heavy because mobile teams have to carry many other equipments. Mobile devices should be robust and able to work in different atmospheric conditions, even in freezing conditions. Mobile devices should have a good battery and a large display. From all these requirements, the best choice are the smartphones. Almost all of them, no matter of the manufacturer, can be used for mobile teams application. There will be used the smartphones running under Windows Mobile (WM) Operating System (OS) [22] which is developed by Microsoft [23] but there is the possibility to extend it to other operating systems from other companies, such as Android [24] developed by Google [25] or iOS [26] developed by Apple [27].
Two different smartphones are used for the platform: HTC Touch Diamond [28] and Garmin-Asus nüvifone M10 [29], shown in Figure 3.2. The application of the mobile team is installed, executed and all the tests are run in these smartphones. Table 3.1 lists some technical specifications of both smartphones.

Furthermore, the satellite handheld has to be determined. As mentioned above it should support Bluetooth and be used as a gateway for other devices, in this case for smartphones. In order to be used as a gateway it should support data transmission and Dial-Up Network (DUN) Profile. The DUN Profile defines the protocols and procedures that should be used to access the Internet and other dial-up services over Bluetooth [30]. A satellite handheld that is Bluetooth enabled, supports data transmission (using GmPRS service [21]), supports the DUN Profile and has a very user friendly interface which makes it easy to use, is Thuraya SG-2520 [31], which will be used in platform. It is shown in Figure 3.3. Some of its technical specifications are listed in Table 3.2.

Just after installing the application of mobile team in the smartphone, before starting it, there are three steps to be completed (only during the first use of the smartphone):

1. Define a new modem connection in the smartphone, according to the mobile network provider (SIM card) used by mobile team;

Figure 3.2: HTC Touch Diamond and Garmin-Asus nüvifone M10

2. Bluetooth pairing (PIN-code exchanging) between smartphone and Thuraya SG-2520;

3. Copy digital map into working directory of the MT's application.

In order to complete the first step there must be known some information from the mobile network provider, such as: Access Point Name, username and password. APN is a point of entry into an IP network for a mobile device, which is actually equivalent to a dialup phone number of Internet Service Provider (ISP). An APN can be also private, i.e. can be used only by a group of subscribers. After defining the new modem connection, the subscriber has Internet access from its mobile device (smartphone). The application of the mobile team can be connected with the server using this modem. Both, mobile teams and managing center are connected with server and communicate with each other only through the server and not directly.

Before two Bluetooth enabled devices communicate with each other over Bluetooth they have to be paired, i.e. they agree to communicate and establish a connection. This "agreement" is arranged by exchanging the same PIN code. Therefore, the smartphone and Thuraya handheld must be paired before Thuraya is used as a gateway. After pairing these devices, on the smartphone can be checked the list of the services Thuraya SG-2520 provides, actually these services should be activated in Thuraya SG-2520 in order to be visible by the smartphone.

Table 3.1: Technical specification of HTC Touch Diamond and Garmin-Asus nüvifone M10

Specifications	**Touch Diamond**	**Nüvifone M10**
Manufacturer	HTC	ASUSTeK Computer
Release Date	June, 2008	February, 2010
Dimensions (W x H x D)	51 x 102 x 11.5 mm	58 x 116 x 14 mm
Embedded Operating System	Microsoft Windows Mobile 6.1 Professional	Microsoft Windows Mobile 6.5.3 Professional
Operating System Kernel	Windows CE 5.2	Windows CE 5.2.23096
CPU-Clock	528MHz	600MHz
CPU	Qualcomm MSM7201A	Qualcomm MSM7227
CPU Core	ARM1136EJ-S	
RAM type and capacity	Mobile DDR SDRAM, 192 MiB	Mobile DDR SDRAM, 512 MiB
Display Diagonal	70 mm	89 mm
Display Resolution	480 x 640 pixels	480 x 800 pixels
Cellular Networks	GSM900, GSM1800, GSM1900, UMTS900, UMTS2100	
Cellular Data Links	CSD, GPRS, EDGE, UMTS, HSDPA	
USB	USB 2.0	
Bluetooth	Bluetooth 2.0 + Enhanced Data Rate	
WLAN/Wi-Fi	IEEE 802.11b/g, 54 Mbit/s	
Built-in GPS module	Supported	
GPS-Protocol	NMEA 0183	
Navigation Chip(set)	Qualcomm MSM7201A gpsOne	Qualcomm MSM7227 gpsOne
Digital Camera Resolution	2048 x1536 pixels	2560 x1920 pixels
Recordable Image Formats	JPG	
Battery Technology	Lithium-ion polymer	Lithium-ion

The DialUp Networking service has to be selected in order to be used. As for the smartphone, in Thuraya SG-2520 the APN has to be defined (when a Internet access is required). There are also other preferences to be defined, such as: if subscriber wants to accept or reject any incoming voice call while Thuraya handheld is being used as gateway.

Figure 3.3: Thuraya SG-2520

These two steps are important for establishing the connection with the server. The first one for connection via GSM network and the second one for connection via satellite. Establishing and handling of these connections are described in detail in chapter 5.

In order to load and show the digital map of the intervention region, this digital map should be provided to the application of mobile teams, as well as to the application of managing center. The digital map must be copied in the working directory of the application of the smartphone. Whenever the application needs to show the intervention region, it just loads and shows it. It is better to copy a larger digital map, like the map of the whole country because it does not matter anymore in which region of the country the intervention operation is taking place. Otherwise, anytime an intervention operation takes place in different regions of the country, the digital map of that region has to be copied. In order to support zooming (In and Out) the whole digital map has been split into smaller tiles (this is done by open source software Quantum GIS - QGIS).

One of the most important requirement of the platform is to show the actual position and track of mobile teams and managing center, as well as position of any other important object found in terrain. After the digital map (or tiles of it) are loaded and shown in the

Table 3.2: Technical specification of Thuraya SG-2520

Specifications	**Thuraya SG-2520**
Operating System Kernel	Windows CE 4.2
System	Thuraya and tri-band GSM 900 / 1800 / 1900
Phone Memory	128 MB, expandable with SD memory cards
Dimensions (W x H x D)	52 x 139 x 19 mm
Display Resolution	177 x 220 pixels
USB	Supported
Bluetooth	Supported
GPS services	Supported
Internet Access	Up to 60/15 kbps (download/upload)
Battery (SAT)	Talk time up to 2.4 hrs, stand-by time up to 40 hrs
Battery (GSM)	Talk time up to 4 hrs, stand-by time up to 75 hrs
Applications	Based on Java (J2ME)
Languages	Supports 12 languages

smartphone, the position of any object has to be known before it is shown on the digital map. This position is calculated by the GPS receiver, which is built in the smartphone and uses the standard NMEA 0183 (see Table 3.1). The GPS receiver receives the GPS signals from satellites and determines its position, geographical coordinates, by using the trilateration method as it has been described in Section 2.3.1. The hardware interface of GPS receivers are compatible with serial ports using the RS232 protocol. The serial port is used to read data from the GPS receiver. Most of the smartphones nowadays are equipped only with a single physical serial port, but in order to increase the number of the applications that can read from the same serial port at the same time they use virtual serial ports, which are created by software and emulate all hardware serial port functionalities. Thus, mobile teams' application uses a virtual serial port to read data from GPS receiver.

Almost all of the smartphones are equipped with camera. Some of them have even two cameras in order to support videotelephony. Using this camera on the smartphone, mobile teams can take photos from terrain. They save them on the smartphone and use them later for any report about the rescue operation or send them to the managing center. As it has been shown in Table 3.1, both smartphones have cameras with high resolution. The supported image format is JPG (compressed image format standardized by the Joint Photographic Experts Group - JPEG).

Another important technical factor is the battery of the smartphones which should be used in very efficient way. The mobile team's application takes care of the Bluetooth radio to be turned on only when it is needed in order to save battery lifetime. For this reason there should be no other applications running in smartphone during the rescue operation, without need. It would be a good idea for MT to have available one or two spare batteries because the length of the rescue operation time cannot be accurately determined.

3.3 Server

According to the requirements defined in Section 3.1, the server has the main role in communication between mobile teams and managing center. It must establish the connections and handle the whole communication traffic, as well as storing it in the database.

Server of the platform does not have special hardware requirements. It requires the basic hardware: a computer, monitor, keyboard, mouse, as well as a network card which is used to have access to Internet in order to establish the connection with mobile teams and managing center. All current Personal Computers (PC) contain this hardware. It would be very preferable that the server has a fast Central Processing Unit (CPU) and a large Random Access Memory (RAM) because both of them effect directly to the server performance. Unnecessary applications should not be installed on the server.

The server consists of:

- Its application;
- Database.

The application is developed for the server running under any of operating system provided by Microsoft, such as: Windows XP, Vista and Windows 7. This application is responsible for connection establishment and handling the communications.

The platform uses star topology, having the server in the center and all other clients (mobile teams and managing center) around it, as shown in Figure 3.4. Each connection is totally independent from the others. In cases where a connection is dropped (for example when the battery of a smartphone is empty) only that specific team loses the connection with the server, the others remain connected. This is an important advantage of this topology and is very useful for the platform. The ring topology, shown in Figure 3.5, would not be suitable because it overloads the whole platform. For example, if mobile team 2 wants to send a message to the managing center, the message should follow the red line in Figure 3.5 which involves, not only the server, but the other mobile teams too. In the star topology only the server is used to deliver the message to the managing center, shown by green line in Figure 3.4.

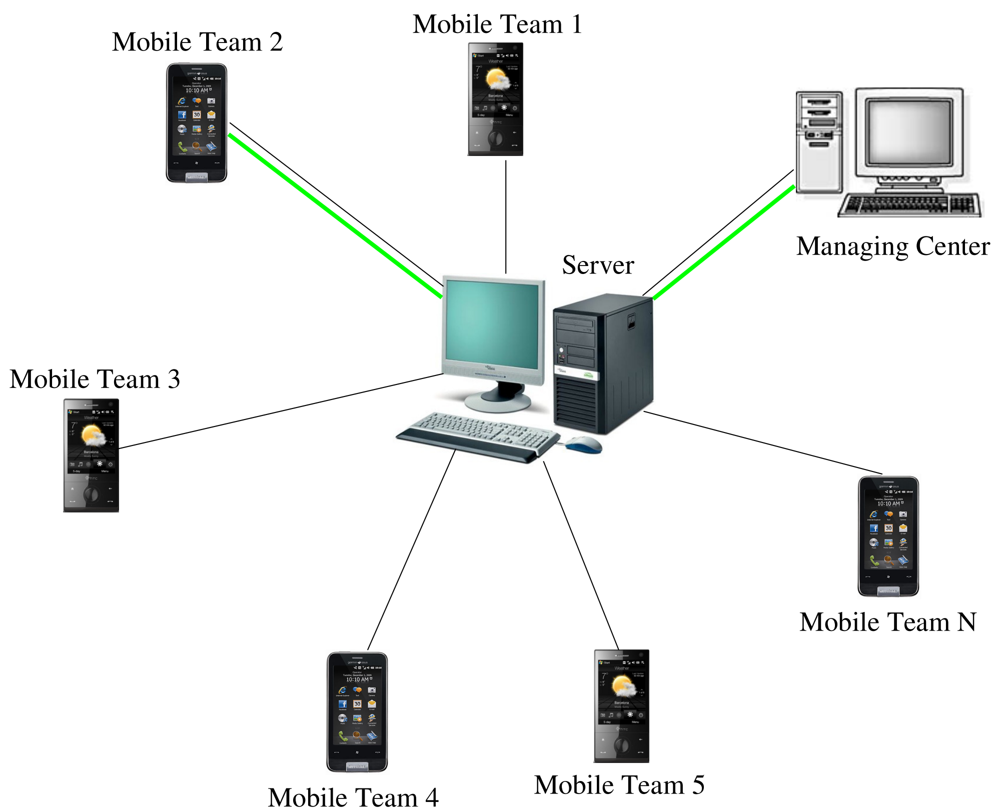


Figure 3.4: Star topology used in the platform

The database is a collection of large amounts of data (information) which are organized in a way to be easily accessed, managed and updated. There is a DataBase Management System (DBMS) used to manage the database, i.e. storing database contents, allowing data creation, searching, maintenance, etc. The DBMS used for the platform, is an open source software, called PostgreSQL [32]. Its source code is available under a liberal open source license and the users are free to modify and distribute it as they want. There are many procedures and library interfaces supported by PostgreSql. There are interfaces for Java (JDBC), ODBC, Perl, Python, Ruby, C, C++, PHP, Lisp, Scheme, and Qt. Another important factor is PostGIS [33] which adds support for geographical objects

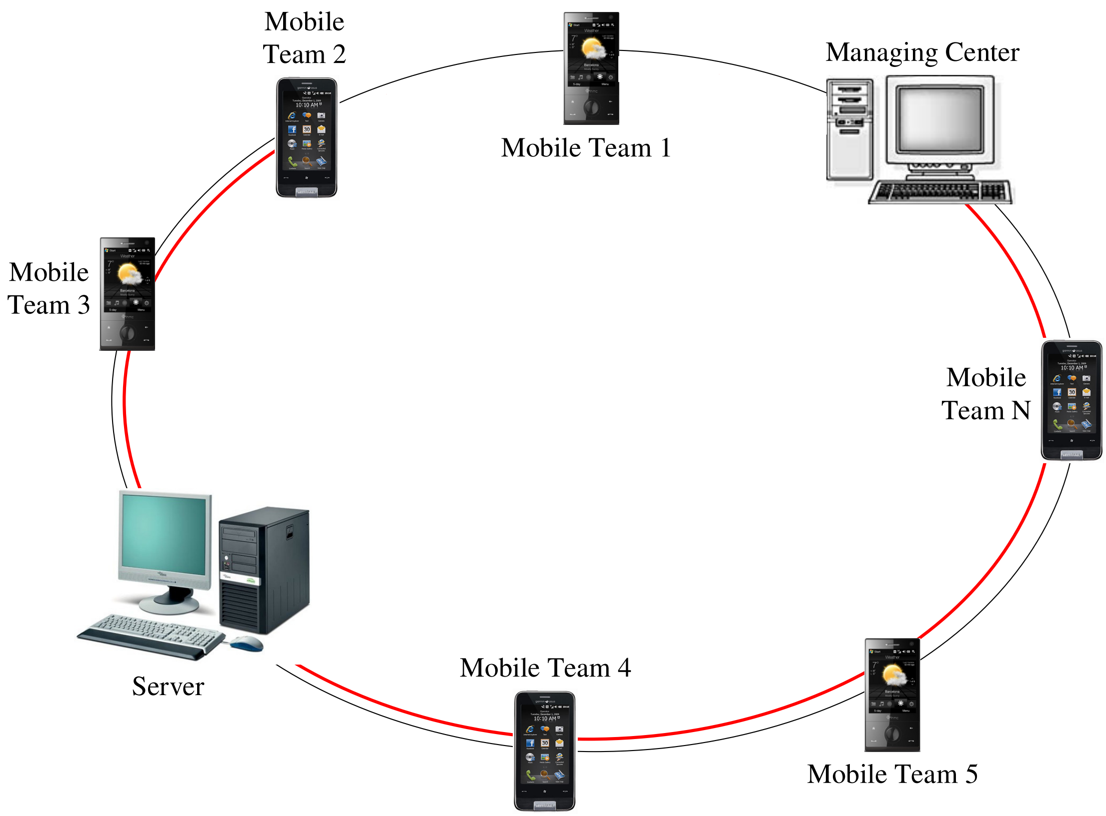


Figure 3.5: Ring topology, not practical for the platform

in PostgreSQL, allowing it to be used as a spatial database for Geographic Information Systems (GIS). There is also used an open source graphical interface administration tool for PostgreSQL. This is pgAdmin, which can be used on Windows, Linux, Solaris, Mac OSX platforms. It supports all PostgreSQL features and is designed to answer the needs of all users, from writing simple SQL queries to developing complex databases [34]. The platform uses relational database which matches data by using their common characteristics and shows them in tables. The rows of the tables are known as Tuple and columns as Attributes. Through the DBMS the tables can be managed by adding, deleting or updating any tuple. Figure 3.6 shows the database in pgAdmin. At the left side of this Figure are shown the tables which contain the information about the mobile teams, managing center, the exchanged messages between teams, the actual positions and some other data related to the rescue operation. These tables are explained in Section 5.3.4.

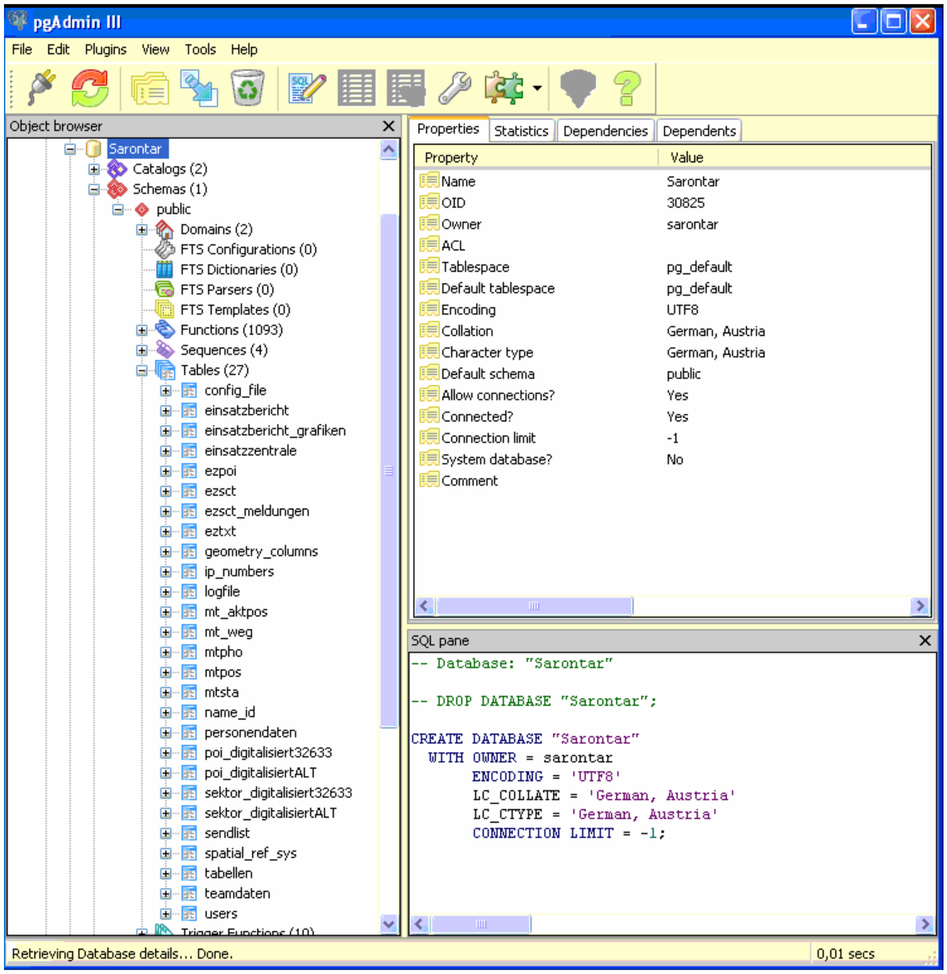


Figure 3.6: Database of the platform in administration tool pgAdmin

Location of the server does not matter and it is not important for mobile teams and managing center to know it. Thus, there is no need to equip the server with any GPS receiver.

The server's application should be always running, no matter whether any rescue operation is taking place or not. It will be stopped only when any updates have to be done.

