Communication Solutions for Forestry Machines

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COMMUNICATION SOLUTIONS

FOR

FORESTRY MACHINES

Master of Science Thesis in Communication Systems

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Abstract

For a long time the forest industry in Sweden has been waiting for nation-wide coverage by the GSM network. However, this has not been realized and therefore this thesis project was initiated, by Holmen Skog, to enable the needed information exchange. This thesis focuses on how to establish a communication system to transfers information to and from the forestry machines, where GSM coverage is not available. This thesis studies several different telecommunication solutions and evaluate an existing communication system called Mobeel.

Abstrakt

Under en lång tid har skogsindustrin i Sverige väntat på utbyggnaden av ett rikstäckande GSM-nät. Detta har dock inte ännu realiserats och därför initierades detta examensarbete, av Holmen Skog, där målet är att få till stånd ett tillfredsställande informationsflöde. Denna uppsats fokuserar på hur ett kommunikationssystem ska implementeras för att kunna skicka information till och från skogsmaskinerna där GSM täckningen inte är tillfredsställande. Examensarbetet involverar en studie av olika telekommunikationssystem och en utvärdering av det befintliga systemet Mobeel.

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Acknowledgements

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1 Problem Statement

Holmen Skog is a company working within the forest industry. Their main functions are forest management, wood procurement, and timber trading. Holmen Skog has decided to replace and modernize their existing communication procedures between their forest machines, management groups, and an industry wide database called Skogs Data Central (SDC). Currently workers out in the field report their harvest progress by phone at the end of each shift. Today this is accomplished by calling an automatic "hotline" and manually entering the day's harvested volume by pressing digits on the mobile terminal. However, this method has been troublesome due to lack of GSM (Global System for Mobile Communications) coverage in the forest. Another disadvantage is that the existing reporting system is burdensome since it requires a lot of button pressing to report the harvest. This takes a considerable amount of time and the workers have little motivation to supply information everyday. Hence, this procedure fails to supply the main office with, sometimes crucial, information -- thus it is difficult to maintain the necessary flow of information.

Today, Holmen Skog wants to extend their communication chain via a reliable digital service to transfer information directly to and from the forest machines. Information sent between the office and the machines includes production files, Global Positioning System (GPS)-tracks, maps, and forwarded volumes. A forwarded volume is the quantity of timber that a forwarder collects and is measured in cubic meters. In order to provide this communication, even where the GSM-coverage is scarce, this thesis project was initiated.

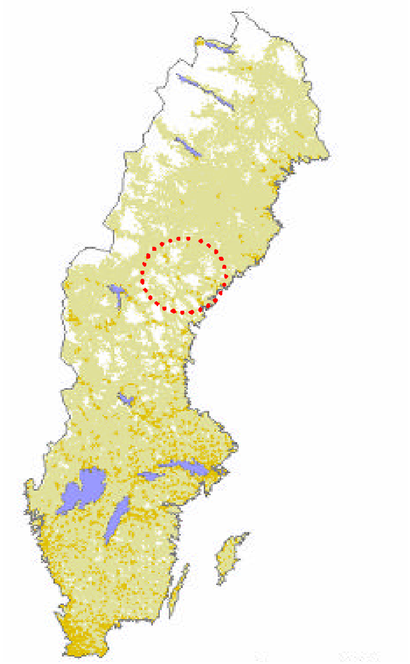

Figure 1. Illustrates the current coverage of mobile networks in Sweden White area= no coverage, Green area = GSM coverage, and Orange area = 3G coverage, appears with permission of [1]

The necessary communication could occur by using one of several different strategies. In this thesis, we present several different solutions that could be used to solve this problem including Mobeel, Low Earth Orbiting satellites (LEO), and future alternatives such as Enhanced Data rates for GSM Evolution (EDGE) and Digital 450. Each of these solutions might be suitable for the forest industry.

The purpose of this thesis was to implement and evaluate a simple and reliable communication mechanism between the forest machines and management groups; in the future, this should also include directly updating the SDC database.

The solution chosen will be an important step toward transferring reliable information from the forest to the rest of the industry. This information is valuable because it provides input to important solving logistic problems including transport, saw mill needs, and to facilitate timber trading.

Although, Holmen Skog has chosen the Mobeel solution, several other solutions will also be evaluated in this thesis. We will evaluate the existing Mobeel application to see how well this system works, to understand how users experience the system, and what impact a more continuous dataflow could contribute to the forest industry. The purpose of this thesis was also to give some suggestions of improvements that should be made to the Mobeel solution in order to become a stable and reliable product that can be used by Holmen Skog and their entrepreneurs. It is important to note that most of the machine teams working for Holmen Skog are independent entrepreneurs, this means that investments in new technology will need to be made by the individual entrepreneurs.