3.4 Managing Center

Due to the requirement that the managing center may be relocated, Notebooks instead of the desktop PCs are preferable. A PC can also be used if it is mounted in a car. It is clear that the Notebook can be used even if the managing center is not mobile. The Notebook should be equipped either with a network card or WLAN adapter to connect to the server (through the Internet) and communicate with mobile teams by sending and receiving messages. It is also possible to connect to the Internet via satellite broadband connection but this requires special hardware, for example the Alden/IPcopter Pro System as shown in Figure 3.7 which has an automatic tracking antenna and a modem that provides the access to the Internet.

Figure 3.7: Alden/IPcopter Pro System

In order to know the position of the managing center it should be equipped with a GPS receiver, which can be internal or external one. The internal GPS receiver, which is integrated in the Notebook would be preferable because data can be read directly from it. There is a small number of such Notebooks which are rather expensive. Thus, the external GPS receiver will be used in platform. There are two ways to use it and both of them are supported in the platform. The first one is to plug it to the Notebook in the appropriate port (serial port or Universal Serial Bus - USB) and read data from it. The second one is totally external, the geographical coordinates will be read in other devices and will be entered manually into the platform. The second way has to be done periodically (when the managing center is mobile) or after a location change.

Application of the managing center is a web application (that can be accessed over a network). It can be operated in any web browser, such as: Mozilla Firefox, Google Chrome, Internet Explorer, etc. Figure 3.8 shows the web application.

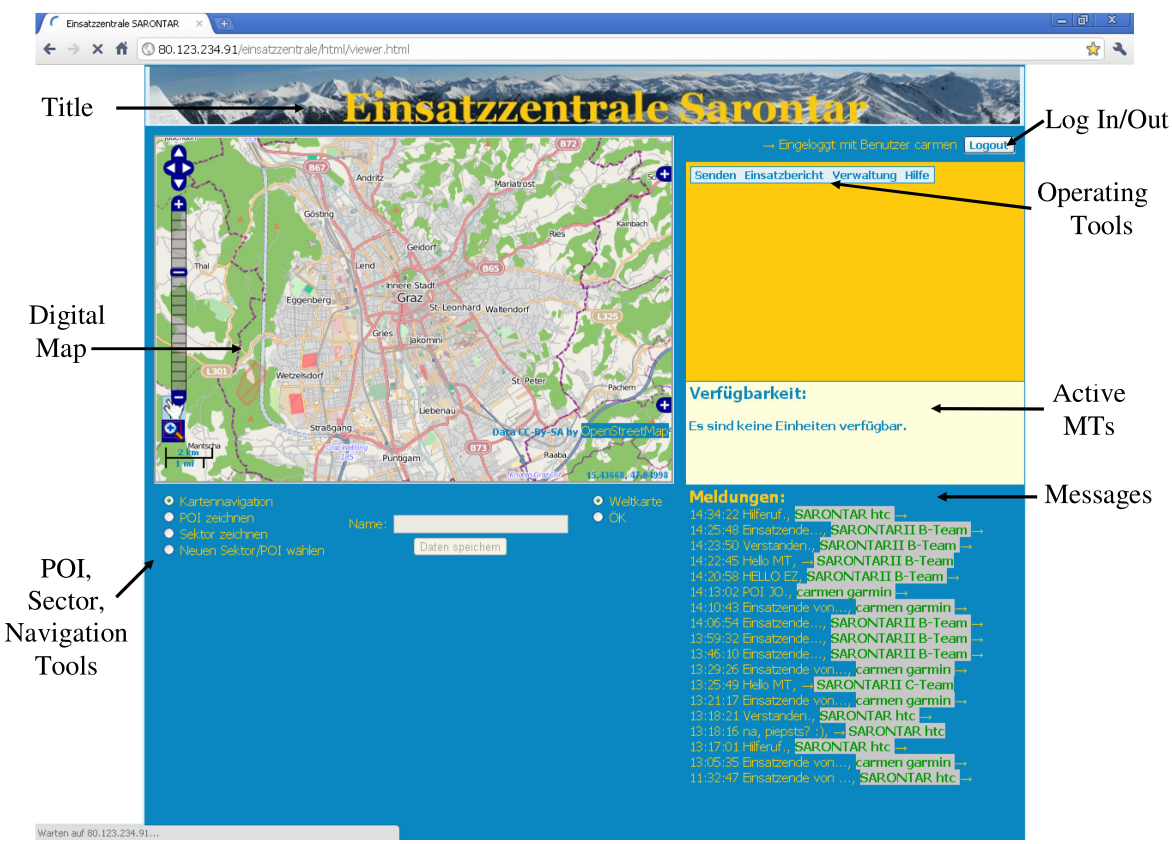


Figure 3.8: Web Application of the Managing Center

In order to better control and manage the rescue operation digital maps are used. This is possible through a web map service. On that digital map the managing center can see the actual position of mobile teams, their search sectors and any other object. In the web application the mobile teams that are active (online) in the rescue operation can be listed. The managing center team is equipped with some operating tools for communication with mobile teams to manage and organize the rescue operation, as well as some navigation tools. A list of all sent and received messages is shown too. The functionality and the services provided by the web application are discussed in chapter 5.

Web application can access directly the database through the Internet, but not through the server, in order to check and store any data.

Derived from all requirements defined in Section 3.1, the technical specifications, hardware selections and connections described in the last three sections, Figure 3.9 depicts a detailed structure of the platform as well as the other systems. The green lines show the connections that can be established through the Internet and the red line shows that there is no direct connection between mobile teams and the managing center.

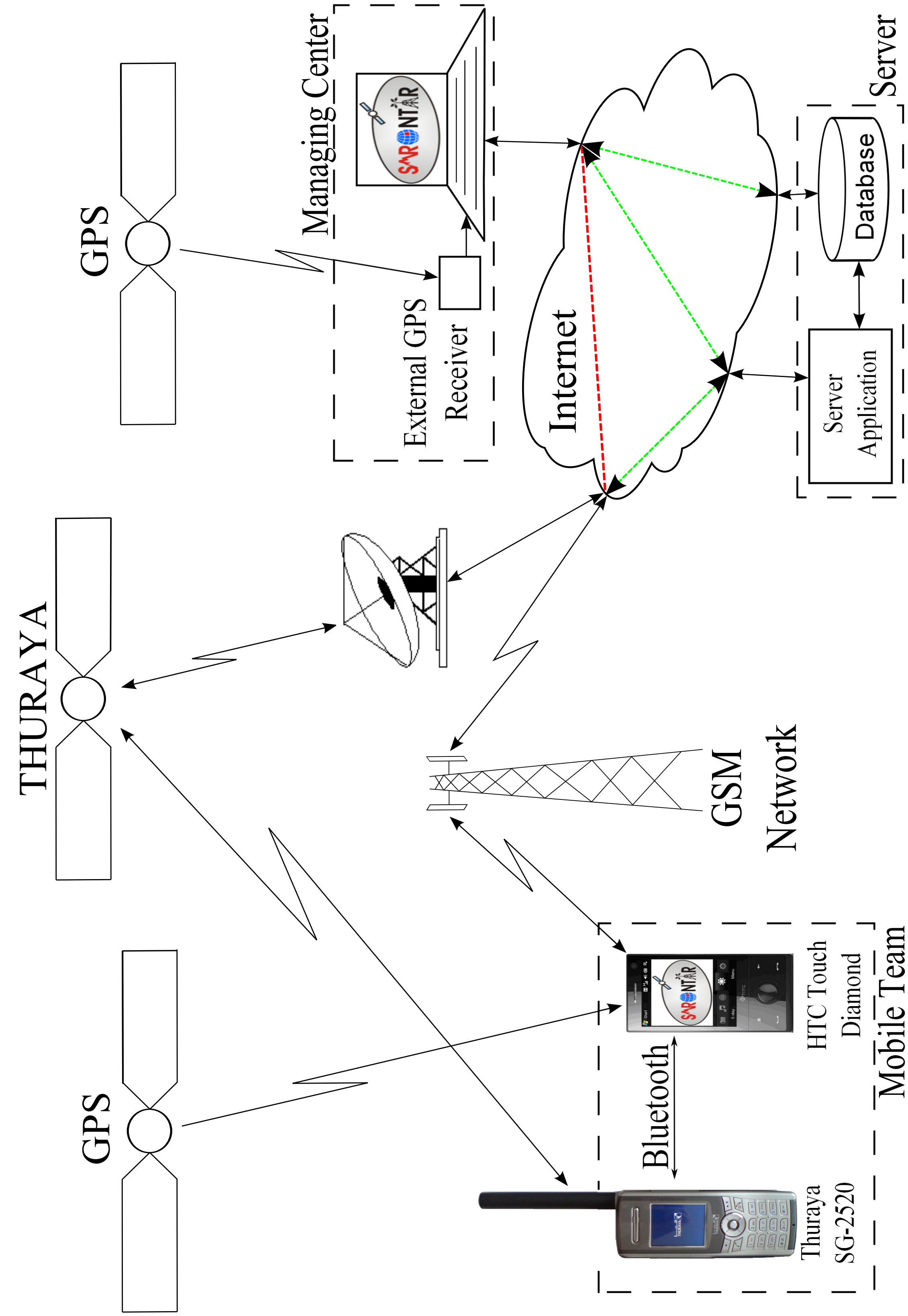


Figure 3.9: Detailed structure of the platform and other systems used

Chapter 4

Data Format

Communication between mobile teams and managing center is based on the messages that they can transmit to each other. Some of these messages are sent automatically and periodically. The messages that a mobile team can transmit are:

- Login Message;
- Position Message;
- Status Message;
- Photo Message;
- Termination Message.

The managing center can send:

- Text Message;
- Points Of Interest (POI) Message;
- Search Sector Message;
- Termination Message.

In this chapter these messages are defined. The format, length and the other parameters that the messages contain are described.

It should be mentioned that in the whole thesis some terms, parameters, words and abbreviations will be shown in German language, specially those shown directly to the user because the platform will be used in Austria. But all of them are also translated into English.

Each message starts with a US Dollar sign "$", same as by the standard NMEA-0183 described in Section 2.3.2. This symbol is followed by five other characters, known as Message Identificator. The first two characters are used to distinguish the transmitter of the message: MT for mobile team or EZ for managing center (in German "Einsatzzentrale"). The next three characters define the type of the message, which can be one of these:

- LOG - login;
- POS - position;
- STA - status;
- PHO - photo;
- TXT - text;
- POI - point of interest;
- SCT - search sector.

The Identification Number of the team (mobile team or managing team) follows. Other important parameters are also part of the messages, such as: local date and time, latitude and longitude, elevation and moving direction as well as any text written by the team. The end part of the message consists of an asterisk symbol "*", two hexadecimal characters, which represent XOR Checksum (CS) of all characters excluding the US Dollar sign and the asterisk. Finally the message ends with a carriage return.

Figure 4.1 shows the main window of the mobile team application. It consists of four buttons, the logo of the "SARONTAR" project and the symbols showing if the received GPS signal has a good quality and if the connection to the server is established.

4.1 Login Message

The login message is the first message to be sent to server. It is used to register the team in platform as online. The format of the transmitted message by mobile teams is:

$MTLOG,ID,IP,NAME*CS\r\n

Figure 4.1: Mobile Team Application - Main Window

The login message is sent by managing center as well (when the managing center team logs in by using the button Log In/Out, shown in Figure 3.8) and it looks like this:

$EZLOG,98,IP,Einsatzzentrale*CS\r\n

Table 4.1: Login Message sent by Mobile Team

Parameter	Format	Unit	Values Range	Remark
$MTLOG				Message Identification
ID	nn		01 to 90	ID of Mobile Team
IP	nnn.nnn.nnn.nnn		000.000.000.000 to 999.999.999.999	IP address of the Server
NAME			Arbitrary text	Optional: Name of the Mobile Team

Fixed values for ID and NAME parameters are used, because the managing center has a defined ID, which is 98 and a defined name, "Einsatzzentrale". There is also a fixed ID for the Server, 99. It is actually not used in the messages, but in the database to know whether the server is online or not. These IDs are both reserved and cannot be used for other purposes.

4.2 Position Message

This message is sent automatically and periodically to managing center in order to inform it about the actual position of the mobile team. Its format is:

$MTPOS,ID,LOCDATE LOCTIME,LAT,LON,H,COG,Q*CS\r\n

As the reference system for all coordinates, World Geodetic System (WGS) 84 is used. As shown in Table 4.2 the geographical coordinates are transmitted: latitude and longitude, elevation (the height above the sea level), the direction that the mobile team is moving and the quality of the received GPS signal.

Table 4.2: Position Message sent by Mobile Team

Parameter	**Format**	**Unit**	**Values Range**	**Remark**
$MTPOS				Message Identification
ID	nn		01 to 90	ID of Mobile Team
LOCDATE LOCTIME	yyyymmdd hhmmss	Year Month Day Hour Minute Second	19991231 to 20991231 000000 to 235959	Local date and time when the message has been created
LAT	(-)dd.ddddd	Degree.decimal	-90.00000 to 90.00000	Latitude, WGS 84
LON	(-)ddd.ddddd	Degree.decimal	-180.00000 to 180.00000	Longitude, WGS 84
H	hhhh.h	Meter	0000.0 to 9999.9	Elevation
COG	ddd	Degree	000 to 359	Moving Direction
Q	q		0 to 9	0 = invalid 1 = GPS valid 2 = DGPS valid 8 = WARNING!

4.3 Status Message

Mobile teams can transmit some predefined messages to the managing center or write any arbitrary message. These messages are used to inform the managing center about mobile teams' status and conditions as well as for anything about the rescue operation. A mobile team can Call for Help (in German "Hilferuf"), inform the managing center about any found object (in German "Fundort") in the terrain, inform about any Point Of Interest "POI" and can write any other message that does not belong to these mentioned categories (in German "Sonstige Nachricht"). Any of these messages can be selected in the messages window, shown in Figure 4.2, which appears by clicking on the messages button (in German "Nachricht") in the main window. On top of the messages window "Neue Nachricht an Einsatzzentrale" appears, which means "New Message to Managing Center". Through the button "Bilder" in the messages window, the mobile team can send any photo from terrain to managing center, but this message type is not a status one. There is also another button "Abbrechen" meaning Cancel.

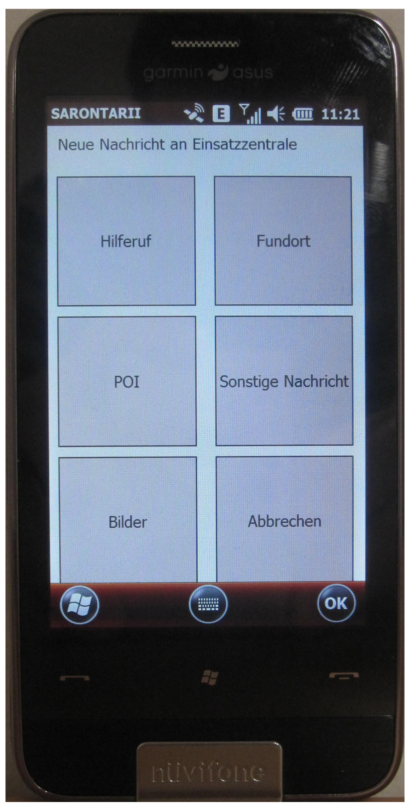


Figure 4.2: Messages Window

For each of the categories of the messages is provided a code which makes them different from each other. The list of the codes is shown in Table 4.3, in German and English. The codes 01, 02, 03 are defined for messages that are used to respond to any received messages from managing center.

Table 4.3: Codes of Status Messages

Code	**Bedeutung**	**Meaning**
00	Hilferuf	Call for Help
01	Verstanden	Understood
02	Später	Later
03	Nicht möglich	Not Possible
04	Fundort	Find Place
05	Point Of Interest (POI)	
06	Sonstige Nachricht	Other Message
07 to 99	Reserved for future	

The format of the status message is:

$MTSTA,ID,LOCDATE LOCTIME,LAT,LON,CODE,REMARK*CS\r\n

Table 4.4: Status Message sent by Mobile Team

Parameter	**Format**	**Unit**	**Values Range**	**Remark**
$MTSTA				Message Identification
ID	nn		01 to 90	ID of Mobile Team
LOCDATE LOCTIME	yyyymmdd hhmmss	Year Month Day Hour Minute Second	19991231 to 20991231 000000 to 235959	Local date and time when the message has been written
LAT	(-)dd.ddddd	Degree.decimal	-90.00000 to 90.00000	Latitude, WGS 84
LON	(-)ddd.ddddd	Degree.decimal	-180.00000 to 180.00000	Longitude, WGS 84
CODE	cc		00 to 99	Check the Table 4.3
REMARK			Arbitrary text	Optional: Detailed describing possible

The last parameter of the status message, as shown in Table 4.4, is used for the text a mobile team can write. It is used only for the messages with code 04, 05 and 06, because the rest of the status messages are already defined and there is no need to write anything more. These already defined messages have this format:

$MTSTA,ID,LOCDATE LOCTIME,LAT,LON,CODE*CS\r\n

4.4 Photo Message

A photo that will be sent to managing center is firstly split into some units (Payloads) with fixed size. The size of the payloads depend on the name of the photo because the photo message has a fixed size. The single parameter of it with variable length is the name of the photo, because the mobile team can name the photo arbitrarily. The total number of payloads depends on the size of the photo. Photo message is used to transmit all payloads to the server and they are used again to reconstruct the photo. Some other information is transmitted too, such as: photo size, local date and time, latitude and longitude, any text written by mobile team to describe the photo, etc. This information is "hidden" inside the photo, using the Steganography. This process and the extraction of this information at the server are described in details in Section 5.3.2.

The photo message has this format:

$MTPHO,ID,PHOTONAME,TMG,AMG,PAYLOAD*CS\r\n

and Table 4.5 describes these parameters.

Table 4.5: Photo Message sent by Mobile Team

Parameter	**Format**	**Unit**	**Values Range**	**Remark**
$MTPHO				Message Identification
ID	nn		01 to 90	ID of Mobile Team
PHOTONAME	xxxxxx.yyy			Is the name of the file (photo) including the extension
TMG	nnn		001 to 999	Total Number of Payloads
AMG	nnn		000 to 998	Actual Payload sent
PAYLOAD				Part of the photo sent to MC

4.5 Text Message

The text message format is:

$EZTXT,ID,LOCDATE LOCTIME,TEXT*CS\r\n

This type of message is used by the managing center to communicate with mobile teams. The managing center can transmit the same message to all mobile teams at once. This is defined by setting the ID parameter to 00 and is known as Broadcast Mode. Otherwise it is the Unicast Mode and the ID parameter contains the ID of the mobile team that the message should be sent to.

Table 4.6: Text Message sent by Managing Center

Parameter	**Format**	**Unit**	**Values Range**	**Remark**
$EZTXT				Message Identification
ID	nn		01 to 90	ID of Mobile Team (00=Broadcast Mode)
LOCDATE LOCTIME	yyyymmdd hhmmss	Year Month Day Hour Minute Second	19991231 to 20991231 000000 to 235959	Local date and time when the message has been written
TEXT			Arbitrary text	Text Message

4.6 Point Of Interest Message

The managing center can create a new Point Of Interest in the digital map on the web application, shown in Figure 3.8. It can also send this created POI or any other POI received before from any mobile team to a single MT or to all of them, the same way as text messages. POI message contains these parameters:

$EZPOI,ID,IDPOI,LOCDATE LOCTIME,LAT,LON,CAT,REMARK*CS\r\n

POI can be any important and interesting point in terrain for the rescue operation, such as: meeting place, injured people found, helicopter landing place, damaged house, etc. The parameter, CAT which stands for Category can be used later in order to group

Table 4.7: POI Message sent by Managing Center

Parameter	**Format**	**Unit**	**Values Range**	**Remark**
$EZPOI				Message Identification
ID	nn		01 to 90	ID of Mobile Team (00=Broadcast Mode)
IDPOI	nnn		000 to 999	ID of POI (000 to 099 = variable) (100 to 999 = static)
LOCDATE LOCTIME	yyyymmdd hhmmss	Year Month Day Hour Minute Second	19991231 to 20991231 000000 to 235959	Local date and time when the message has been created
LAT	(-)dd.ddddd	Degree.decimal	-90.00000 to 90.00000	Latitude, WGS 84
LON	(-)ddd.ddddd	Degree.decimal	-180.00000 to 180.00000	Longitude, WGS 84
CAT	cc		00 to 99	Reserved for future use
REMARK			Arbitrary text	POI Description

the POIs according to categories. Different numbers for different POIs are used, i.e. for POIs which can change their position the numbers from 000 to 099 are used and called variable POIs. The other POIs (static ones) cannot change their position and they can have the values from 100 to 999. A variable POI can be the meeting place which may be changed for any reason. A static POI can be a found house in terrain.