The current GSM coverage of Sweden can be viewed in Figure 1. The circle in Figure 1 refers to Figure 2 to illustrate the GSM coverage of the area of where this thesis was performed. The machine team and administration were located in Bredbyn, 50 kilometers outside Örnsköldsvik, and during the testing machine team were located in the forest outside Åsele (see red circle in Figure 2). In the white areas of the figures is where there exists no GSM coverage.

After investigating several possible solutions that could be used to the solve existing problem we suggest to Holmen Skog the use of LEO. Although we believe that a LEO solution is the best solution, Holmen Skog decided to evaluate the Mobeel system in the field. However, in the spirit of a master thesis we will analyze multiple alternatives - perhaps demonstrating why alternative solutions might be better.

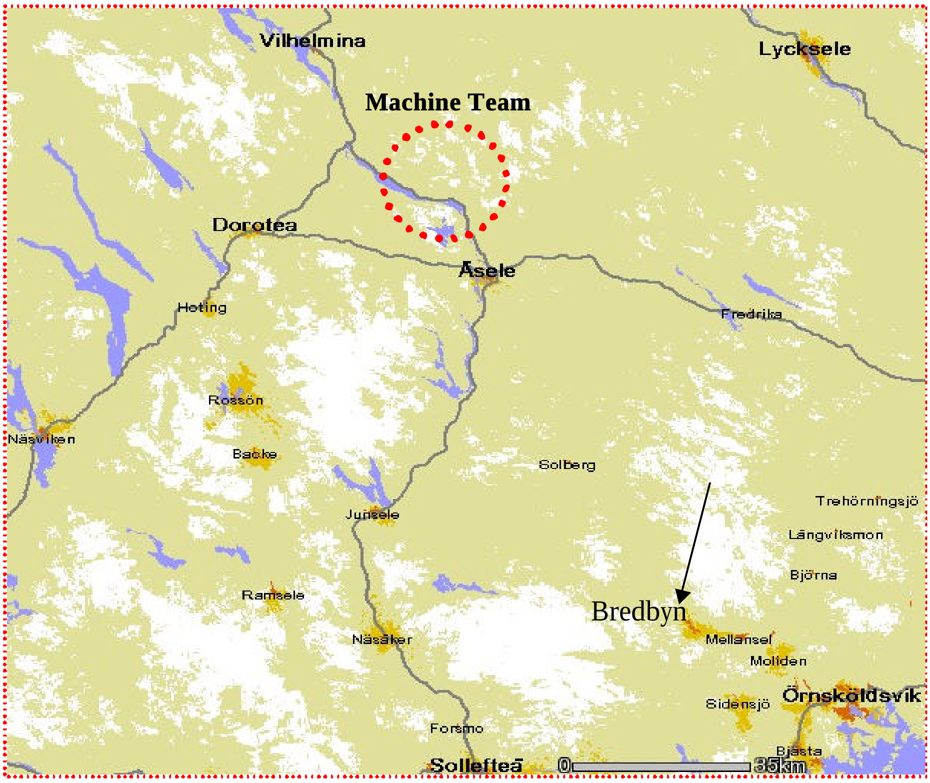

Figure 2. Illustrates the GSM coverage in the area where the thesis was performed, appears with permission of [1]

2 Introduction to Forest Industry

2.1 Holmen Skog AB

Holmen Skog AB manages the Holmen Group's forests, they buy wood from private forest owners and provide wood for Holmen's swedish units. Holmen Skog operates in most parts of Sweden. Some 68 percent of the wood supplied to Holmen's swedish mills comes from swedish forest owners and 28 percent come from the group's own forests. The sum of these forests produce nearly 2.7 million cubic meters of wood a year. However, not all this wood is delivered to Holmen's own units. Some wood is "swapped" with other swedish forest companies. There are several reasons for these "wood swaps". One is that different mills require different types of wood, and another is the forest industry's ambition to decrease transport requirements. Thus, reducing both costs and environmental impact.

One of the main roles of Holmen Skog is forest management. It manages the Holmen Group's forests, consisting of one million hectares of productive forestland. The second role is wood procurement to provide wood for Holmen's swedish units: Braviken Paper Mill, Hallsta Paper Mill, Wargön Mill, Iggesund Mill, and Iggesund Sawmill. The last main role is supplying Holmen's swedish units with wood. The source of all this wood is from Holmen's forests and from private forest owners in Sweden. [2]

2.2 Forest Production

Activities in the forest need to carefully consider environmental and cultural values. It is important to, for example, save trees and groups of trees that are suitable as nesting sites for birds, leaving specific animal habitats undisturbed and avoiding damage to ancient stonewalls or old forest roads. This has to be done to preserve the forest as a national resource and at the same time maintaining its biological diversity.