4.7 Search Sector Message

The search sector (in German "Suchsektor") can be created only by managing center and can be transmitted to mobile teams. The search sector is a polygon that consists of at least three vertices. It is assumed that the first and the last vertex are the same and only one of them must be sent. Through this message type the geographical coordinates (latitude and longitude) of the vertices of the search sector are transmitted. Having the message with fixed length limits the number of vertices that can be sent. If the search sector consists of more than six vertices, it has to be split into more messages. The total number of messages that can be used to transmit one search sector is nine, thus the total number of the vertices that a search sector can have is $6 \cdot 9 = 54$. The message format is:

$EZSCT,ID,IDSCT,LOCDATE LOCTIME,TOTALMSG,NRMSG,POINTLAT,
POINTLON,POINTLAT,POINTLON,...,POINTLAT,POINTLON*CS\r\n

Table 4.8: Search Sector Message sent by Managing Center

Parameter	**Format**	**Unit**	**Values Range**	**Remark**
$EZSCT				Message Identification
ID	nn		01 to 90	ID of Mobile Team (00=Broadcast Mode)
IDSCT	nnn		000 to 999	ID of Search Sector
LOCDATE LOCTIME	yyyymmdd hhmmss	Year Month Day Hour Minute Second	19991231 to 20991231 000000 to 235959	Local date and time when the message has been created
TOTALMSG	n		1 to 9	Total number of messages
NRMSG	n		1 to 9	Number of the actual message
POINTLAT	(-)dd.ddddd	Degree.decimal	-90.00000 to 90.00000	Latitude, WGS 84
POINTLON	(-)ddd.ddddd	Degree.decimal	-180.00000 to 180.00000	Longitude, WGS 84

4.8 Termination Message

This type of messages is used only on voluntary application termination in order to inform mobile teams when the web application of managing center is terminated or when any mobile team terminates its application in the smartphone. When connection is dropped for any reason and if there is no communication anymore between teams, the managing center does not know whether the mobile team terminated the application voluntarily or something else happened that the connection was lost. Something else may have happened: running out of battery or connection via GSM network is not possible anymore.

The message format sent by mobile teams is:

$MTSTA,ID,LOCDATE LOCTIME,LAT,LON,99,OnOk*CS\r\n

and the message format transmitted by the managing center is:

$EZSTA,98,LOCDATE LOCTIME,99,OnOk*CS\r\n

This message contains the parameters that already have been explained except the "99,OnOk" which is used to distinguish it from the other status messages. As well $EZSTA is the single status message transmitted by managing center.

Chapter 5

Platform Implementation

This chapter describes the implementation of the whole platform, how the connections are established, data transmission between mobile teams and managing center, data read from the GPS receiver, the way the connection is switched from GSM network to Thuraya network and vice versa, how the managing center controls and manages the rescue operation, how the server handles the whole communication traffic and how data are organized in the tables of the database, as well as some algorithms showing the flow of the control of any thread.

The application of mobile teams is a project written in C++ programming language in Microsoft Visual C++. It uses the Microsoft Foundation Class (MFC) Library as well as other libraries, specially those for network programming. The web application of the managing center is written in HyperText Markup Language (HTML) and PHP programming languages. The server application is programmed in JAVA.

In the platform multithreading is also implemented, where threads are used to handle single tasks, such as: read data from GPS receiver, establish connection with the server (either via GSM network or via satellite network), handle the incoming and outgoing messages, handle the photo transmission, etc. In order to synchronize the access to the shared resources in the platform are used mutexes. A mutex is a variable that has two states:

- locked - the shared resource is being used;
- unlocked - the shared resource is free and can be used.

A description of the mutexes and the multithreading, as well as the benefits of using them in a platform or system can be found in [35].

The mobile team application supports both display orientations: landscape and portrait. All the buttons and control items used in it are programmed dynamically, i.e. the dimensions of them and their positions on the display depend entirely on the height and width of the display of the device. If the device is rotated, the items on the display should be redrawn according to the new dimensions of the display. Even if it is not the main purpose to use the application in the landscape orientation because of the small dimensions of the items (specially the keyboards), it is used to show all items in the right order and position. Otherwise some of them would be invisible because they would be drawn outside the boundaries of the display. Some figures of this feature supported in the platform will be shown.

5.1 Navigation Communication

As mentioned above, the platform uses GPS as the navigation system, in order to know the actual position of the mobile teams and the managing center, as well as the track they followed. Data are read from the GPS receiver, which firstly has calculated its position, as it has been described in Section 2.3.1. There is a thread (called NAV-thread) dedicated to handle all the navigation communication, from reading the data from the GPS receiver until creating the position messages for the platform which later will be sent to the managing center.

The NAV-thread firstly connects to the GPS receiver through the virtual serial port, defined in the smartphone. Instead of using the GPS receiver a test case can be simulated by defining a message which is supposed to be read from the GPS receiver. The data read from the GPS receiver are based on the standard NMEA-0183, where each sentence starts with a "$" sign which is followed by the talker and sentence identifier, mentioned in Section 2.3.2. The talker identifier describes the type of the instrument sending the data. Some of them are shown in Table 5.1. The sentence identifier is used to distinguish the type of the message sent by the talker. The most important sentence identifier are shown in Table 5.2. The whole list of talker and sentence identifiers including a detailed description can be found in [16]

For the platform only the talker identifer = **GP** and the sentence identifier = **GGA** are important. Both of them form the sentence that are read from the GPS receiver. The general format of this sentence looks like this:

$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh\r\n

Table 5.1: Talker Identifier

Identifier	**Meaning**
AP	Autopilot - Magnetic
CS	Communications - Satellite
CV	Communications - Radio-Telephone (VHF)
EP	Emergency Position Indicating Beacon (EPIRB)
ER	Engine Room Monitoring Systems
GP	Global Positioning System (GPS)
HC	Heading - Magnetic Compass
IN	Integrated Navigation
SN	Electronic Positioning System, other/general
WI	Weather Instruments
YX	Transducer

and an example of it would be:

$GPGGA,095849.3,4703.515465,N,01527.560745,E,1,09,0.9,403.7,M,0,M,,*7A\r\n

Actually the example includes the information of a position at the Graz University of Technology, on the street "Inffeldgasse" in Graz (on January 21, 2011). Table 5.3 describes the meaning of the parameters of the sentence and the values of them in the example.

The NAV-thread searches the data stream from the GPS receiver for the start of the sentence, "$GPGGA", then checks for errors by calculating a new checksum of the sentence and compares it with the received one. If they seem to be different, the thread concludes that errors have occured. There is no method or algorithm implemented for error correction, thus the errors only can be detected but not corrected. After knowing that the received sentence is corrupted, the NAV-thread drops it and checks the next one. Using some of the parameters of the sentence, the NAV-thread creates a new position message for the platform. The NAV-thread changes the GPS signal symbol in main window (see Figure 4.1) to green colour which informs the mobile team that the received GPS signal has a good quality, otherwise the symbol has red colour for bad quality. On the digital map (which can be shown by clicking the button "Karte" in the main window of the application, Figure 4.1) the actual position will be shown. If the connection with the server exists, the created position message is added at the end of the Position Queue (a queue containing the position messages to be sent to the server when a connection exists) and waits until it is sent to the server. If the connection is dropped, the position messages are saved in a

Table 5.2: Sentence Identifier

Identifier	Meaning
ALM	GPS Almanac Data
ASD	Autopilot System Data
DBS	Depth Below Surface
DBT	Depth Below Transducer
FSI	Frequency Set Information
GGA	Global Positioning System Fix Data. Time, Position and fix related data for a GPS receiver
GLL	Geographic Position - Latitude/Longitude
GSV	Satellites in view
MTW	Water Temperature
MWV	Wind Speed and Angle
RMA	Recommended Minimum Navigation Information
RSD	RADAR System Data
VLW	Distance Traveled through Water

buffer. When the connection is re-established all the messages in that buffer are sent one by one to the server. Thus, the managing center can observe the track the mobile team followed, even if the connection did not exist on that time.

The NAV-thread runs as long as the mobile team application is not terminated.

5.2 Connection Establishment

After starting its application, the mobile team can set values to some parameters which are used to identify the mobile team, to establish a connection with the server, to select the mobile network provider, as well as to save the "$GPGGA" sentences (explained in the previous section), and to show the distance from the last position. These parameters can be found in the settings window, shown in Figure 5.1, by clicking "Einstellungen" in the main window (see Figure 4.1).

Changing the values of these parameters (ID and Name of mobile team, IP address and Port of the server to connect to) will effect directly the connection by dropping it and trying to establish a new one according to the new values. Changing the mobile network provider (in German "Betreiber"), by clicking the combo box and picking the desired one, will effect the connection, but this change cannot be done during the rescue operation.

Table 5.3: Global Positioning System Fix Data

Parameter	Description	Example
$GPGGA	Sentence Identifier	$GPGGA
hhmmss.ss	Time (UTC)	095849.3, i.e. 09:58:49
llll.ll	Latitude	4703.515465 or 47° 03' 30.93"
a	N or S (North or South)	N
yyyyy.yy	Longitude	01527.560745 or 15° 27' 33.64"
a	E or W (East or West)	E
x	GPS Quality Indicator 0 - fix not available 1 - GPS fix 2 - Differential GPS fix	1
xx	Number of satellites in view	09
x.x	Horizontal Dilution of Precision (HDOP)	0.9
x.x	Antenna altitude above mean-sea-level	403.7
M	Units of antenna altitude, meters	M
x.x	Geoidal separation	0
M	Units of geoidal separation, meters	M
x.x	Age of Differential GPS data (seconds)	
xxxx	Differential reference station ID	
hh	Checksum	7A

Changing the mobile network provider means changing the SIM card in the smartphone which actually requires battery removal. The state of the two check-boxes, Check and Log can be changed without any effect on the application, just by clicking on it. The Check parameter (when selected) informs the mobile team about the distance from the last position. The Log parameter, when it is checked, saves all sentences read from the GPS receiver in a file which is named according to the date (for example: `"losPos_20110123.txt"`).

On the settings window five buttons are shown. "Abbrechen" (Cancel) and "OK" have their usual function, but more important to be described are three other Resetting buttons: Track, Search Sector and POI. The geographical coordinates of the position of the mobile team are saved in a buffer in order to show them later again on the digital map including the track the mobile team followed. Resetting the Track will delete all these coordinates. After clicking on the button "Reset Track" a pop up window will appear to ask the user once more before deleting it and avoiding any accidental deletion. That is totally the same with the search sectors and Point Of Interests that the mobile team receives from the managing center. They are saved in appropriate buffers and they would be deleted by resetting.

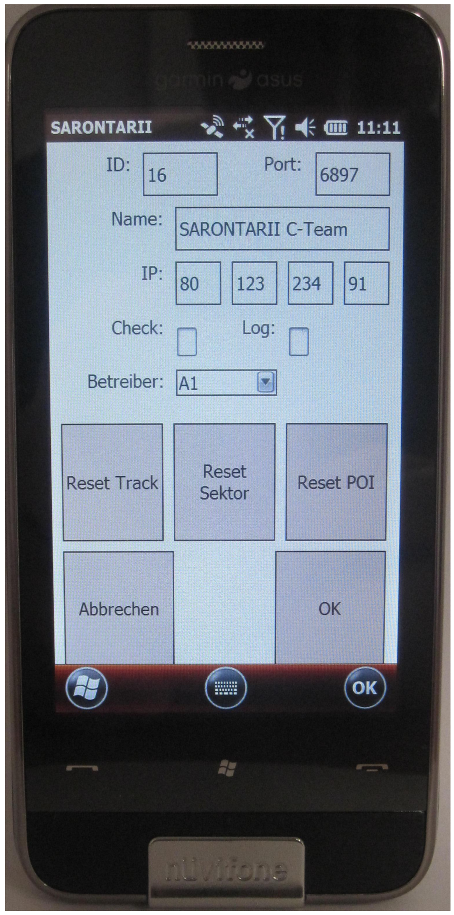


Figure 5.1: Settings Window

The best way would be to set the values of these parameters before the first use of the smartphone. They should not be changed until it is necessary, i.e. if the IP address of the server is changed or the mobile team is going to use another mobile network provider. It is recommended to make these changes, if they are necessary, just when starting the application and not during the rescue operation.

5.2.1 Connection between Mobile Team and Server

The main task of the platform is to provide an almost permanent connection between the mobile teams and the managing center. As already mentioned, there are two ways the mobile team can be connected with the server. These are:

- via mobile networks - through GPRS;
- via satellites - the satellite handheld Thuaraya SG-2520 is used as gateway.

The application of the mobile team should always attempt to connect with the server via mobile networks and try to avoid the connection via satellite because of the high costs and the battery life of both devices, smartphone and Thuraya SG-2520, because the Bluetooth radio has to be used as well.

5.2.1.1 Mobile Team Implementation

Three threads are used to establish the connection, to handle it and communicate with the managing center. The first thread is responsible for connection to the Internet through the mobile network. If necessary the second thread is created for connection via satellite. The algorithm of the first thread is shown in Figure 5.2.

As mentioned above it is better to change the parameters at the start of the application, before the connection is established. This is marked by letter A in Figure 5.2. Later changes can be made. The first thread checks for any of these changes during the run time of the application (rescue operation of the mobile team), in condition B. If any of the important parameters is changed, the thread drops the connection (if it was already established), shuts down and closes the socket and tries to reconnect (the red line in the flow chart). But if no parameter was changed the thread has to check if the connection has been already established (condition C in the flow chart). If it is not established, then it tries again and checks the status of the connection. If it is not established, it checks if the conditions for connection via satellite are fulfilled (condition D). The first condition is the time the mobile team waits before the application tries to connect via satellite. This time, β, is defined in seconds and is configurable. The first thread uses an incremental variable α in order to wait as long as the predefined by time β. The other conditions are used to make sure that the connection via satellite is not established, as long as a connection via GSM network is possible. If these conditions are fulfilled, the first thread creates the satellite thread (named SAT-thread) which firstly turns the Bluetooth radio on and attempts to establish the connection via satellite.
Turning back to the condition C, where the status of the connection is checked. If it already exists, via GSM network, the thread has to make sure that the connection via satellite (if it was active before) is dropped and not used. Actually this connection via satellite is not dropped immediately after the connection via GSM network has been established.

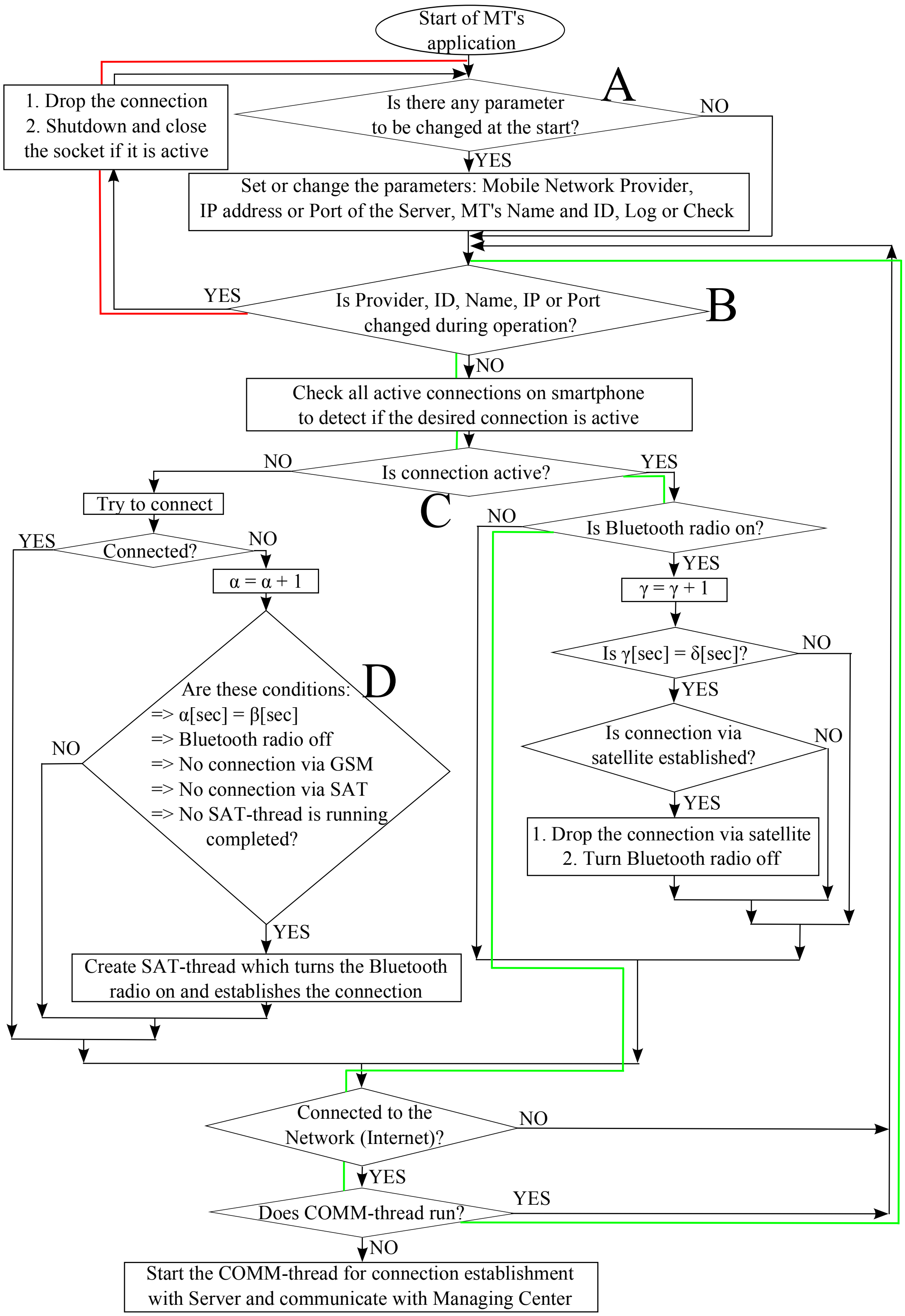


Figure 5.2: Algorithm of the first thread

Before dropping it the thread waits for δ seconds. The reason is: it can happen that the connection via GSM network is dropped just after it was established and if the connection via satellite was voluntarily dropped, then there is no connection at all. Thus, it is better to wait for δ seconds before switching the connection from satellite to GSM. The case of switching from GSM to satellite does not occur, because the connection via satellite is established only when the connection via GSM network has been dropped and the two connections are not active at the same time. The thread must then turn the Bluetooth radio off in order to conserve the lifetime of the smartphone battery.
On the other hand the mobile team should turn the Bluetooth radio off manually in Thuraya SG-2520, because the mobile team application is not able yet to handle this. After the first thread or the satellite thread (SAT-thread) achieves to connect to the Internet, then the third thread (named COMM-thread) is created. It defines some parameters to connect with the server. The COMM-thread establishes the connection and handles the communication with the managing center. After the connection has been established, via GSM network or via satellite, the first thread runs and checks for any changes during the operation (the green line in Figure 5.2). The first thread runs, same as the NAV-thread, until the mobile team application terminates.