In Sweden the forest industry works with silvicultural methods, which means that the planted trees are selected to adapt well to the natural conditions of the site. The cycle of silviculture methods describe how a site should treated in everything from regeneration of new seedlings to the final felling of mature trees. Investing in a forest involves several generations and a perspective of roughly 100 years is necessary.

The cycle of silviculture consists of regeneration, cleaning, thinning, and regeneration felling; below we will describe each step. Figure 3 shows the lifecycle of the silvicultural method. [3]

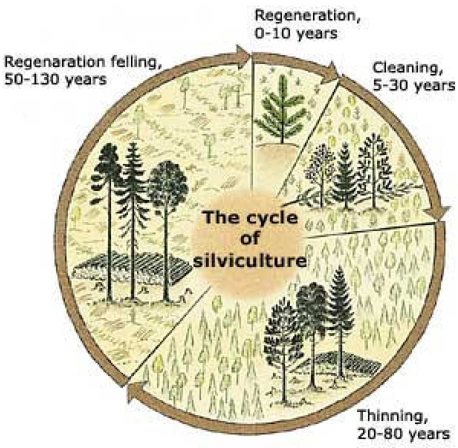

Figure 3. The cycle of silviculture, appears with permission of [3]

2.2.1 Regeneration

Forestry legislation in Sweden requires regeneration after felling. It is essential to have good knowledge of suitability of the selected plants and well they adapted to the conditions of the site. It is also important when establishing new forests to know how different methods and environmental interests can be satisfied in the long term. About 140 000 hectares are planted annually in Sweden using about 330 million plants. Natural regeneration is done on about 60 000 hectares. Figure 4 shows an example of a seedling that is ready to be planted.

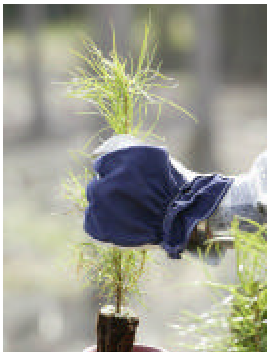

Figure 4. A seedling, appears with permission [2]

2.2.2 Cleaning

Cleaning is a done when the young trees reach a height about 2-4 meters. During this cleaning phase, decisions are made of which species and which individual trees to leave uncut to develop into the future stand. Annually about 200000 hectares are cleaned in Sweden, but the need is actually about 275 000 hectares annually.

2.2.3 Thinning

The procedure of thinning is done when the trees has reached an age of 20-80 years. This period is the vigorous growth period for the stand and thinning is done for two reasons. The obvious one is that trees culled during thinning generate income and the second is that it favors the development of the stand since the remaining trees receive better growth conditions. A stand is normally thinned 2-4 times during its growth cycle. About 270 000 hectares are thinned annually generating about 15 million cubic meter of standing volume. Standing Volume is the total volume of wood (included branches) in cubic meters. The standing volume contains some non-recoverable volume, but excludes bark. [4]

2.2.4 Regeneration felling

When the trees within a forest stand have reached a certain thickness and height, their growth rate decreases. This usually occurs when the trees reach an age of 50-130 years, then it is time to harvest. The time for regeneration felling varies depending on environment factors, such as soil fertility and climate, but also on how the stand has been managed over the period it has been growing. In Sweden, regeneration felling is carried out on about 200 000 hectares annually, which is less than 1% of the total forest area. This gives an annual timber yield of about 50 million cubic meters standing volume.

2.3 Forestry machines

Timberjack [5] is a company that produces a wide range of forest machines developed to meet the specific needs of a variety of different forestry sites. The forestry equipment used during this project include a Timberjack 1070D harvester and Timberjack 1110D forwarder. A harvester (shown in Figure 6) is a heavy vehicle that is used for felling and delimbing. Delimbing is the process of removing side branches from the stem of a felled tree. A forwarder (shown in Figure 5) is used for transporting logs from the felling to a landing area close to a road that usually is accessible by trucks.

Figure 6. Harvester at work, appears with permission of [2]

Figure 5. Forwarder at work, appears with permission of [2]

2.3.1 Timbermatic 300™ and Timbermatic 700™

Timberjack machines use a PC-based computer system called Timbermatic. In this project, a Timbermatic 300™ is utilized in the harvester and a Timbermatic 700™ in the forwarder.