The SAT-thread (Figure 5.3), has a single task, to establish the connection via satellite. Just at the beginning of it, the SAT-thread defines the modem it has to use. As explained before the smartphone and Thuraya SG-2520 has to be Bluetooth paired and the two devices should be close to each other, according to the Bluetooth specifications. The mobile team should turn the Bluetooth radio on manually in Thuraya SG-2520 and activate also the DUN Profile. The SAT-thread attempts to establish the connection until it is successful or the first thread has already established it via GSM network.

As it has been shown in Figures 5.2 and 5.3, both threads access the Bluetooth radio, which is considered a shared resource. In order to synchronize the usage of the Bluetooth radio, thus only one thread uses it at a time a mutex is used. Both threads must check the state of the mutex first before accessing the Bluetooth radio. If it is locked (because the other thread is using the Bluetooth radio), the calling thread will wait until the state of the mutex is changed to unlocked. Otherwise it changes the mutex state to locked and uses the Bluetooth radio.

The SAT-thread terminates itself if the connection is realized somehow, either via GSM network or via satellite, or the mobile team application in the smartphones is in termination process.

The mobile team application is able to connect to the Internet via the most popular mobile network providers in Austria, which are: A1, T-mobile, Drei, Telering, Orange, Yesss, bob. In order to connect to the Internet through any of them a new modem in the smartphone should be defined by setting the right parameters (APN, username and password), as it was explained in Section 3.2. The best way would be to define all the modems and no matter which mobile network provider is used the application can be connected.

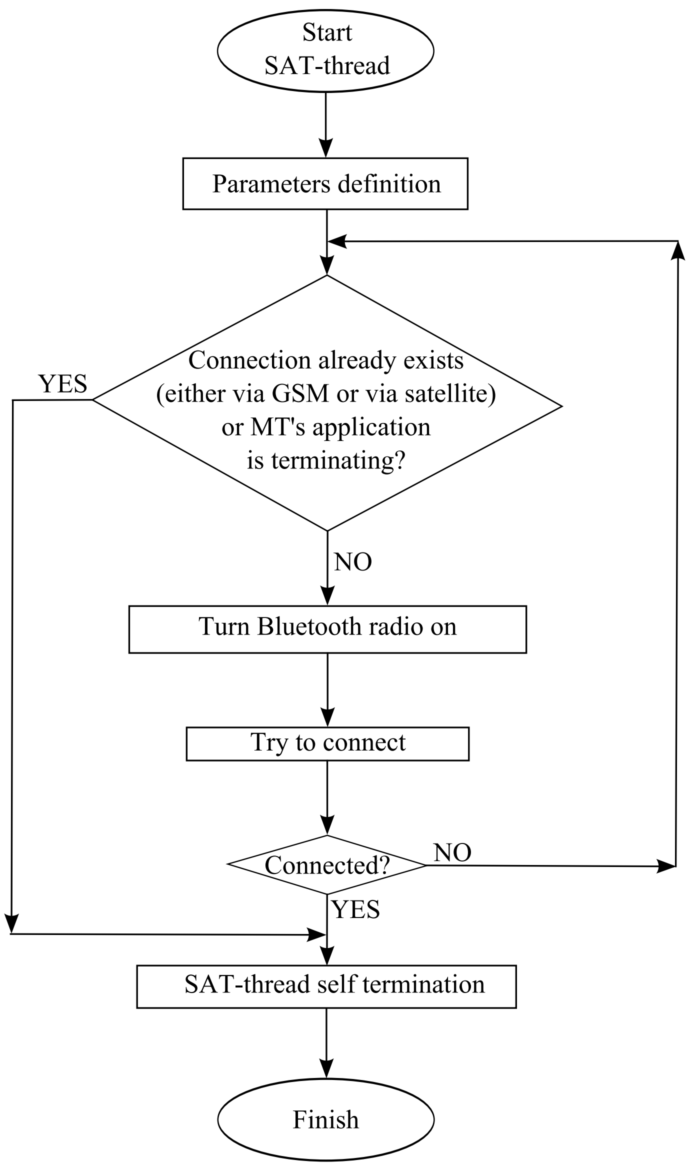
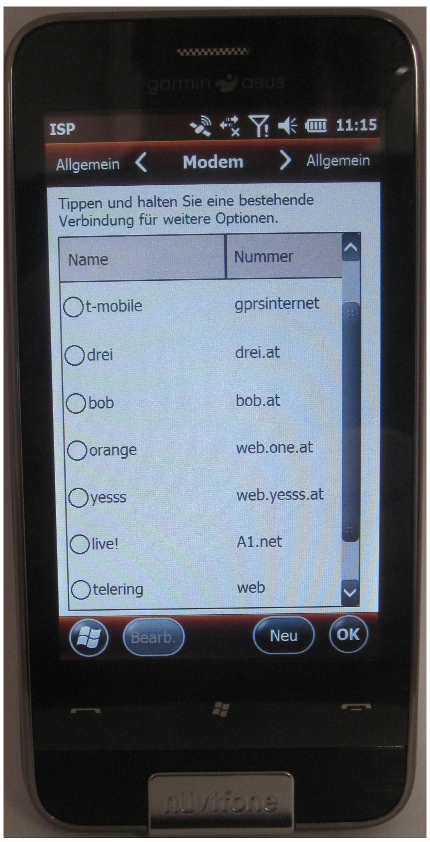
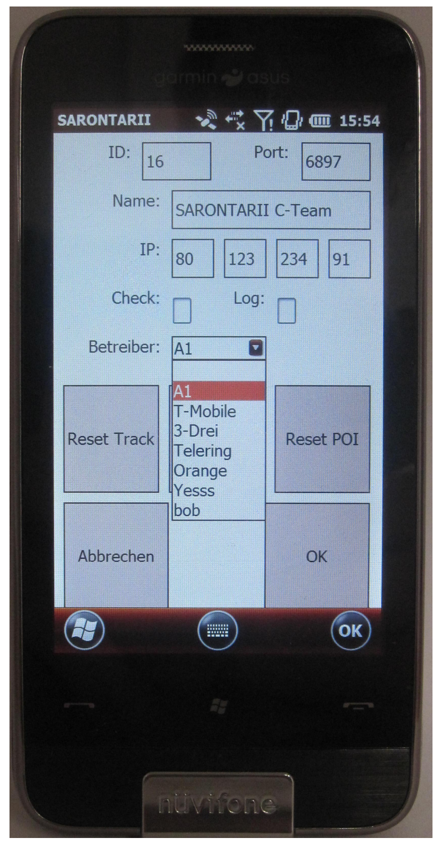


Figure 5.3: Algorithm of the satellite thread (SAT-thread)

The mobile team can select any of these providers, in the settings window shown in Figure 5.1, depending on the SIM card it uses in the smartphone. Figure 5.4 shows: a) Modems in the smartphone and their APNs (in "Nummer" column) and b) Providers which can be used in the platform. It is not important how the modems are listed because their names are checked to find the right one. Thus, the names of modems should be the same as they have been defined in the source code, as shown in Figure 5.4a.



(a) Modems defined in the smartphone



(b) Possible mobile network providers

Figure 5.4: Modems definition and Mobile Network Providers

The COMM-thread is only created by the first thread, as shown in Figure 5.2, only when the mobile team application is connected to the Internet. This thread runs also until the termination of the application. If the connection is dropped for any reason, it does not have to be terminated.

The COMM-thread has two tasks:

- Connect to the server using the Internet connection established by the first thread or SAT-thread;
- Handle the communication with the managing center through the server.

In order to establish the connections in the platform the sockets are used. A socket is an endpoint of a bidirectional communication flow across a computer network based on the Internet Protocol suite. On socket creation there are some parameters to be defined, such as: socket type, protocol used, address family specification and a socket descriptor is returned by the function creating the socket. The socket descriptor is the ID of that socket to distinguish it from the others. It is used to access the socket, as well as to transmit and receive data through it [36]. It is also possible to change or set any new property of the socket. In the platform the Internet Protocol version 4 (IPv4) is used. The socket type is "Stream Socket", which provides sequenced, reliable, two-way, connection-based byte streams. It uses the Transmission Control Protocol (TCP) as the transport protocol. The other basic type of the socket is "Datagram Socket" which supports datagrams. The User Datagram Protocol (UDP) is unreliable and connectionless. Both types of sockets use the Internet Protocol.

There are still some important parameters to be defined before a socket is used:

- Local Socket Address (IP address and Port number of the mobile team);
- Remote Socket Address (IP address and Port number of the server).

The IP address of the local socket (of the mobile team) is provided by the mobile network provider or the provider of the Thuraya service when the connection to the Internet has been established. It is a dynamic IP address, i.e. every time the mobile team connects to the Internet, the provider assigns a new IP address from the range it owns. These IP addresses of the mobile teams can be seen in the database and in the web application of the managing center. The IP addresses of version four consist of 32 bit (which leads to the total number of IP addresses of $2^{32} = 4,294,967,296$). Due to the rapid growth of the Internet and the predicted lack of the available addresses the new version of IP called Internet Protocol version 6 (IPv6) provides $2^{128} \cong 3.403 \times 10^{38}$ addresses.

Defining only the IP addresses of the two users (hosts) would not be enough for establishing a connection between them. There is also a Port number that must be defined and used. By knowing only the IP address, it is possible to "find" the right host, but there is no information about the process to communicate with (the process that the incoming packets have to be delivered to). A host computer can handle many connections at the same time, allowing different processes (applications) to share the network resources simultaneously, but without that Port number the host computer does not know to whom the received packets belong. Thus, the Port numbers have to be defined at both hosts in order to define the processes that would receive the packets. The Port numbers can be different, for example Dynamic Host Configuration Protocol (DHCP) uses UDP port 67 for sending data to the server, and UDP port 68 for data to the client.

A very good example of describing the Port numbers, is a company having a telephone number and the extensions for each employee. In order to reach a certain person, its extension must be known exactly (the possibility of calling someone else in the company and asking him or her to divert the call to the desired person is eliminated). Otherwise communicating with that person would be impossible. The telephone number of the company has the same role as the IP address of the host. The extension, used to call the right person, has the same role as the Port number to define the process in the host computer in order to receive the incoming packets. The Port number is a 16 bit number with a maximum possible value $2^{16} = 65,536$, beginning from 0. The Port numbers from 0 to 1023 are reserved for the standard services. In Table 5.4 a list of some of these well known Port numbers is shown [13]. If a host, actually a process in it, wants to transfer a file to a host using the File Transfer Protocol (FTP) it should connect to Port number 21 of the destination. A list with the well known Port numbers can be found in [37]. There are two possibilities to define the Port number in a host computer: by finding a free Port and using it or by allowing the Kernel to do that. For the mobile team application the second choice is used.

In order to establish the connection with the host computer in the network its IP address and the Port number on which it is listening must be known. These two parameters specify the address of the remote host computer or remote socket. In the platform it is the server. Knowing that the server can be relocated, the mobile teams have the possibility to define manually the IP address and Port number of the server and they can change them whenever it is required. But changing them drops the actual connection (if it exists). These two parameters can be changed in the settings window. Their current values are, Server IP address: 80.123.234.91 and Server Port number: 6897. The server is located in the University Center Rottenmann (in German "Universitätszentrum Rottenmann" [38]).

Table 5.4: Port Numbers

Port	Protocol	Use
21	FTP	File Transfer
23	Telnet	Remote Login
25	SMTP	E-mail
69	TFTP	Trivial File Transfer Protocol
79	Finger	Lookup information about a user
80	HTTP	WWW
110	POP-3	Remote E-mail Access
119	NNTP	USENET news

Only now, after definition of all these mentioned parameters the socket can be used to establish the connection.

5.2.1.2 Server Implementation

Same as for the mobile team application, the server must create and define parameters of a socket. Actually there are more sockets but they are created and used only when they are needed, i.e. when a new connection is going to be established. TCP provides only point-to-point connections and no multicasting or broadcasting (see Section 2.2). For this reason, an individual connection will be established for each mobile team.

The server application (better say the thread that handles the socket) should define the same parameters as described in Section 5.2.1.1, but with some exceptions which are explained in the following paragraph.

The server must use a static IP address, in order to make it easier for the mobile teams and managing center to connect with it. On defining the local socket address, the server application should provide its static IP address, which currently is "80.123.234.91" and the Port Number 6897. The server does not need to define the remote socket address, because it does not initiate the connection. It receives any connection requests from the mobile teams. After creating the socket, with the SOCKET primitive, shown in Table 2.1 and setting the right values for the IP address and port number the server binds the local address with the socket, by the BIND primitive. The server then startes listening, by using the LISTEN primitive, for any connection request sent by the mobile teams. The server listens (waits) on the defined Port.

5.2.1.3 Connection Establishing

Since the server listens for any of the connection request, the mobile team is the connection initiator, by using the CONNECT primitive, shown in Table 2.1, which sends a connection request to the server. This request is directed to the process in the server that is listening on the same Port as the one defined in the connection request. The process creates a new thread which will handle the connection and the communication with this mobile team. There is a thread for each connection. The thread accepts the connection request, by using the ACCEPT primitive, and replies with an acknowledgement. It can also reject the connection request. As the final step, the mobile team acknowledges the received server's acknowledgement and the mobile team and server are connected. These described steps in order to establish the connection between two hosts are known as three-way handshake which is used in TCP protocol. The thread runs as long as the connection with the mobile team is active. When the connection is closed or dropped for any reason the thread terminates itself immediately. When the new connection request is received, the process creates a new thread to handle the new connection.

The first message, after connection establishment, sent by mobile team to the server is the login message, described in Section 4.1. It is used to register the mobile team in the platform as active mobile team.

After the connection has been established successfully, the mobile team and server can send and receive data between each other. The COMM-thread in the mobile team application changes the COM symbol to green colour which is shown in the main window. Otherwise, as long as the connection is not established the COM symbol has red colour.

A summary, in ascending order, of all primitives (also known as socket calls) used to establish connection is shown in Table 5.5. The order of execution of the primitives is given by the numbers. In the Client side the BIND primitive is missing, but as mentioned before, the Kernel will assign a Port number for the connection and the user does not have to take care of it.

5.2.1.4 Connection Release

There are two possibilities that a connection can be dropped. The first one occurs when the mobile team terminates its application, when the rescue operation is completed or the communication with the managing center is not needed anymore. This is done by sending a termination message and using the CLOSE primitive which is the last step in Table 5.5.

Table 5.5: Ascending order of the primitives (socket calls)

Client	**Server**
1. Create Socket	1. Create Socket
2. Set Socket parameters	2. Set Socket parameters
	3. Bind Socket with address
	4. Listen to the Port
5. Send Connect Request	
	6. Accept Connection Request
7. Send and Receive packets	7. Send and Receive packets
8. Close connection	8. Close connection

This is the termination of the application done by the mobile team on purpose. The second way is an involuntary dropping of the connection and can take place in following situations:

- No GSM network coverage - the mobile team "gets in" the area where no signal of the mobile network provider can be received by the smartphone;
- No Thuraya network coverage - the mobile team is in the area where no signal of the Thuraya network can be received. This can happen when there is no line of-sight to the satellite [17].

There is also a special case that the connection can be dropped involuntarily, when any of devices of the mobile team is out of battery.

5.2.2 Connection between Managing Center and Server

The managing center is also considered as host computer (client) which uses the socket to connect with the server. The server defines and handles the connection with the managing center the same way as with mobile teams and the connection is initiated by the managing center.

5.2.2.1 Managing Center Implementation

As it has been shown in Figure 3.9 the managing center can establish two connections with the server:

- The first connection with the application running in the server for communication with the mobile teams;

- The second connection with the database for adding, deleting, updating and checking any new data.

In order to establish these two connections the managing center defines a socket for connection with server application and uses the PostgreSQL functions to establish a connection with database. Even if it has to be connected with the same host (server) it needs two different connections which are handled by different processes. The Port number used to connect with the server application is 6897 and for connection with the database 5432 is used. According to these different Port numbers the packets received by the server will be correctly directed to the server application or to the database.

Any connection established between the web applications and any host computer does not last too long (at least in the present implementation) because when the web application is reloaded the connection is dropped. The web application of the managing center will establish a new connection anytime it wants to connect with the server or with the database. After completion of its task, it closes the connection voluntarily.

5.3 Communication and Data Transmission

Establishing successfuly the connections with the server and registering the mobile team and the managing center as active (online) in the platform makes it possible to start the communication between them. The whole communication in the platform is realized through the server using the messages defined in chapter 4. The whole communication traffic between mobile teams and managing center is stored in the database located in the server. The web application of the managing center can access directly the database, as shown in Figure 3.9, to add, delete, update or check any new data, but it cannot communicate with the mobile teams through the database.

Only two entities from the Table 2.1 are not mentioned yet, SEND and RECEIVE. Both of them are used for transmission and receiving the messages over the defined sockets. After reading the data stream on the socket, the beginning ("$EZ" and "$MT") and the end of the message have to be detected in order to process the whole message. The checksum of the received message is proofed also. If it is not correct that message is dropped and the next one is read. No correction algorithm is implemented. Depending on the type of the message received, they are handled differently, i.e. the text messages received by the mobile team are shown directly on the display (Figure 5.7c). The POI or search sectors are saved first in an appropriate buffer, then are shown in the digital map and on the display as well.

In order to organize the communication better, the messages are grouped in different types but there is also a possibility to send an arbitrary message (in German "Sonstige Nachricht") which does not belong to any of these types. As well there are predefined messages with fixed length. No more can be added. Such messages are:

1. Login Message;
2. Position Message;
3. Status Message;
   (a) Call for Help (in German "Hilferuf"),
   (b) Understood (in German "Verstanden"),
   (c) Later (in German "Später"),
   (d) Not Possible (in German "Nicht möglich").
4. Termination Message.

The messages of the other types can contain any text written by the mobile team or managing center team in order to describe something, part of a photo for the managing center or geographical coordinates of any Find Place, POI or any search sector. These messages are:

1. Status Message;
   (a) Find Place (in German "Fundort"),
   (b) Point Of Interest (POI),
   (c) Other Message (in German "Sonstige Nachricht").
2. Photo Message;
3. Text Message;
4. Search Sector Message.

5.3.1 Position and Status messages sent by the Mobile Team

The login message and position messages are sent automatically and the mobile team does not need to take care of them. Contrary to the login message that is sent only once, the position messages are sent periodically with a configurable period. The other messages are sent only when the mobile team wants to communicate with the managing center.

The mobile team can send any of the messages shown in Figure 4.2 by just clicking on any of the buttons as decribed in Section 4.3. Two keyboards for writting text messages are provided. The first one is used for the letters and the second one for numbers, some mathematical symbols and some punctuation marks. These two keyboards are shown in Figures 5.5 and 5.6, in both display orientation, landscape and portrait.

(a) Portrait (b) Landscape

Figure 5.5: Letters Keyboard

The letter keyboard shows by clicking on: "Fundort", "POI" or "Sonstige Nachricht" buttons in the messages windows (Figure 4.2). There is a button in each keyboard that makes it possible to switch from one keyboard to the other (in the letter keyboard it is the "123" button and in the other one is the "Fertig" button, meaning "Done").