The Timbermatic 300™ is a Microsoft Windows™ 2000 based system which is installed in the harvester. It performs timber measurement, stores information about produced timber, records the location of timber, and performs other basic machine control functions. The Timbermatic 300™ helps the operator to effectively utilize the wood by performing full tree calculation and value optimization when it comes to price, distribution, and limitation matrices. (A limitation matrix is an array of numerals that shows estimations of the diameter of the entire stem, from top to bottom.) The system also has e-mail and GPS facilities can be used for informing the harvester current with mill needs; and providing the contractor with production and performance figures. However, this on-line updating is only possible when there is GSM connectivity at the harvester's current location. These facilities are not used by Holmen Skog due to the lack of GSM coverage and therefore the Mobeel system must be used to send and receive information. The Timbermatic 300™ is responsible for generating production files and GPS-tracks. [6] The Timbermatic 700™ is the control and communication system designed for the forwarder. This computer-based system registers assortments, mass per load, and number of loads. This information is vital for transport logistics. [7]

3 Mobeel

The forest industry in Sweden has suffered due to the limited GSM-coverage of swedish forests. Unfortunately, this has created difficulties with reporting procedures between the machine operators and management. Today the workers out in the field dial a number and reporting their work at the end of each shift. This has been troublesome since the GSM coverage is not always available, thus the workers often fail to supply the main office with, sometimes crucial, information.

Mobeel is a concept that has been developed, in another thesis, together with Mobilassistenten [8], SkogForsk [9], and representatives from the forest industry. [10] Mobeel is a mobile solution designed for the forest industry. The concept behind Mobeel is to transfer information between the production leader and the forest machines even when they are located where GSM-coverage is scarce or non-existent. The main purpose of Mobeel is to improve and simplify the reporting of relevant production information for the machine operators and production leader. Data should be communicated between the production leader, machines, and, in the future, the central database SDC.

3.1 *Mobeel Technology*

Mobeel uses Bluetooth and General Packet Radio Service (GPRS) technology combined with temporary storage of files in mobile phones. In the original version of Mobeel, the system had the following operations: the driver of the harvester had a Bluetooth equipped phone (in this case a Sony Ericsson P900) with the Mobeel software installed on it. Changes to files happen usually after finishing a working shift. The Timbermatic 300™ (i.e. the computer inside the harvester) saves the production (prd) and bucking (apt) files (further details of these files are given in section 7.9.1), which have not been sent before, into a directory containing files which are to be transmitted and transfers these files to the driver's mobile phone using the Mobeel application. Bucking is the act or process of transversely cutting the stem or branches of a felled tree into logs. This application transfers the files over a Bluetooth link from a Possio PX30 [11] router attached to the Timbermatic 300™ to the P910. Conversely, data can be transferred from the mobile phone to the Timbermatic 300™ when the operator arrives at the harvester at the start of a shift.

The Mobeel system assumes that the operator brings the phone to/from work and has it available during the shift. Once the phone is within GPRS coverage the Mobeel software automatically connects to see if there are any files that need to be sent or received.

3.1.1 General Packet Radio Service (GPRS)

GPRS is a wireless data service currently available in nearly all GSM networks. GPRS allows mobile phones to send and receive data more rapidly than simply using GSM as a dialup connection. Via a GPRS connection, the phone can transfer data packets at typically between 32 and 48 kbps. However, this speed depends on how many users are sharing each cell at any given time. Additionally, data can be transferred at the same time as a voice call, but the existence of the voice call will decrease the GPRS transfer rate.

3.1.1.1 GPRS Technology

GPRS is part of a series of technologies that were designed to move second generation (2G) networks closer to the performance of third generation (3G) networks. GPRS can operate at speeds up to 115 kbps, compared to a circuit switched GSM call which can only support a maximum of 9.6 kbps. However, the actual throughput rates of the GPRS are ~40 kbps, i.e., approximately five times faster than the current circuit switched data services of GSM networks. [12] Due to this higher speed, GPRS is suited for sending and receiving large volumes of data. [13]

To achieve the theoretical maximum GPRS data transmission speed, ~172.2 kbps, a single user would take all eight timeslots in a single GSM frequency channel (without any error protection) This would not allow any time slots for other users and would also prevent calls from using this channel. Obviously, a network operator will be reluctant to allow all timeslots to be used by a single GPRS user. In addition, most GPRS terminals only support use of up to four timeslots, therefore the bandwidth available to a user will be limited to less than 86 kbps. [12]

As GPRS is a packet switched service, the system only uses the network when there is data to be sent -- instead of sending a continuous stream of data over a circuit switched connection.

3.1.1.2 GPRS Architecture

The Mobeel solution requires mobile phones with GPRS functionality. When a handset is located in a GSM coverage area it communicates via a GSM base station to the GSM/GPRS infrastructure. Files are sent as a series of GPRS packets to the base station and which in turn is connected to the Serving GPRS Support Node (SGSN). [14] Figure 7 shows the basic GPRS architecture.

The SGSN sends and receives data to and from the base station. It keeps track of the mobiles within its service area so that it knows to which base station each packet should be forwarded. The SGSN communicates with a Gateway GPRS Support Node (GGSN) [12]. The GGSN acts as a gateway to external networks (such as the Internet) and acts as a router. To forward IP packets between the SGSN and GGSN packets are encapsulated using a specialized protocol called the GPRS Tunnel Protocol (GTP).

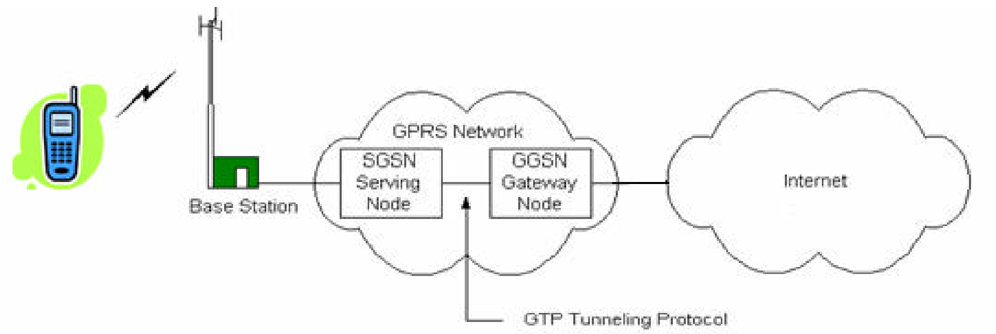

Figure 7. GPRS architecture

3.1.2 Bluetooth

Bluetooth [109] is a communication standard, which allows local wireless connectivity between devices. Bluetooth communication avoids the limitations of short cables and the line-of-sight requirement of infrared.

Bluetooth is a simple wireless personal area network that can permit up to eight devices to be connected together in a piconet. This is considered a 'personal' network because it operates over only a very short range, the typical operating range is 10 m.

Bluetooth offers speeds between 120-723 kbps, this is considered to be fast enough for most “cable replacement” typical of applications used with cellular phones, PDAs, etc. [15]

3.1.2.1 Bluetooth Technology

Bluetooth devices communicate via short-range radio links, devices can communicate as long as they are within range. The range of Bluetooth is about 10 meters, but a range of 100 meters is possible with some equipment (as described below). Bluetooth has three different defined ranges, based on their output power ratings.

Class 1 devices are the most powerful. These can emit up to 100 mW of power, and a regular antenna will give them a range of about 40-100 meters.

Class 2 devices are lower power; they emit up to 2.5 mW of power. A regular antenna will give them a range of about 15-30 meters.

Class 3 devices emit even less power than class 2, the emitted power is up to 1 mW. A regular antenna will give them a range of about 5-10 meters.

Most Bluetooth devices are class 2 or class 3. The Bluetooth specification was the basis for the IEEE 802.15.1 standard. Low complexity, low power, and low cost were the goals for Bluetooth. [16][17] [111]

3.1.2.2 Bluetooth Architecture

The Bluetooth architecture is abstractly segmented into multiple layers and a theoretical view of the system architecture is shown in Figure 8. A conceptual view of the Bluetooth Architecture [17][20]

The radio frequency (RF) layer works as the interface to the communication channel allowing different computing devices to communicate. [17]

The baseband layer controls the RF layer. By providing Frequency Hopping Spread Spectrum (FHSS) the baseband layer avoids (or reduces) interference with other units that use the same frequency, for example other Bluetooth-units or microwaves. It also encodes packets over the wireless link and encrypts them for secure links transfers. [17]

The Link Manager layer controls the baseband layer. Its responsibilities include authentication, security services, Quality of Service (QoS), and baseband state control. [18]

The Logical Link Control and Adaptation Protocol (L2CAP) layer allows multiple applications to use a link between two devices at the same time. This layer also performs segmentation, reassembly, and QoS. [19]

The data packets are transmitted by L2CAP and over the channel provided by the link manager. L2CAP provides services to all the upper-level protocols.