There is the possibility to delete any written letter by "Korrektur" button meaning "Correction", as well as to insert a space symbol between words by the button "Leerzeichen". Every time the mobile team wants to send a message (button "Senden") it is asked once more to make sure that the right message will be sent.

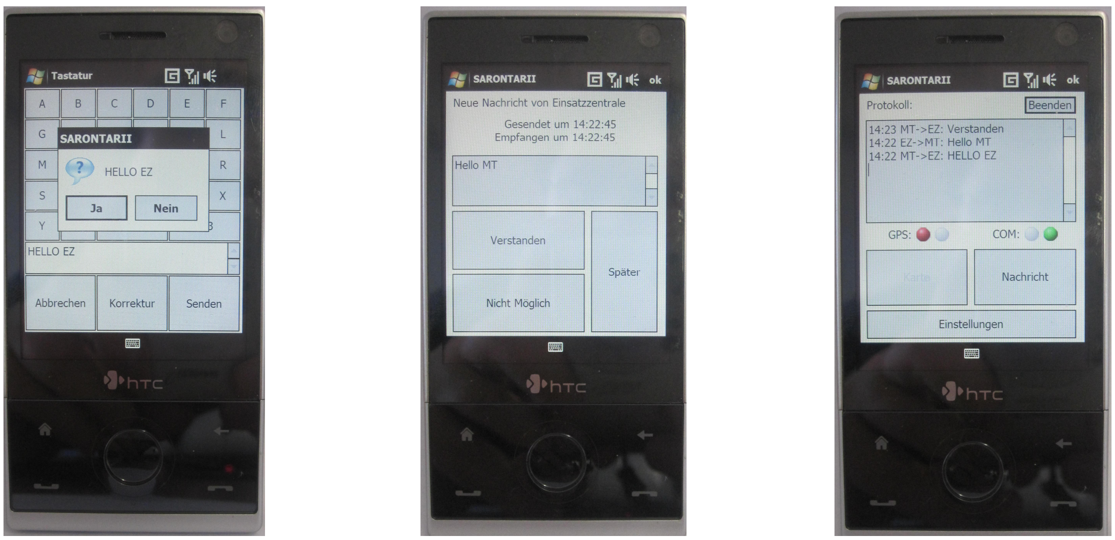
(a) Portrait

(b) Landscape

Figure 5.6: Mathematical symbols and Punctuation marks Keyboard

By clicking on any of these three buttons: "Fundort", "POI" or "Sonstige Nachricht" a status message is created with the appropriate code, as shown in Table 4.4. The written text is added at the end of the status message as content of the parameter "REMARK".

Figure 5.7 shows the communication between a mobile team and the managing center. In Figure 5.7a is shown the message "Hello EZ" which is sent to the managing center. "Neue Nachricht von Einsatzzentrale" stands at the top of the window of the received messages (Figure 5.7b). It means "The new message from Managing Center". It is followed by the time the message was sent (in German "Gesendet um:") and the time it was received (in German "Empfangen um:"). Then the content of the received message "Hello MT" is shown. As well, three buttons: "Verstanden", "Später" and "Nicht möglich" can be used for responding to the managing center. The third Figure 5.7c shows the communication traffic between the mobile team and the managing center. It appears instead of the project logo in the main window and shows the time when the messages were sent or received, the transmitter and the receiver of the messages and the messages content.



(a) Write and send the message (b) Received message (c) Protocol

Figure 5.7: Sending and receiving the messages

None of position and status messages are lost even if the connection to the server is dropped for any reason. They are saved into the buffers and when the new connection is established again, a new thread is created to handle them. They are sent one by one same as they have been saved into the buffer, using the First In First Out (FIFO) method. If the connection is dropped again and not all messages have been sent, the rest of them is saved again in the buffer, waiting for the new connection to be established. The access to these buffers is synchronized by using the mutexes.

5.3.2 Photo Transmission by a Mobile Team

Based on the adage "A picture is worth a thousand words", the mobile teams have the possibility to send any photo instead of writing long messages. The main idea of this service in the platform is showing the real situation of the terrain. A mobile team can send any photo taken before or any photo taken at the moment. The photo is saved on the server computer and the managing center is informed about it.

The platform supports only these formats: JPG, JPEG, JPEG File Interchange Format (JFIF), Portable Network Graphics (PNG). A thread will be created to handle the photo transmission. It terminates itself on completed transmission or if the connection is dropped and the photo cannot be transmitted. In both cases the mobile team is informed by this thread. The mobile team can send only one photo at a time, i.e. before the first photo has been sent completely (or is stopped due to losing connection) the second photo is not transferred. In order to avoid high costs, the photo is transmitted only when the connection is established via GSM network and not via satellite.

This service can be used by clicking on "Bilder" button in the messages window (see Figure 4.2). There are two possibilities:

- Send any already existing photo - after selecting the photo it will be shown for a short time in order to avoid sending not the right one;
- Take and send a new photo - the mobile team can define the photo name and the camera will be started automatically and is ready to take a new one. The new photo has the JPG extension and is saved in a folder dedicated only for new photos which are located in the working directory of the mobile team application.

The mobile team can add some text in order to describe the photo. This text is part of a message which has this format:

MSG,PLD,FSIZE,DATE,TIME,LAT,LON,H,COG,TEXT

These parameters are decribed in Table 5.6. The length of all parameters are fixed except the last parameter, TEXT, which has variable length starting from zero characters. The starting value of the first parameter, MSG, is 61 Bytes. Actually, this is the length of the message when no text has been written. The length of the whole photo message is 2000 Bytes. Both boundaries (γ and φ) of the photo size are variable and the upper one is used to limit the photos that can be sent over the platform. As mentioned before, the whole photo is split into the payloads which are sent to the server one by one and they are used to reconstruct the photo again on the server side.

This message is sent to the server as well. It is hidden inside the photo using Steganography [39]. Steganography is an art of hiding data such as: text messages, text documents, photos into other photos or sound files. If the third party achieves to get the "transporting photo" with hidden data, it must know the exact procedure how they have been hidden

Table 5.6: The hidden Message

Parameter	**Format**	**Unit**	**Values Range**	**Remark**
MSG	nnn	Byte	61 to 999	Message length
PLD	nnnn	Byte	1 to 1973	Payload length
FSIZE	nnnnnn	Byte	γ to φ	Photo size
DATE	yyyymmdd	Year Month Day	19991231 to 20991231	Local date when the message was created
TIME	hhmmss	Hour Minute Second	000000 to 235959	Local time when the message was created
LAT	(-)dd.ddddd	Degree.decimal	-90.00000 to 90.00000	Latitude, WGS 84
LON	(-)ddd.ddddd	Degree.decimal	-180.00000 to 180.00000	Longitude, WGS 84
H	hhhh.h	Meter	0000.0 to 9999.9	Elevation
COG	ddd	Degree	000 to 359	Moving Direction
TEXT			Arbitrary text	Optiontal: Text Message

in order to extract these data again, otherwise the data are unextractable. The difference with cryptography is that its goal is to make data unreadable by a third party.

Typically the photos use either 8 bit or 24 bit colour. Using the 8 bit colour a pixel in the photo can have $2^8 = 256$ values which actually represent the intensity of the colour shown in that pixel (0 is the black colour and 255 is the white colour). 24 bit (3 Byte) colour helps to show any photo with very high quality because there is a wide range of the values that a pixel can have ($2^{24} = 16.777.216$). Each Byte shows the intensity of one of the primary colours Red, Green and Blue, known as RGB and through the combination of them the other colours can be obtained, e.g. the yellow colour is obtained by this combination, R=255, G=255, B=0. It is obvious that the memory requirements are higher for photos with 24 bit colour.

In both cases, 8 bit and 24 bit, the bits at the left side have more "influence" on defining the colour intensity and are known as Most Significant Bits (MSBs). The bits at the right side have less effect and are called Least Significant Bits (LSBs), as shown in Figure 5.8.

Changing the least significant bit (in 8-bit colour photo) or the two least significant bits (in 24-bit colour photo) will change the intensity of the pixel slightly but these changes are not detectable by the human eyes. Steganography uses this "shortcoming" of the human eyes and hides the data by changing the values of the LSBs of the "transporting photo".

5.3.2.1 Hiding the Message in the Photo

The photo is opened in binary mode and is copied in a block of the memory, actually in a byte array. Each element of this array is one byte long (8 bit). The message consists of characters where each of them requires a Byte in memory. Both the message and the photo are using zero-based indexing, i.e. the first element of the array is indexed by zero. In order to hide the message, the values of the least significant bit of the Bytes of the photo will be changed according to the values of the bits of the message. This hiding procedure is shown in Figure 5.8. In order to extract only the value of a single bit from the Byte of the message and do some logical operations, bitwise operations are used. The Bytes of the message are denoted by letter M with the index i within the integer values range $0 \leq i \leq (Message\_length - 1)$. Starting with the first Byte of the message, where $i = 0$. The values of each bit are shown by the letter Y with the red colour. For extracting these values **mask1** = **10000000** is used. Depending on the bit that has to be extracted, a bitwise right shifting of the mask1 (shown in Figure with this symbol ">>") for j positions is done. The j can have the values $0 \leq j \leq 7$, e.g. shifting the mask1 for $j = 1$ it becomes **mask1** = **01000000**, for $j = 4$, **mask1** = **00001000** or for $j = 7$,
mask1 = **00000001**. Then a bitwise AND (shown with this symbol "&") between the Byte of the message and the shifted mask1 is done. The obtained result is a Byte (called Byte A) with all bits set to zero except the extracted bit. No matter on which position this extracted bit is, another bitwise right shifting has to be done in order to place this bit at the first position from the right side. Thus, it will become the least significant bit of the Byte A and all the other bits in its left side are zero. This LSB of the Byte A is the bit that will be hidden in the Bytes of the photo.

The Bytes of the photo are denoted by the letter P with the index k within the integer values range: $0 \leq k \leq Photo\_size$. Only $Message\_length * 8$ Bytes of the photo are used to hide the message. In most of the cases, the header of the pictures is located in the first Bytes. In order to avoid damaging these headers, it is better to start from another Byte and not from the first one. In the platform the starting Byte is $l = 100$. Thus, the boudaries of the index k are: $100 \leq k \leq (100 + Message\_length * 8)$.

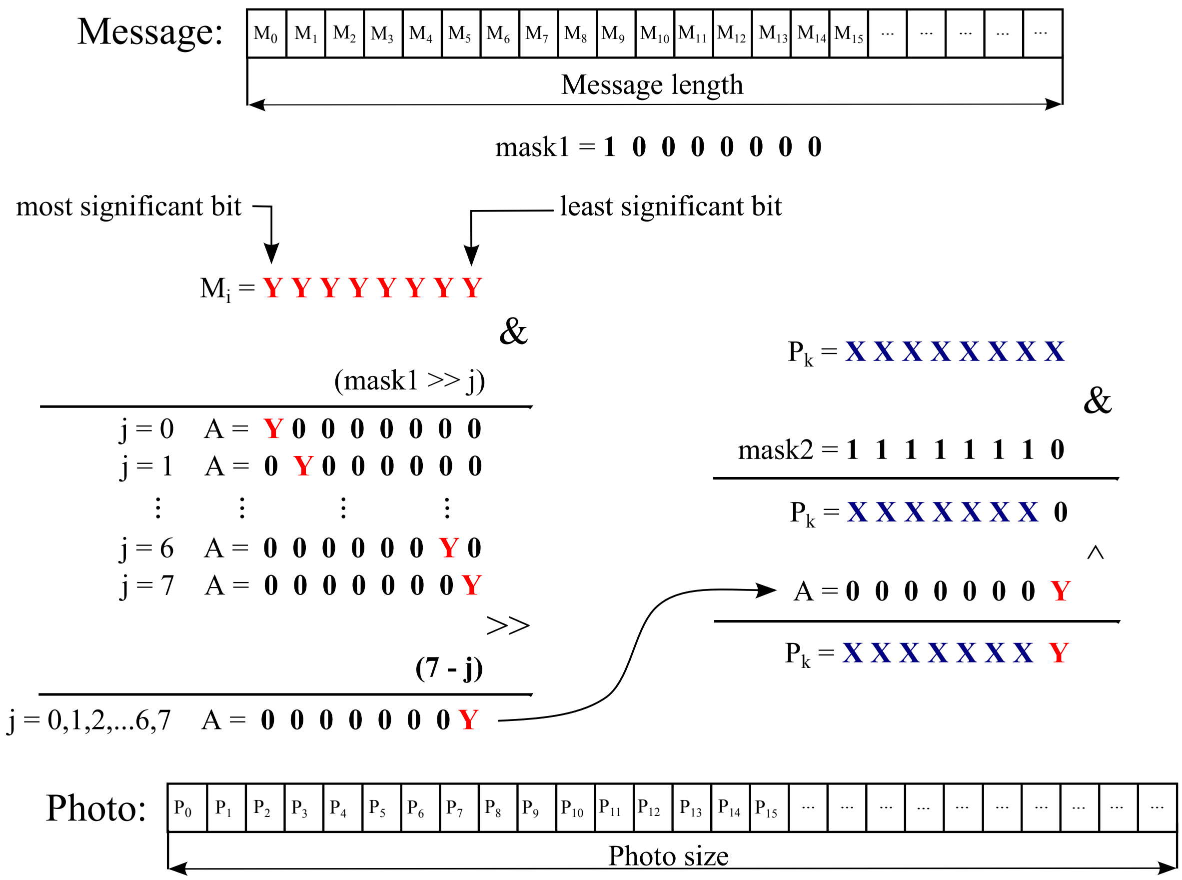


Figure 5.8: Hiding the message inside the photo

The first bit of the message is hidden in the Byte P_k. The values of its bits are marked by the blue letter X (Figure 5.8). In order to hide a bit of the message in the LSB of the Byte of the photo, the value of this LSB must be set to zero by doing bitwise AND between the Byte of the photo and the **mask2** = **11111110**. Then a bitwise XOR (shown with this symbol "∧") is done between the Byte $P_k = XXXXXXX0$ and the $A = 0000000Y$ in order to set the value of LSB of A into the LSB of P_k. Finally the Byte $P_k = XXXXXXXY$ has a new LSB and this new value of P_k is saved again in the same location (with the same index k).

Let assume $M_0 = 01001001$ whose decimal representation is the number 73 and $P_k = 00111011$ with decimal representation 59. The MSB of M_0 must be hidden into the LSB of P_k. Since it is the MSB ($j = 0$) the mask1 should not be shifted at all, only a bitwise AND should be done which creates the Byte $A = 00000000$. Then a bitwise right shifting for seven positions ($7-j = 7-0 = 7$) is processed and changes the Byte into $A = 00000000$. Doing the bitwise AND between P_k and the mask2 changes P_k into 00111010. The last step of hiding is the bitwise XOR between Byte A and P_k which changes the value of it into $P_k = 00111010$ and now its decimal representation is 58. Thus, it changed the colour intensity only for one value, from 59 to 58 which is not detectable by the human eyes. It is possible that the LSB of P_k is not changed at all because the bit of M_i has the same value as the LSB of P_k.

After hiding the other bits of the first Byte of the message into the photo, the procedure is repeated with the bits of the other Bytes of the message. Only a single bit is hidden in a single Byte of the photo. This hiding procedure is repeated for all $Message\_length * 8$ bits of the message.

When the whole message is hidden, the mobile team application starts sending the photo using the photo message to send all the payloads.

5.3.2.2 Extract the Message from the Photo

At the server side when the first payload is received, only the first three parameters (message length, payload length and photo size) of hidden message are extracted. According to the photo size parameter enough memory will be reserved (a byte array with photo size). Every received payload will be saved after the previous one until the last one is received and the whole photo is reconstructed.

Extracting of the message from the received photo is shown in Figure 5.9. The extracting procedure is started from the Byte where the first bit of the message was hidden, which is the Byte P_k. In order to extract only the LSB of P_k, a bitwise AND between P_k Byte and **mask3 = 0 0 0 0 0 0 0 1** must be done. The result is a new Byte B with all bits set to zero, except the LSB of it. It has the desired bit (Y). The mask3 can be obtained by using the bitwise NOT operation of the mask2, which does the logical negation of each bit. Depending on the real position that this LSB of the Byte B, had in the Byte of the message, it should be shifted to the left (shown with this symbol "<<") for appropriate positions. This is achieved by using the modulo operation (shown with the percentage symbol "%"). Knowing that a Byte consists of 8 bits, the modulo 8 operation is applied which yields only the values $0, 1, ...6, 7$. The first bit hidden was the MSB bit of the Byte M_0, thus it should be shifted by 7 positions to the left. The right position to be shifted to the left is calculated by $(7 - (k\%8))$.

The extracting procedure is repeated eight times (using eight Bytes of the photo $P_{k+0}, ..., P_{k+7}$) to get all eight bits of the Byte M_0. Each time a new bit is extracted and shifted to the right position, a bitwise XOR operation between the Byte B and the

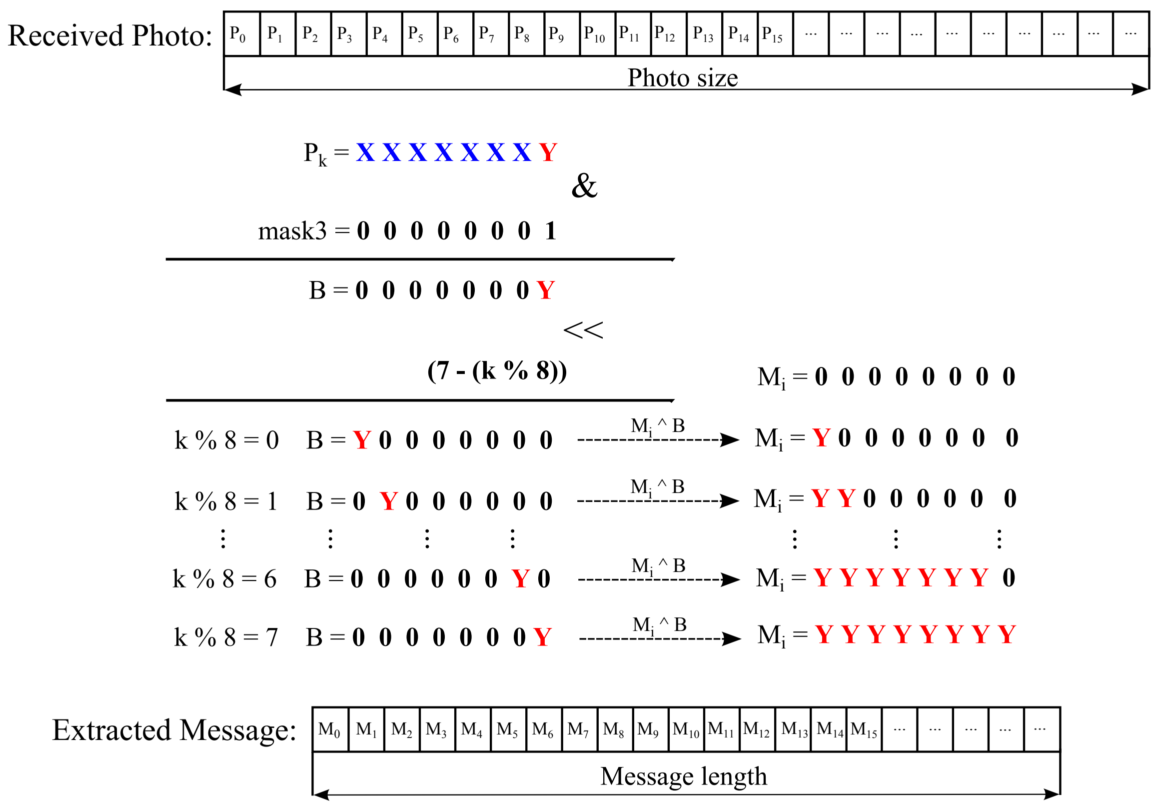


Figure 5.9: Extracting the message from the photo

actual value of Byte M_i is done. After eight of these bitwise XOR operations the Byte M_i has its real value, shown by the Y letters in red colour. This extracting procedure is repeated for $Message\_length * 8$ times by using the Bytes $P_k, ..., P_{k+Message\_length*8}$ of the received photo to create the whole message.