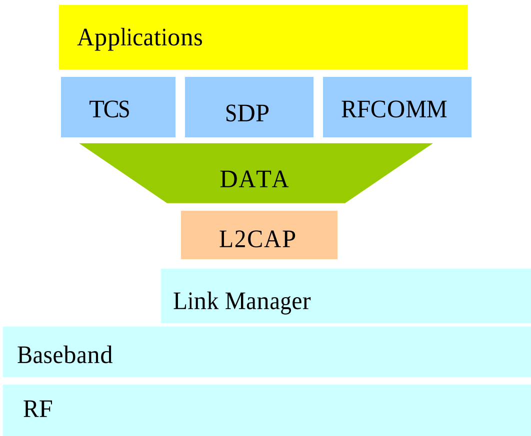

Figure 8. A conceptual view of the Bluetooth Architecture [17][20]

Next layer contains the Bluetooth protocols: Telephony Control Protocol Specification (TCS), Service Discovery Protocol (SDP), and Radio Frequency Communications Protocol (RFCOMM).

In the Mobeel solution, the Possio PX30 router (see section 3.3.2) is a Bluetooth-enabled device using Bluetooth Class 1 technology and the JSR-82 Java Bluetooth API. [21] The JSR-82 Java Bluetooth API enables protocols to use RFCOMM and L2CAP. [22] The RFCOMM protocol was chosen in the implementation of Mobeel since the Possio PX30 provides this simple emulation of a serial link transport protocol for data stream transfers. [17][20]

For more information about establishing a Bluetooth connection and the architecture of the Mobeel solution, see sections 3.2 and 3.3.

3.2 Mobeel Architecture

The Sony Ericsson P910 mobile phones are used to transfer files via the Bluetooth equipped Possio PX30 router. When a file is found to be available from the Timbermatic the router forwards this file via an USB port to the Timbermatic 300 computer. This is illustrated in Figure 9, which shows the transfer of files between the Timbermatic and the mobile phone and then later from this mobile to a web server (via GPRS)

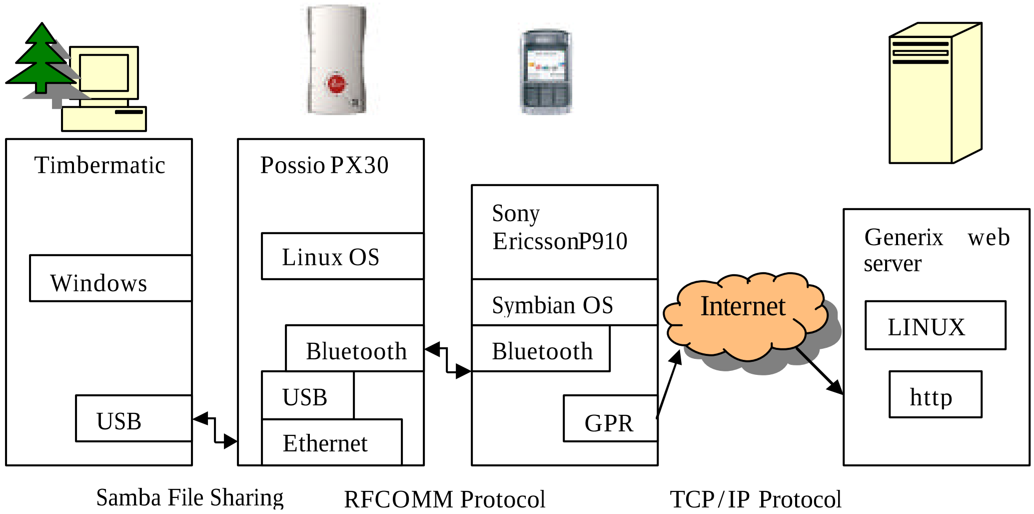

Figure 9. Mobeel Architecture

3.3 Establishing a Bluetooth Connection

The process for establishing a connection via Bluetooth to the Possio PX30 involves the following steps:

Inquire: In the Mobeel solution, the PX30 automatically initiates an inquiry to find other mobile phones. PX30 repeats this process every 30 minutes to establish a connection with mobile phones that are nearby. After inquiring, all nearby mobile phones respond with their addresses, and the Possio PX30 picks all of them. Every 10 seconds the PX30 checks to see if there is a new file in the forestry machine's out going directory.

Page: The paging procedure synchronizes the Possio PX30 with the other mobile phones.

Establish a link: The Link Manager Protocol (LMP) establishes a link with the mobile phones.

Discover services: LMP uses the Service Discovery Proto col (SDP) to find out what services are available from each of the mobile phones. Here we are interested in finding out if the Mobeel service is available.

Create an L2CAP Channel: The LMP uses information obtained from the Service Discovery Protocol (SDP) to create an L2CAP channel to the mobile phones. Once the L2CAP channel is established the application can use a protocol such as RFCOMM over the L2CAP channel. RFCOMM emulates a serial link.