During transmission errors can occur, changing the values of any bit "violently", which leads to different intensity of the colour of any pixel as well as different characters (letters) of the hidden message.

The received photo by the server computer will be saved in an appropriate folder and its name will be extended by adding the mobile team ID. It was mentioned before that the mobile teams can name their photos arbitrarily and it can happen that two mobile teams name their photos identically. But the problem occurs when the photos are received by the server, the second photo received will overwrite any photo with the same name. Since each mobile team has a unique ID, this avoids having two photos with the same name or overwriting any other photo.

For each received photo by the server, the managing center is informed about it. It receives a message with the photo name, mobile team ID that has sent it, text description of the photo (if it was written) as well as the photo itself. The managing center team can see the received photo and send a message back to the mobile team letting it know if the photo was received correctly or is damaged and should be sent again.

5.3.3 Text Messages sent by the Managing Center

Sending a text message is possible through the "Senden" button, under the operating tools, shown in Figure 3.8. Figure 5.10 shows the interface for writting a text message. There is the possibility to send the message to a single mobile team (Unicast Mode) by selecting this or to all the active mobile teams, by selecting "alle Einheiten" (Broadcast Mode). The text can be written using the keyboard of the Notebook or the PC. It supports as well the special characters in German language such as: ä, Ä, ö, Ö, ü, Ü. The message is sent by clicking on the button "Textmeldung versenden".

The two other messages, POI and Search Sector Messages that can be sent by managing center are described later in Section 5.4 where is demonstrated how a POI or a sector is created, seen on the digital map and sent the to mobile teams.

5.3.4 Handling the messages in the Server

A general overview of the routes followed by the messages used in platform is shown in Figure 5.11. The routes of these messages in the Internet cannot be defined, due to the different routing algorithms used in different networks, and for this reason they are marked by dashed lines. Only a single mobile team is shown for simplicity, but as it was described before for each new registered mobile team in the plaform the server application defines a new socket and the rest remains the same.

The mobile team application uses a single socket for communication. Using this socket, the mobile team sends and receives the messages. The socket is marked in Figure 5.11 by bi-direction magenta arrow. All the messages sent by the mobile team are marked with red colour. They are received by the server application which handles and stores them in the database.

The managing center uses two connections for the communication and managing the rescue operation. The main goal of accessing the database directly from the managing center is to reduce the load of the server application. The managing center will use the

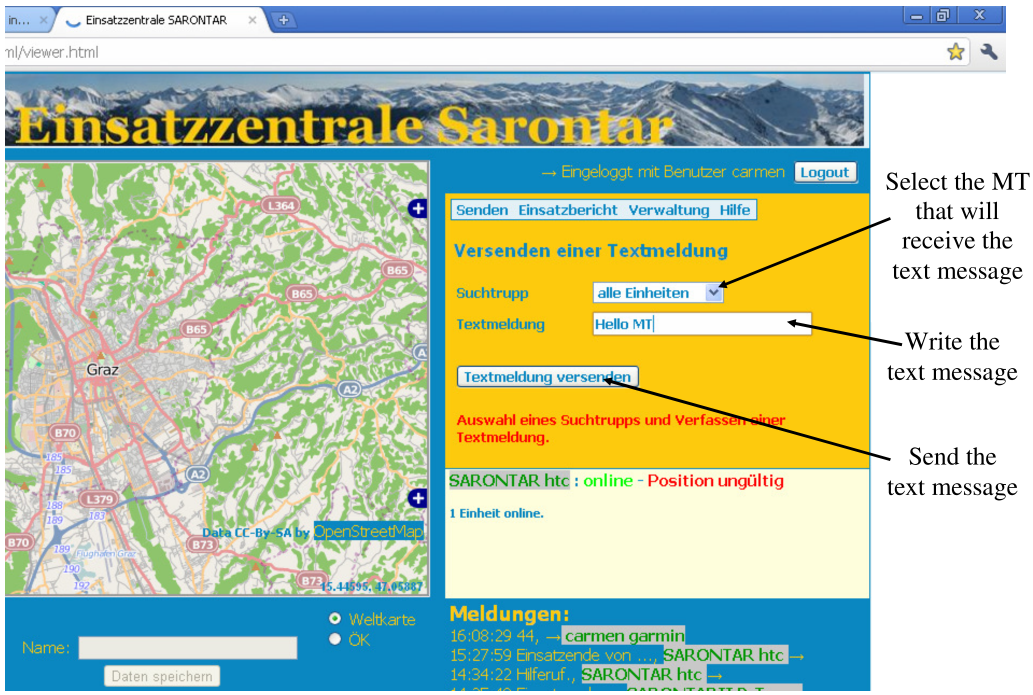


Figure 5.10: Writing and Sending Text Message by the Managing Center

connection with the server application only when it has to send something to mobile teams. This is shown by the uni-direction blue arrow. Any received message by the server application is just directed to the respective mobile team or to all active mobile teams if the Broadcast Mode is used. In this case the server application does not need to access the database.

During the rescue operation, it can happen that the managing center can define any POI or any search sector but it does not want or it does not need to send them immediately to the mobile teams. These just created POIs and search sectors are stored in the database, shown by the dashed green arrow in Figure 5.11. Later, when the managing center wants to send them, it uses the other connection. The managing center accesses periodically the database, through the PostgreSQL functions, to check for new data, i.e. the new messages sent by the mobile teams. It establishes the connection with the database and checks its tables if any new entries (Tuples) are added. If this is the case (shown by the dashed red arrow), it shows them to the managing center team by pop-up windows and adds them

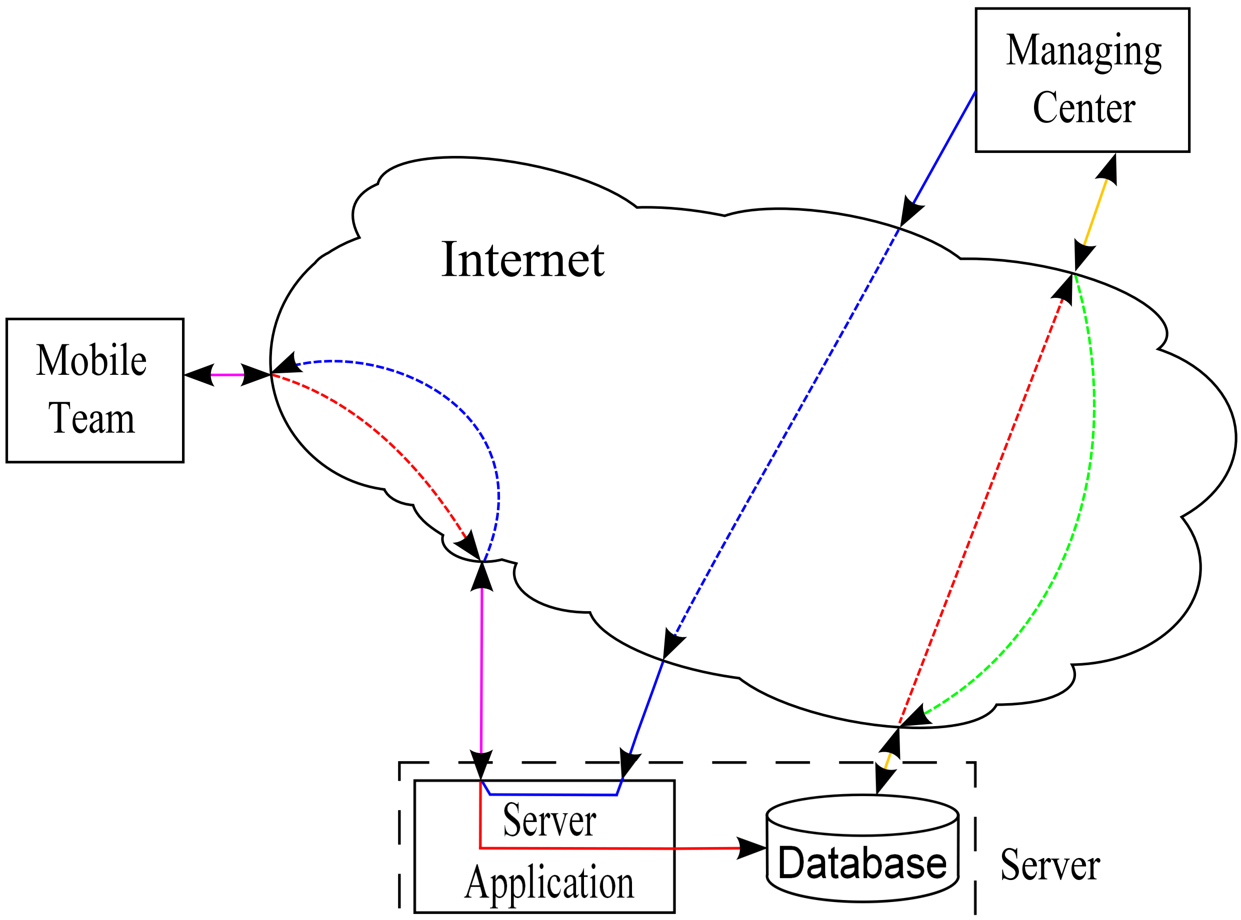


Figure 5.11: Data transmission in the platform between a single MT and MC

into the list of the messages, shown in Figure 3.8. After checking the tables it closes the connection.

As it has been mentioned in Section 3.3 and shown in Figure 3.6 the data in the database are stored in the tables. Important information about the communication and the whole rescue operation is stored. Depending on the data that are stored, the tables have different attributes. The tables containing the transmitted messages by the mobile teams or managing center have almost the same attributes as the parameters of the messages. They have the same names with the Message Identificator mentioned in chapter 4. There are also other tables not used for communication, but used for other purposes in the rescue operation. Some of the tables, also shown in Figure 3.6, are:

- **EINSATZBERICHT** - means in English "Rescue Operation Report". The managing center can automatically create a report about the whole rescue operation, this is described in Section 5.5. This table contains the information about all created reports, such as: Report title, its date and time of creation, involved mobile teams, the person leading the rescue operation, etc.;
- **EINSATZZENTRALE** - shows the name of the managing center and its geographical coordinates;
- **EZPOI** - contains all Points Of Interest defined by the managing center, used in the platform;
- **EZSCT** - contains all search sectors and their information, such as: mobile team ID the sector is sent to, the sector ID, local date and time the sector was defined, total number of messages used to transmit the sector to mobile team and the geographical coordinates of the vertices of the sector;
- **EZTXT** - shows all the text messages sent by the managing center, the mobile team ID which received the message, as well the date and time the message was created;
- **IP_NUMBERS** - this table shows the IP addresses of all teams involved in the rescue operation, including the server and managing center, as well as the ID and Name of the teams;
- **MT_AKTPOS** - shows the actual position, latitude and longitude, of all active teams and the local time this position has been calculated;
- **MTPHO** - has a list with all transmitted photos by the mobile teams;
- **MTPOS** - contains the position messages sent by all mobile teams;
- **MTSTA** - all status messages of all mobile teams are stored, including the code number to distinguish each type of status messages;
- **NAME_ID** - this table contains the IDs and Names of all teams ever used, including the server and the managing center;
- **PERSONENDATEN** - names and tasks of all people involved in the rescue operation, as well their organizations or departments (as described in Section 5.5) taking part in the rescue operation. This is used for rescue operation reports;

- **TEAMDATEN** - information about each involved team, such as: team ID, team leader and all team members;

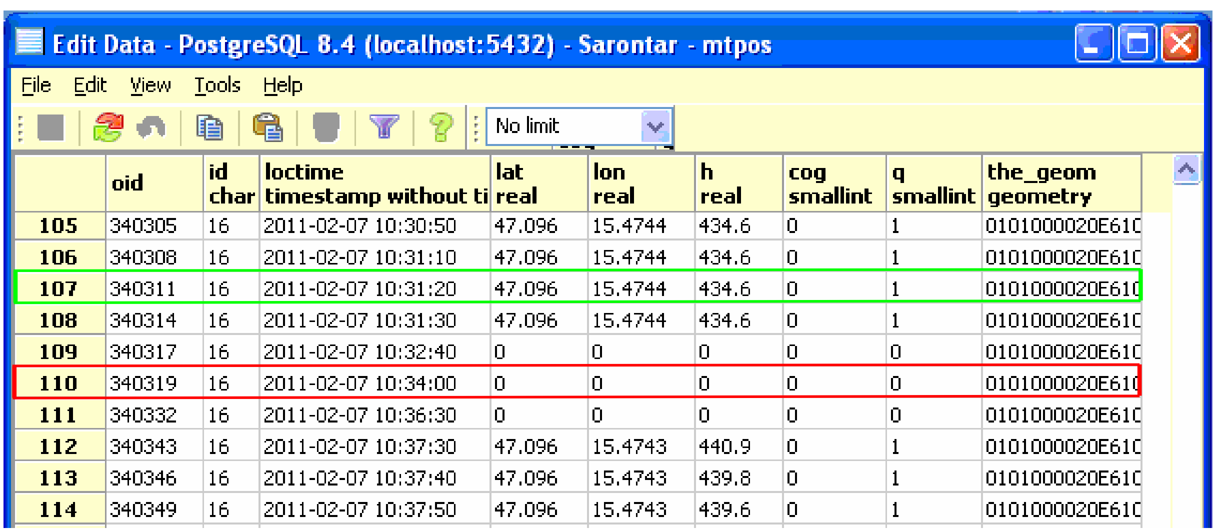
- **USERS** - contains the username, password and actual status if one is logged or not in the web application of the managing center, shown in Figure 3.8.

Two messages, a position message and a POI message are shown below. As well, it is described the way they are stored in the appropriate tables in the database. In order to find the right table that the message should be stored in, the message identificators are used, in these cases: "MTPOS" and "EZPOI".

The MTPOS message, marked with green colour in Figure 5.12, is:

$MTPOS,16,20110207 103120,47.09600,015.47440,0434.6,000,1*79\r\n

It is transmitted by the mobile team with ID = 16, at 10:31:20 AM, on February 7, 2011 from the location with latitude = 47° 05’ 45.6”, longitude = 15° 28’ 27.84” and elevation = 434.6 Meters which actually corresponds to the offices of the company **"Tele-Consult Austria"** GmbH [1], on the street "Rettenbacher Straße 22" in Graz. The zero value of the parameter "Moving Direction" tells that the mobile team is not moving.



	oid	id char	loctime timestamp without ti	lat real	lon real	h real	cog smallint	q smallint	the_geom geometry
105	340305	16	2011-02-07 10:30:50	47.096	15.4744	434.6	0	1	0101000020E610
106	340308	16	2011-02-07 10:31:10	47.096	15.4744	434.6	0	1	0101000020E610
107	340311	16	2011-02-07 10:31:20	47.096	15.4744	434.6	0	1	0101000020E610
108	340314	16	2011-02-07 10:31:30	47.096	15.4744	434.6	0	1	0101000020E610
109	340317	16	2011-02-07 10:32:40	0	0	0	0	0	0101000020E610
110	340319	16	2011-02-07 10:34:00	0	0	0	0	0	0101000020E610
111	340332	16	2011-02-07 10:36:30	0	0	0	0	0	0101000020E610
112	340343	16	2011-02-07 10:37:30	47.096	15.4743	440.9	0	1	0101000020E610
113	340346	16	2011-02-07 10:37:40	47.096	15.4743	439.8	0	1	0101000020E610
114	340349	16	2011-02-07 10:37:50	47.096	15.4743	439.6	0	1	0101000020E610

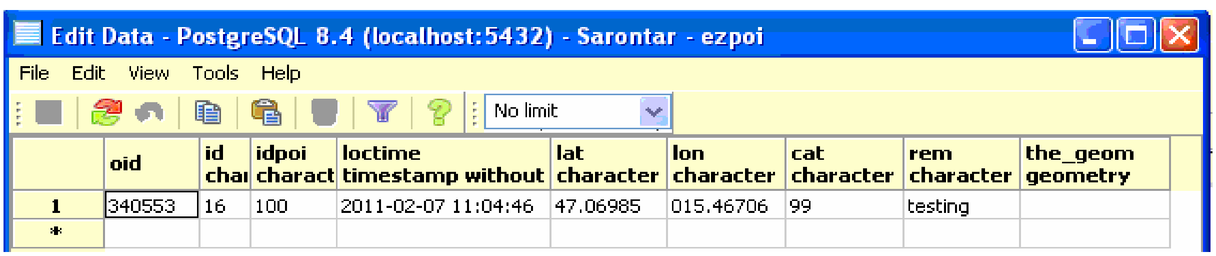
Figure 5.12: Position Message stored in the table MTPOS in the database

The POI message sent by the managing center is:

$EZPOI,16,100,20110207 110446,47.06985,015.46706,99,testing*32\r\n

It is sent to the same mobile team (ID = 16) on the same date but almost half an hour (11:04:46 AM) later than the position message was received by the managing center. The geographical coordinates of the POI are: latitude = 47° 04' 11.46", longitude = 15° 28' 1.42" which is just a place in the city of Graz. The last parameter, REMARK from the POI message, is the text used to describe the POI, in this case it is just the word "testing".

In Figure 5.13, the table EZPOI with the POI message stored in is shown. The first column in the table shows the row number in that table, the second one (oid) is used to identify the record (Tuple) and is generated automatically by the database system.



	oid	id char	idpoi charact	loctime timestamp without	lat character	lon character	cat character	rem character	the_geom geometry
1	340553	16	100	2011-02-07 11:04:46	47.06985	015.46706	99	testing	
*									

Figure 5.13: POI Message stored in the table EZPOI in the database

In case where a status message, described in Section 4.3, is sent by the mobile team, this message is stored first in the database and the server application checks if the managing center is active (online). If not, then it replies to the mobile team with a text message, where the last parameter of it is: "EZ ist nicht online!", meaning "The Managing Center is not online". This cannot happen the other way around because the managing center can send a message only to those active mobile teams, i.e. only the active mobile teams can be selected to send a message, as shown in Figure 5.10.

5.4 Digital Maps

Showing the intervention region, the actual position and track of active teams as well position of any important object are some of the requirements defined in Section 3.1. This can be done by using digital maps, which are loaded first, then shown on the smartphone display and on the web application. In order to be more useful and practical the digital maps should support zooming in and out, shifting in any direction, drawing any symbols (circles, squares), lines or writing any text on them.

The digital maps used in the platform consist of:

- The map of the intervention region as background;
- Actual position and track of active teams;
- Points Of Interest;
- Search Sectors;
- Zooming In and Out buttons;
- The map scale.

5.4.1 Digital Maps in the Web Application

In the web application (Figure 3.8) a digital map is shown which is integrated from a web map service. As it can be seen, it supports all the requirements: zooming in and out, shifting the digital map and showing the map scale. Before the managing center sends any POI or search sector to any mobile team, it should create them by using the POI, Sector and Navigation tools. To create a POI or a search sector the managing center team should select "POI Zeichnen" or "Sektor zeichnen", meaning drawing a POI or a search sector. For a POI it needs only to click at the right position on the map to show the new POI, while for a new search sector it needs to define all the vertices of the sector by clicking on the map to show the created sector. Both, the new POI and new search sector are shown in orange colour. In order to give a name to the new item, "Neuen Sektor/POI wählen", meaning "Select the new POI/Search Sector" must be selected. Then one has to click on the created POI or sector which changes its colour to blue. In the Name field, the managing center team can give a name to the selected POI or search sector. Finally by clicking on the button "Daten speichern", meaning "Save the data", the new item (POI or search sector) is saved in the appropriate table in the database. The colour of the new item is changed to red. So far the items have been just created and not sent to any mobile team.

A new POI and a new search sector created in the web application are shown in Figure 5.14. Their names are "First POI" and "First Sector" which are shown on the circle (POI symbol) and on the polygon (the form of the sector). The actual position and the track (the red line) the mobile team followed are shown as well.

Sending a POI or a search sector is almost the same as sending text messages (see Section 5.3.3) by using the "Senden" button, under the operating tools. The POI or the search sector that will be sent can be selected through their IDs.

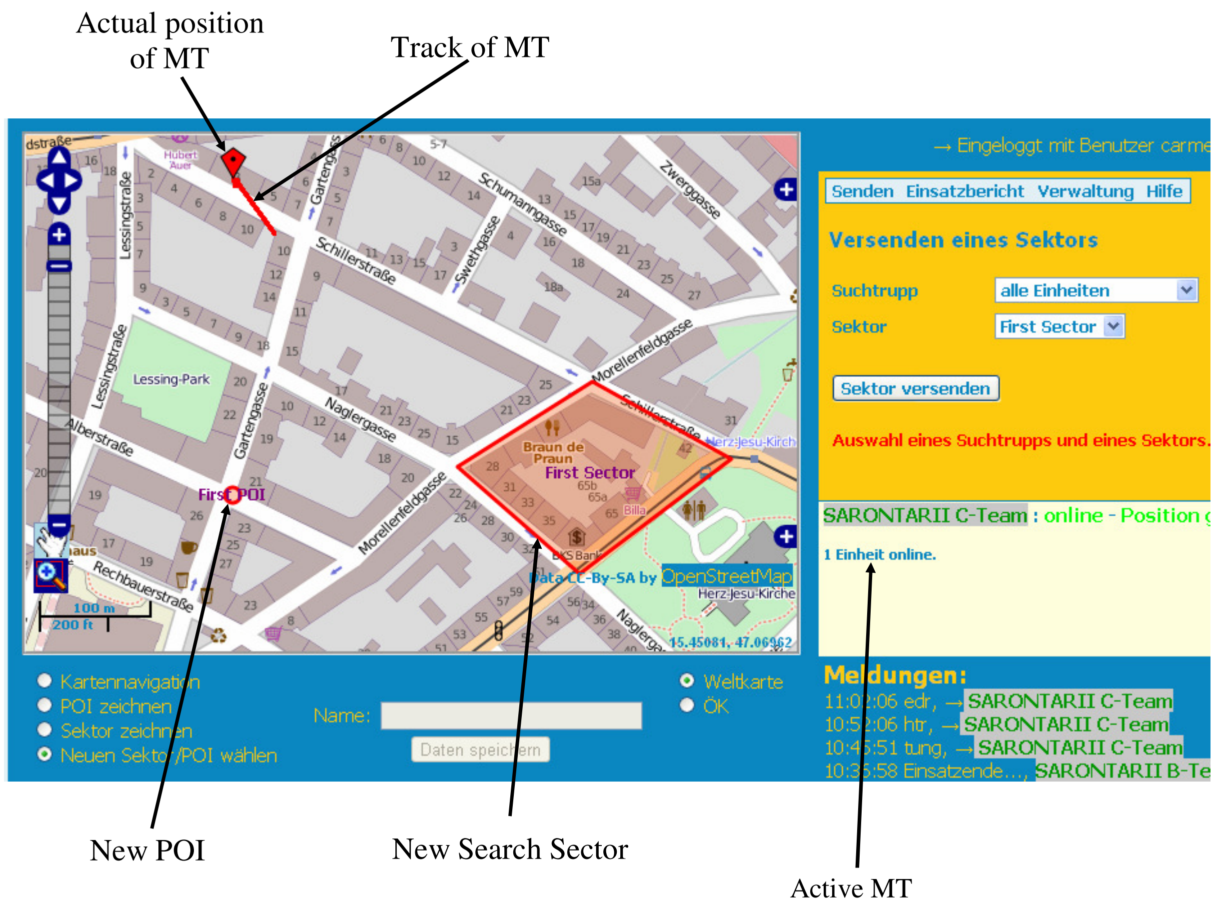


Figure 5.14: Creating new POI and new Search Sector in the Web Application

5.4.2 Digital Maps in the Mobile Team Application

The situation for applications in a smartphone seems to be different. There is no web map service that can be used in the smartphones. Due to this reason, in the smartphone are used the digital maps as images in JPG format. The images should be copied into the working directory of the application, as it was described in Section 3.2.

In order to make it possible to zoom the digital map in and out, the same digital map (showing the same region) but with a different map scale is used. The scale shows the ratio of a distance on the map to the corresponding distance on the ground. For the mobile team application are used three digital maps with these scales: 1:500.000, 1:200.000 and 1:50.000. These maps are being switched depending on the zooming level. Attempt to load a single image of very large size (MBytes order) and which consists of a large number of pixels fails, in spite of map scale of the image. It blocks the whole application in the smartphone and there is no possibility to display such digital maps. Therefore the digital maps are split into smaller tiles which have smaller size (around 400 KB) and consists of 750 x 750 pixels. Depending on the actual position of mobile teams only the appropriate tiles are loaded and shown. Only four tiles can be loaded which cover the whole display of the smartphone. When the mobile team shifts the digital map in any direction, it loads the other tiles in order to cover the whole display and unloads the tiles that are not visible anymore.

The digital map on the smartphone can be shown by clicking on the button "Karte" in the main window (Figure 4.1). This button is not active as long as a GPS signal with good quality is not received because this signal will help the application to define in which region the mobile team is and load the appropriate map tiles. Before this signal is received the position message sent to managing center contain a latitude and longitude equal to zero degrees. This lets the managing center team know that the GPS signal received by the smartphone has a bad quality and does not show the right position, see Figure 5.12.

All the GPS signals with good quality received by the smartphone are saved in a buffer and are used to show the track the mobile team followed. The track line has a different colour from the actual position. On the digital map with small scale the track is shown as a line and on those with larger map scale is shown as a series of circles.

The received POI and search sectors from the managing center are saved in their buffers, one buffer is used for POIs and the other one for search sectors. The POIs are drawn on the digital map with their names. The search sectors are drawn only when all their vertices are received. In case of more than six vertices, it is split in more messages. The sectors on the digital map of the mobile team application are filled with horizontal parallel lines.

In order to draw and show these items (actual position, track, POI and search sector) in the right position on the digital map, a conversion of the geographical coordinates of the real world into the coordinates of the display of the smartphone is needed.

In the digital map window on the smartphone three buttons are shown. Two of them, "Zoom In" and "Zoom Out", are used for zooming the digital map and the third one, "OK", closes the digital map window. The next time when this window is opened it shows the same view with the same map scale as before window closing. Here is also the map scale drawn to help the mobile team assuming any distance in terrain.

In Figure 5.15, the new POI and the new search sector created in the web application are shown. On the POI stands its name "First POI" and on the search sector only "Sektor". In this Figure, the actual position of the mobile team and the map scale are indicated. The track may not be clearly visible if the map scale is small. By zooming in the digital map the track is more visible, but the received POI and search sector will be out of the display boundaries of the smartphones and will not be drawn at all.

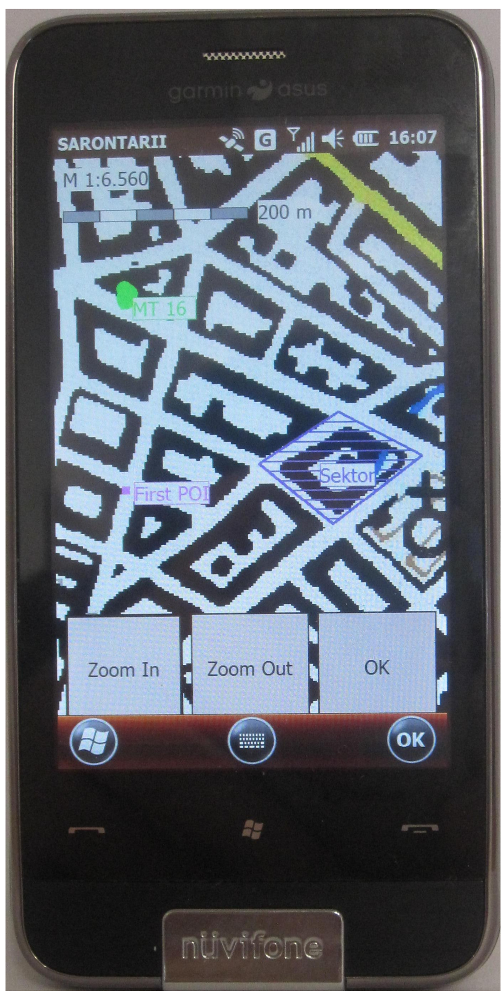


Figure 5.15: Received POI and Search Sector and the actual position of the MT

5.5 Other Services of the Platform

In addition to all the services mentioned above, there are some other services the platform provides. They are used more for administrative purposes about the rescue operation. These services can be accessed and used through the operating tools provided by the web application, as shown in Figure 3.8.

There is the possibility to use more mobile teams in terrain in order to cover larger area and these teams can be from different organizations or departments, such as: Police Department, Alpine Police Department, Fire Department, Alpine Rescue Department, Red Cross, etc.

Before the rescue operation is started, it is possible to register all the people involved in it. Some basic information about the person will be registered, such as: First Name, Family Name, organization the person comes from and the tasks in the rescue operation. These data are saved in the table PERSONENDATEN in the database. The teams can be defined by grouping the registered people. There should be a team leader as well. Each team is also registered in the database, in the table TEAMDATEN. It is possible to register new people and set them as members of a team after the rescue operation has been started. The information about the mobile teams and their members can be checked anytime.

Moreover, there is an opportunity to check the IP addresses that are being used by the teams, including the server and the managing center, for their connections.

Another important service for documentation of the rescue operation is creating rescue operation reports. Those will be created automatically and include important information about the rescue operation, such as: involved teams, team members' information, the communication traffic (all sent and received messages, including the Points Of Interest and search sectors), etc. Also all previous reports can be opened and read anytime.

The managing center can delete any data during or after the rescue operation. It actually deletes the entries in the tables of the database.

Chapter 6

Testing the Platform in Terrain

In order to show the platform "in action", a simulated rescue operation was performed where a little child is lost. The platform was used to organize, manage and synchronize this operation. This was a small rescue operation but the main goal of it was to show the services and the functionality of the platform in a practical case. The other tests and simulations in mountains and any rough terrain will be done in the future. These future tests will be part of the documents of the project "SARONTAR" [2].

This rescue operation took place on February 9, 2011, in the district St. Leonhard of the city Graz. Two mobile teams were involved (each of them consisted of two people) and the managing center team which was also located in Graz. For connection establishment and communication between mobile teams and managing center team all the message types defined in platform were used. Connection was switched from GSM network to satellite. Photos from terrain were sent. The digital maps with actual positions, tracks, POIs and search sectors were also shown. After completion of the rescue operation, a rescue operation report was created.

Photos and screenshots of mobile team and web applications illustrate the usage of the platform. This rescue operation is described in the following section.

6.1 Simulated Rescue Operation

Just after receiving the alarm that the rescue operation had to be started mobile teams moved to the intervention area. As long as they needed to get there, the managing center team registered the team members and the teams as well in the platform which are shown in Table 6.1.

Table 6.1: Teams and their members

Team ID	Team Name	Team Members
1	SARONTARII A-Team	Kuçi Driton (Teamleader) Fösleitner Claudia
2	SARONTARII B-Team	Obergröbner Stefan (Teamleader) Bytyqi Halil
98	Managing Center Team	Sommer Carmen

It also defined the search sectors for each team. After the mobile teams started their application they received their search sectors. Figure 6.1 shows the starting position of the teams and both search sectors.

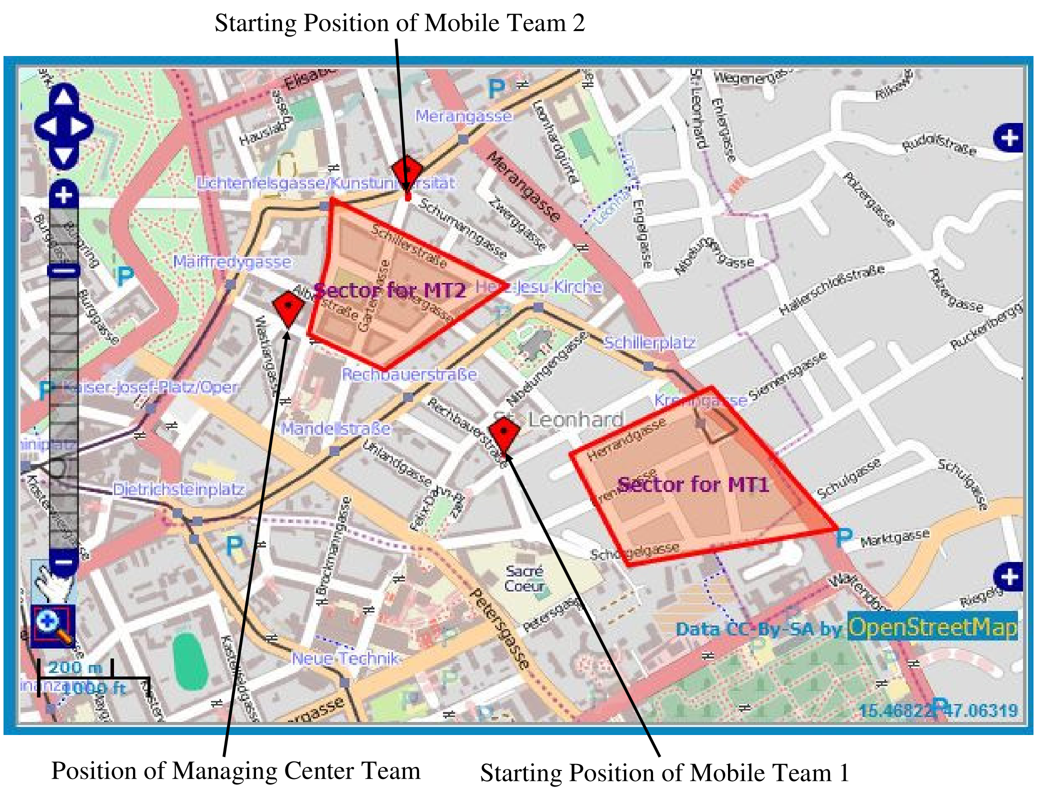


Figure 6.1: Starting Position of teams and the Search Sectors

Both mobile teams moved inside their search sector in order to find the lost child. This is shown in next two Figures. The first one, 6.2, is a screenshot made by managing center team and shows the tracks (in red colour) inside the sectors of both mobile teams. The second Figure, 6.3, shows the same view, but this time made by mobile teams on their smartphones. The track of mobile teams is marked by blue dots and the current position of them is marked with a yellow dot.

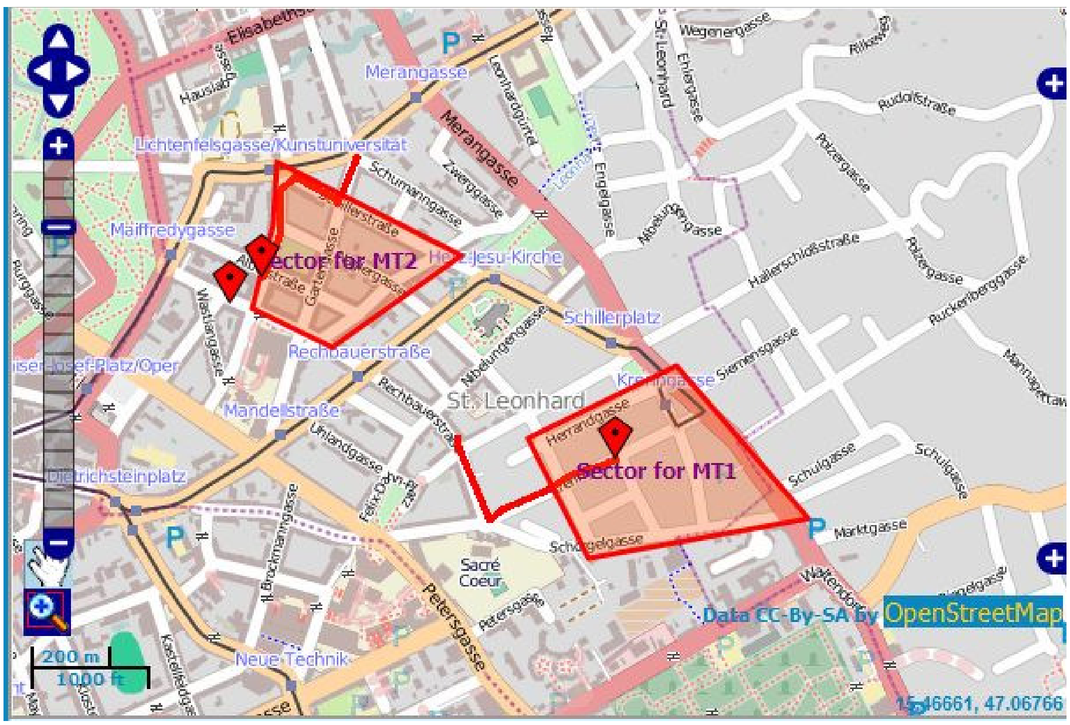


Figure 6.2: Mobile Teams moving inside their Search Sectors (Web Application)

After some minutes of searching SARONTARII A-Team found the jacket of the child and informed the managing center team about that by sending a "Find Place" message. This team sent a photo of the jacket as well and received a confirmation about the photo. Meanwhile the other mobile team checked the whole sector and informed the managing center team that nothing was found. The managing center sent a POI message, "THE JACKET", to SARONTARII B-Team and asked them to go over there. It was the location where SARONTARII A-Team has found the jacket of the child. The track the mobile team followed on the road to POI "THE JACKET" is shown in Figure 6.4.

(a) SARONTARII A-Team (b) SARONTARII B-Team

Figure 6.3: Mobile Teams moving inside their Search Sectors (MT Application)

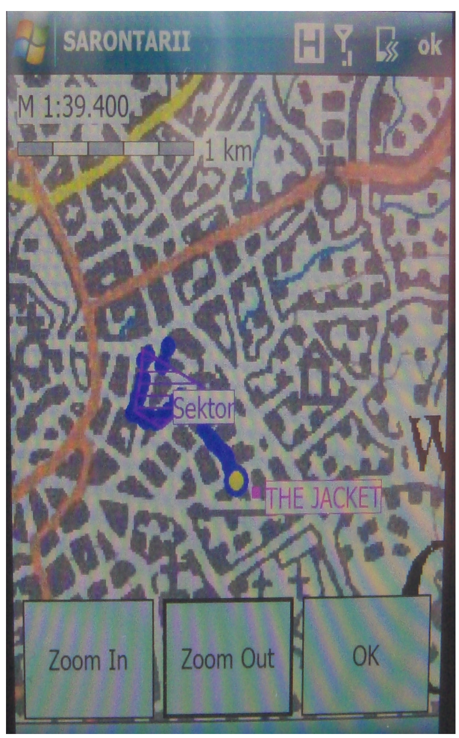


Figure 6.4: SARONTARII B-Team toward POI "THE JACKET"

SARONTARII A-Team continued searching in its search sector and after some time connection via GSM network dropped down because there was no more coverage of the mobile network. The mobile team activated the Bluetooth radio in Thuraya SG-2520 and the DUN Profile. After a short time connection with server was re-established and communication between mobile team and managing center team was possible again. To make sure that the connection was established via satellite, the IP addresses were compared, which are shown in Figure 6.5.

Figure 6.5: Compared IP addresses of SARONARII A-Team

In the beginning of the rescue operation, when the connection was established via GSM network, the IP address was: 178.114.169.107. When the connection was established via satellite, the IP address changed to: 85.115.79.111. Using any geo IP solutions in the Internet, it was found to whom these IP addresses belonged. The first one belonged to mobile network provider "3-DREI" from Austria and the second one to "Thuraya Network" from United Arab Emirates.

SARONTARII A-Team found the lost child at the edge of its search sector and let the managing center team know. Then a text message "**Rescue Operation completed. Child has been found**" was sent by managing center team to all mobile teams. They terminated their application and got back to the managing center.

The final step of this simulated rescue operation was creation of the rescue operation report, which can be found in Appendix A.

Chapter 7

Summary and Outlook

After the description and the demonstration of the platform in the previous chapters, the last chapter in this master thesis is dedicated to a summary of the whole platform with the main ideas standing behind it and the services provided by the platform. As well, future extensions and enhancements of the platform, other devices, operating systems, regions, navigation systems and satellite networks are briefly addressed.

7.1 Summary

The main goal of the platform is to help the rescue teams during intervention in any disaster. The platform consists of three main parts: mobile teams (which are active in terrain), server and managing center (which manages and organizes the rescue operation). In order to provide help very rapidly and efficiently, well organized communication between mobile teams and managing center is very important. This communication is realized only through the server. The platform provides an almost permanent connection between all teams involved in the rescue operation even if the GSM network is not available. There is also a database where the whole communication traffic is stored.

In disaster situations the communication infrastructure such as: GSM network, fixed line networks and private networks may become unavailable. The communication via satellite remains the only way. This possibility is used by the platform.

A very important factor of the rescue operation is knowing the actual position of all teams, the tracks they followed, the position of any important object. The platform uses digital maps to show all of these items and to split the whole intervention region into small search units called search sectors. This service is realized by using the GPS navigation system, which is based on satellites.

7.2 Outlook

Although the platform was developed for rescue operations in Austria and for Alpine terrain, with some small changes, it can be used in other countries and regions all over the world and for other purposes as well. It can be used in other disaster cases, such as floods, earthquakes, fires, where an intervention operation must take place to save people's lives.

Other message types, services and functions in platform for future use can be defined, such as sending any photo by managing center to mobile teams. This extension of the platform is supported by the database as well. There can be added new tables or modify any of already existing ones.

A good perspective of the platform is to make it available and useful not only for the smartphones and server computers running under operating systems provided by Microsoft but also under other operating systems developed by other companies, such as: Android [24], iOS [26] (OS for smartphones) and Mac OS and Linux (OS for server computers).

Although the Thuraya network proved to be very practical, other satellite networks with coverage of the countries not supported by Thuraya can be envisaged. An alternative to Thuraya is Iridium network which covers the entire Earth, even the South and North Poles. But on the other hand the satellite handhelds used for Iridium network are not very practical and do not provide any advanced services. They are equipped with a serial port (actually through a converter) and with no Bluetooth radio. Neither DUN Profile is supported which makes it complicated to use it as a gateway for external devices. The single possibility, nowadays, is to use any converter (Serial to Bluetooth or Serial to USB) available in the market to attempt to connect these two devices.

In the future, other navigation systems: Galileo, GLONASS and COMPASS can be used as an alternative to GPS as in combination with GPS.

Appendix A

Rescue Operation Report

The Rescue Operation Reports can be created using the operating tools in the web application by clicking on the button "Einsatzbericht" (see Figure 3.8). The report can be created after the members and teams are registered and defined. The following has to be defined: the report title, the date and time when the report is created, all the involved teams with their members and a short description of the rescue operation, for example: the main goal of the operation, the region or area where the operation took place, etc. The created report is stored in the table EINSATZBERICHT of the database. Any of the created reports can be opened, read and printed. By opening the report, there can be decided how the structure of the report should be organized. There are three possibilities:

- Chronologically - it lists all communication traffic (except position messages) according to the sent and received time by the managing center;
- Mobile Teams - it groups the messages according to the mobile teams;
- Thematically - it groups the messages according to their type.

These different structures of the report from the simulated rescue operation are shown on the next three pages. Since the platform is going to be used in Austria, reports are in German language.

```
**********************************************************
**************        EINSATZBERICHT        **************
**********************************************************

- Name des Einsatzes: Vermisstes Kind
- Einsatzleitung    : Sommer Carmen
- Einsatzteam 'A-Team'
   Teamleiter   : Kuçi Driton
   Einsatzkräfte: Kuçi Driton,Fösleitner Claudia
- Einsatzteam 'B-Team'
   Teamleiter   : Obergröbner Stefan
   Einsatzkräfte: Bytyqi Halil,Obergröbner Stefan

Erstellt am 09.02.2011, 11:26:06


KURZBESCHREIBUNG:
Suche nach einem vermissten Kind in St. Leonhard, Graz.




======================================================================
2011-02-09 11:06:39: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 2 empfangen.
2011-02-09 11:05:20: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 1 empfangen.
2011-02-09 11:04:50: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 11:04:35: Textmeldung 'Rescue operation completed. Child has been found'
an Suchtrupp 2 versendet.
2011-02-09 10:51:57: Statusmeldung 'Verstanden' von Suchtrupp 1 empfangen.
2011-02-09 10:51:35: Textmeldung 'Rescue Operation completed. Child has been found'
an Suchtrupp 1 versendet.
2011-02-09 10:48:26: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 1 empfangen.
2011-02-09 10:34:27: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 1 empfangen.
2011-02-09 10:33:59: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 10:33:49: Textmeldung 'Please go to POI - The Jacket' an Suchtrupp 2
versendet.
2011-02-09 10:32:30: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 10:32:20: POI 'THE JACKET' an Suchtrupp 2 versendet.
2011-02-09 10:30:50: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 2 empfangen.
2011-02-09 10:24:11: Statusmeldung 'Verstanden' von Suchtrupp 1 empfangen.
2011-02-09 10:23:56: Textmeldung 'photo received correctly' an Suchtrupp 1
versendet.
2011-02-09 10:11:36: Statusmeldung 'Fundort' von Suchtrupp 1 empfangen.
2011-02-09 09:50:32: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 09:50:16: Sektor 'Sector for MT2' an Suchtrupp 2 versendet.
2011-02-09 09:50:14: Statusmeldung 'Verstanden' von Suchtrupp 1 empfangen.
2011-02-09 09:50:00: Sektor 'Sector for MT1' an Suchtrupp 1 versendet.
2011-02-09 09:48:52: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 09:48:47: Textmeldung 'Rescue Operation started' an Suchtrupp 2
versendet.
2011-02-09 09:42:38: Statusmeldung 'Verstanden' von Suchtrupp 1 empfangen.
2011-02-09 09:42:23: Textmeldung 'Rescue Operation started' an Suchtrupp 1
versendet.
======================================================================
```

```
*********************************************************
**************         EINSATZBERICHT        **************
*********************************************************

- Name des Einsatzes: Vermisstes Kind
- Einsatzleitung    : Sommer Carmen
- Einsatzteam 'A-Team'
   Teamleiter   : Kuçi Driton
   Einsatzkräfte: Kuçi Driton,Fösleitner Claudia
- Einsatzteam 'B-Team'
   Teamleiter   : Obergröbner Stefan
   Einsatzkräfte: Bytyqi Halil,Obergröbner Stefan

Erstellt am 09.02.2011, 11:26:06


KURZBESCHREIBUNG:
Suche nach einem vermissten Kind in St. Leonhard, Graz.





=========================================================
==================== SUCHTRUPP 1 ========================
=========================================================
2011-02-09 11:05:20: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 1 empfangen.
2011-02-09 10:51:57: Statusmeldung 'Verstanden' von Suchtrupp 1 empfangen.
2011-02-09 10:51:35: Textmeldung 'Rescue Operation completed. Child has been found'
an Suchtrupp 1 versendet.
2011-02-09 10:48:26: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 1 empfangen.
2011-02-09 10:34:27: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 1 empfangen.
2011-02-09 10:24:11: Statusmeldung 'Verstanden' von Suchtrupp 1 empfangen.
2011-02-09 10:23:56: Textmeldung 'photo received correctly' an Suchtrupp 1
versendet.
2011-02-09 10:11:36: Statusmeldung 'Fundort' von Suchtrupp 1 empfangen.
2011-02-09 09:50:14: Statusmeldung 'Verstanden' von Suchtrupp 1 empfangen.
2011-02-09 09:50:00: Sektor 'Sector for MT1' an Suchtrupp 1 versendet.
2011-02-09 09:42:38: Statusmeldung 'Verstanden' von Suchtrupp 1 empfangen.
2011-02-09 09:42:23: Textmeldung 'Rescue Operation started' an Suchtrupp 1
versendet.


=========================================================
==================== SUCHTRUPP 2 ========================
=========================================================
2011-02-09 11:06:39: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 2 empfangen.
2011-02-09 11:04:50: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 11:04:35: Textmeldung 'Rescue operation completed. Child has been found'
an Suchtrupp 2 versendet.
2011-02-09 10:33:59: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 10:33:49: Textmeldung 'Please go to POI - The Jacket' an Suchtrupp 2
versendet.
2011-02-09 10:32:30: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 10:32:20: POI 'THE JACKET' an Suchtrupp 2 versendet.
2011-02-09 10:30:50: Statusmeldung 'Sonstige Nachricht' von Suchtrupp 2 empfangen.
2011-02-09 09:50:32: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 09:50:16: Sektor 'Sector for MT2' an Suchtrupp 2 versendet.
2011-02-09 09:48:52: Statusmeldung 'Verstanden' von Suchtrupp 2 empfangen.
2011-02-09 09:48:47: Textmeldung 'Rescue Operation started' an Suchtrupp 2
versendet.
```

```
*************************************************************
*************        EINSATZBERICHT        *************
*************************************************************
```

- Name des Einsatzes: Vermisstes Kind
- Einsatzleitung : Sommer Carmen
- Einsatzteam 'A-Team'
  Teamleiter : Kuçi Driton
  Einsatzkräfte: Kuçi Driton,Fösleitner Claudia
- Einsatzteam 'B-Team'
  Teamleiter : Obergröbner Stefan
  Einsatzkräfte: Bytyqi Halil,Obergröbner Stefan

Erstellt am 09.02.2011, 11:26:06

KURZBESCHREIBUNG:
Suche nach einem vermissten Kind in St. Leonhard, Graz.

=============== VERSENDETE TEXTMELDUNGEN ===============

ST	Datum und Zeit	Text
1	2011-02-09 09:42:23	Rescue Operation started
2	2011-02-09 09:48:47	Rescue Operation started
1	2011-02-09 10:23:56	photo received correctly
2	2011-02-09 10:33:49	Please go to POI - The Jacket
1	2011-02-09 10:51:35	Rescue Operation completed. Child has been found
2	2011-02-09 11:04:35	Rescue operation completed. Child has been found

================ VERSENDETE POIS ================

ST	POI	Datum und Zeit	Breite[°]	Länge[°]	Kat	Beschreibung
2	100	2011-02-09 10:32:20	47.06705	015.45905	99	THE JACKET

================== VERSENDETE SEKTOREN ==================

ST	Datum und Zeit	Skt	T	N	Beschreibung
1	2011-02-09 09:50:00	001	1	1	Sector for MT1
2	2011-02-09 09:50:16	002	1	1	Sector for MT2

============= EMPFANGENE STATUSMELDUNGEN =============

ST	Datum und Zeit	Breite[°]	Länge[°]	Kat	Bestätigung
1	2011-02-09 09:42:38	47.0675	15.4550	01	
2	2011-02-09 09:48:52	47.0723	15.4525	01	
1	2011-02-09 09:50:14	47.0675	15.4550	01	
2	2011-02-09 09:50:32	47.0723	15.4524	01	
1	2011-02-09 10:11:36	47.0671	15.4591	04	THE JACKET
1	2011-02-09 10:24:11	47.0664	15.4595	01	
2	2011-02-09 10:30:50	47.0698	15.4524	06	SECTOR IS CHECKED,NOTHING IS FOUND
2	2011-02-09 10:32:30	47.0698	15.4524	01	
2	2011-02-09 10:33:59	47.0698	15.4524	01	
1	2011-02-09 10:34:27	47.0661	15.4605	06	TEST VIA SATELLITE
1	2011-02-09 10:48:26	47.0665	15.4628	06	CHILD IS FOUND
1	2011-02-09 10:51:57	47.0665	15.4628	01	
2	2011-02-09 11:04:50	47.0671	15.4589	01	
1	2011-02-09 11:05:20	47.0663	15.4630	99	Einsatzende von MT1
2	2011-02-09 11:06:39	47.0671	15.4590	99	Einsatzende von MT2

List of Figures

1.1 Surviving probability 2

2.1 Splitting area into units 5
2.2 Cluster and cells 6
2.3 Data Rate provided by GSM, GPRS and UMTS (Release 99) 8
2.4 TCP/IP and OSI architecture 9

3.1 General overview of the platform 18
3.2 HTC Touch Diamond and Garmin-Asus nüvifone M10 20
3.3 Thuraya SG-2520 22
3.4 Star topology used in the platform 25
3.5 Ring topology, not practical for the platform 26
3.6 Database of the platform in administration tool pgAdmin 27
3.7 Alden/IPcopter Pro System 28
3.8 Web Application of the Managing Center 29
3.9 Detailed structure of the platform and other systems used 31

4.1 Mobile Team Application - Main Window 34
4.2 Messages Window 36

5.1 Settings Window 48
5.2 Algorithm of the first thread 50
5.3 Algorithm of the satellite thread (SAT-thread) 52
5.4 Modems definition and Mobile Network Providers 53
5.5 Letters Keyboard 61

5.6 Mathematical symbols and Punctuation marks Keyboard 62
5.7 Sending and receiving the messages 63
5.8 Hiding the message inside the photo 67
5.9 Extracting the message from the photo 69
5.10 Writing and Sending Text Message by the Managing Center 71
5.11 Data transmission in the platform between a single MT and MC 72
5.12 Position Message stored in the table MTPOS in the database 74
5.13 POI Message stored in the table EZPOI in the database 75
5.14 Creating new POI and new Search Sector in the Web Application 77
5.15 Received POI and Search Sector and the actual position of the MT 79

6.1 Starting Position of teams and the Search Sectors 82
6.2 Mobile Teams moving inside their Search Sectors (Web Application) 83
6.3 Mobile Teams moving inside their Search Sectors (MT Application) 84
6.4 SARONTARII B-Team toward POI "THE JACKET" 84
6.5 Compared IP addresses of SARONARII A-Team 85

List of Tables

2.1 Socket primitives for TCP 10

2.2 Frequency bands for satellites 14

3.1 Technical specification of HTC Touch Diamond and Garmin-Asus nüvifone M10 21

3.2 Technical specification of Thuraya SG-2520 23

4.1 Login Message sent by Mobile Team 34

4.2 Position Message sent by Mobile Team 35

4.3 Codes of Status Messages 37

4.4 Status Message sent by Mobile Team 37

4.5 Photo Message sent by Mobile Team 38

4.6 Text Message sent by Managing Center 39

4.7 POI Message sent by Managing Center 40

4.8 Search Sector Message sent by Managing Center 41

5.1 Talker Identifier 45

5.2 Sentence Identifier 46

5.3 Global Positioning System Fix Data 47

5.4 Port Numbers 56

5.5 Ascending order of the primitives (socket calls) 58

5.6 The hidden Message 65

6.1 Teams and their members 82

Bibliography

[1] http://www.tca.at/, visited on: 02.12.2010

[2] http://www.sarontar.at.tf/, visited on: 02.12.2010

[3] http://steiermark.orf.at/stories/247440/, visited on: 02.12.2010

[4] http://www.spiegel.de/reise/aktuell/0,1518,676070,00.html, visited on: 02.12.2010

[5] http://www.slf.ch/praevention/lawinenunfaelle/unfallstatistik/index_DE, visited on: 02.12.2010

[6] Theodore S. Rappaport (January 15, 1996): Wireless Communications, 1st Edition. Prentice Hall

[7] http://www.gsmworld.com, visited on: 04.12.2010

[8] Ray E. Sheriff and Y. Fun Hu (2001): Mobile Satellite Communication Networks, 1st Edition. John Wiley & Sons Ltd. University of Bradford, UK.

[9] Michel Daoud Yacoub (December 21, 2001): WIRELESS TECHNOLOGY - Protocols, Standards and Techniques, 1st Edition. CRC Press.

[10] Andreas F. Molisch (2005): Wireless Communications. John Wiley & Sons Ltd.

[11] Martin Sauter (2006): Communication Systems for the Mobile Information Society. John Wiley & Sons Ltd.

[12] William Stallings (1996): Data and Computer Communications , 5th Edition. Prentice Hall.

[13] Andrew S. Tanenbaum (March 17, 2003): Computer Networks, 4th Edition. Prentice Hall.

[14] Hofmann-Wellenhof, Lichtenegger, Wasle (2008): CGNSS - Global Navigation Satellite Systems. GPS, GLONASS, Galileo & more. Springer. Wien, New York.

[15] http://www8.garmin.com/aboutGPS/, visited on: 11.12.2010

[16] http://www.nmea.org, visited on: 11.12.2010

[17] http://www.thuraya.com, visited on: 14.12.2010

[18] http://www.iridium.com, visited on: 14.12.2010

[19] http://www.globalstar.com, visited on: 14.12.2010

[20] http://www.inmarsat.com, visited on: 14.12.2010

[21] http://www.thuraya.com/thuraya-sg-2520-user-manual, page 151, visited on: 15.12.2010

[22] http://www.microsoft.com/windowsphone/en-us/default.aspx, visited on: 17.12.2010

[23] http://www.microsoft.com, visited on: 17.12.2010

[24] http://www.android.com/, visited on: 17.12.2010

[25] http://www.google.com/, visited on: 17.12.2010

[26] http://www.apple.com/ios/, visited on: 17.12.2010

[27] http://www.apple.com, visited on: 17.12.2010

[28] http://www.htc.com/www/product/touchdiamond/overview.html, visited on: 11.01.2011

[29] http://www.garminasus.com/en_GB/phones/nuvifone-m10/, visited on: 11.01.2011

[30] http://www.bluetooth.com/SiteCollectionDocuments/DUN_SPEC_V12.pdf, visited on: 11.01.2011

[31] http://www.thuraya.com/products/voice/thuraya-sg, visited on: 11.01.2011

[32] http://www.postgresql.org, visited on: 14.01.2011

[33] http://www.postgis.org/, visited on: 14.01.2011

[34] http://www.pgadmin.org/, visited on: 14.01.2011

[35] Andrew S. Tanenbaum (March 3, 2001): Modern Operating Systems, 2nd Edition. Prentice Hall.

[36] http://beej.us/guide/bgnet/, visited on: 25.01.2011

[37] http://www.iana.org/, visited on: 26.01.2011

[38] http://www.uzr.at/, visited on: 26.01.2011

[39] Ingemar J. Cox, Matthew L. Miller, Jeffrey A. Bloom, Jessica Fridrich, Ton Kalker (November 27, 2007): Digital Watermarking and Steganography, 2nd Edition. Morgan Kaufmann. Amsterdam, Boston, Heidelberg, London, New York, Oxford, Paris, San Diego, San Francisco, Singapore, Sydney, Tokyo.