Create an RFCOMM channel: Creating an RFCOMM channel over the L2CAP channel allows any existing application that works with serial ports to work with Bluetooth without any modifications.

Send and receive data: The PX30 and the Mobeel client, which is running on a mobile phone, now use standard network protocols such as TCP/IP to send and receive data.[10]

3.3.1 Sony Ericsson P910

The Sony Ericsson P910 is a mobile phone, which combines the functions of a phone with that of a Personal Digital Assistant (PDA). This phone is equipped with a 156 MHz ARM processor, 32 MB RAM, and 64 MB of internal memory. The P910 supports up to 2 GB Memory Stick Duo Pro, which offers additional memory. The P910 uses the Symbian 7.0 operating system[23] with UIQ 2.1 [24], a user interface platform. There are also facilities for executing Java applications (J2ME) in this phone. [25]

Figure 10. Sony Eric

This phone uses 1260 mAh Li-Polymer battery and a graphical touch screen, which is capable of displaying a 262k colors (18-bits per pixel) with a resolution of 208x320 pixels. The P910i is a tri-band GPRS phone with a Bluetooth class 2 transceiver.

A new version of the Sony Ericsson P910 (called Sony Ericsson P990) will soon be available.

3.3.2 Possio PX30

The Possio PX30, Figure 11, is a personal Bluetooth wireless connectivity gateway implemented according to the Open Services Gateway initiative (OSGi) model [32]. OSGi provides a platform for Java applications to control devices attached to this gateway. The PX30 can route data among devices or networks connected via any port. The device has Bluetooth, Ethernet, and USB interfaces.[33]

Figure 11. Possio PX30 wireless router

The Possio PX30 was chosen for the implementation of Mobeel since it has USB interface and supports Linux operating system, and Bluetooth.

Unfortunately, Possio PX30 gateway is not available [34]; to buy anymore, and thus if Mobeel is going to be a viable product another Bluetooth equipped wireless router needs to be considered or a Bluetooth interface and appropriate software could be added directly to the PC that is part of the

Timbermatic. For further information see section 8.6.1.

3.3.2.1 Possio PX30 - Technical Specification

The PX30 is a small box, weighing only 210 grams, that can only be used indoors. The operating temperature range is between +5 to +40 °C, thus it needs to be in the cabin of the forestry vehicles. The PX30 consists of an Intel® PXA255 processor, with integrated Bluetooth, USB-host, and Ethernet 10/100 interfaces, and features a 32 MB Flash PROM [33] and a 64 MB SDRAM. PX30 has a Bluetooth class 1 radio configuration with an integrated antenna. [33]

3.3.3 Web Server

A web server was chosen by Mobilassistenten, for experiment purposes, during the developing the Mobeel solution. This web server is operated by Nufort AB, a Swedish consulting company, and can be found at http://generix.nufort.net. For this project, the same web sever has been used. However, if Holmen Skog chooses to implement the Mobeel system then their own web server would be considered. This is an Apache 2.0 web server with PHP4. PHP stands for Programming Hypertext Pre-processor; it is a general-purpose scripting language [35]. A web interface was developed to give an overview of all transferred files and is built using PHP. The Apache 2.0 web server with PHP4 was chosen by Nissen & Danial for their Mobeel system [10] since it is able to interpret PHP-code. The Apache [35] web server is open source and is widely used for building, hosting, and maintaining web sites and applications.

Nufort's web server uses the SUSE Linux 10.0. SUSE Linux is available in 32-bit and 64-bit versions. [36]

4 Satellites

Satellites are used for diverse purposes as stated by Hubbel [37] *"a satellite is anything that orbits something else, as, for example, the moon orbits the earth"*. In a communications context, a satellite is a specialized wireless receiver or transmitter that is launched by a rocket and placed in an orbit around the earth.

Satellites are used for many different purposes, including weather forecasting, television broadcasting, Internet communications, and positioning systems such as the GPS, GLOSNASS [38] and the new GALILEO [39] systems. Today's satellite systems are also designed as a backup system to existing land based wireless systems. Because of the global coverage available from some types of satellite systems, it becomes more economic for rural areas where there is no wired communication infrastructure. Satellites could be used to extend for example the cellular phone system coverage, for example rather than using GSM to cover all of Sweden, some portions could be serviced via satellites – thus avoiding the cost of installing cellular infrastructure in regions where there are few potential users. The satellite systems are also beneficial because they are not affected by terrestrial natural disasters and can continue to provide service in such situations. [113]

4.1 Introduction to Satellites

Modern satellites can receive and transmit thousands of signals simultaneously, from simple digital data to television programs. There are three types of communications satellite systems and they are categorized according to the shape and diameter of the orbit they follow:

- Geostationary Orbit Satellites (GEO)
- Medium Earth Orbit (MEO) Satellites
- Low Earth Orbit (LEO) Satellites

4.2 Geostationary Orbit Satellites

Probably the most widely known constellation of satellites is the geostationary which are placed in the Geostationary Orbit, GEO. As shown in Figure 12, Geostationary Orbit Satellites are located in an equatorial orbit at a distance of 36000 km above the surface of the earth. A satellite placed in such a geostationary orbit appears stationary with respect to a fixed point on earth. The topology of GEO can be viewed as a ring of potentially interconnected satellites spaced around the equator. Some examples of GEO constellations are Spaceway [40], Astrolink [41], and Inmarsat [42]. All satellites share the same altitude and orbital inclination to the equator, to minimize the effects of precedence and simplify control of ground coverage.

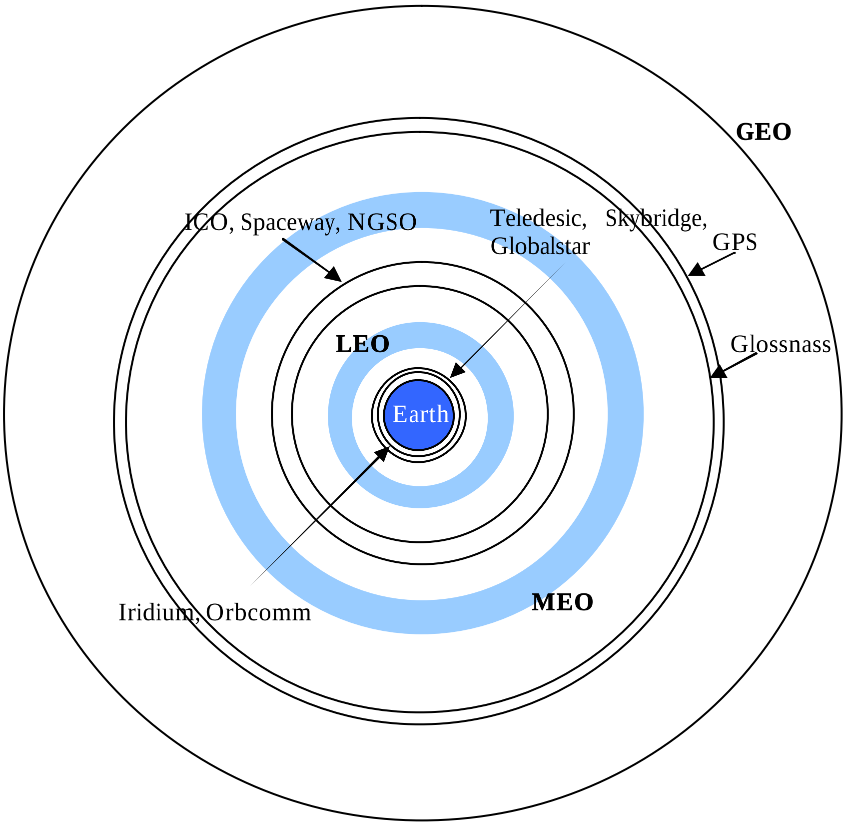

Figure 12. Orbit altitudes for satellite constellations [43]

4.3 Medium Earth Orbit Satellites

Medium Earth Orbit (MEO) refers to a satellite, which orbits the earth at an altitude below the altitude of a geostationary orbit, GEO, and above the altitude of Low Earth Orbit (LEO) satellites. A MEO satellite orbits at a distance of 6000-20000 kilometers, see Figure 12 above the surface of the earth and they have an orbital period ranging from two to twelve hours. Some MEO satellite constellations can be seen as orbiting in almost perfect circles and therefore they have almost constant altitude and travel at a constant speed. The Global Positioning System satellites, usually called GPS, are an example of a set of MEO satellites.

4.4 Low Earth Orbit Satellite

Low Earth Orbiting satellites orbit at an altitude of 500-1500 km, Figure 12. The characteristics of LEO satellites are circular orbits, orbital periods of 1½ to 2 hours, and their footprint (spot beams) has a coverage area on the Earth about 8000 km in diameter each. The round-trip signal propagation delay is less than 20 ms and a satellite can be visible from earth for up to 20 minutes.

LEO satellites are further classified into three groups: little, big and broadband LEOs

Little LEOs operate in the lower part of the LEO range, with perigees (lowest altitude) and apogees (highest altitude) up to a few hundred kilometers. They operate at frequencies below 1 GHz. Little LEOs provide simple store-and-forward messaging, two-way paging, fax, and e-mail. [44] Orbcomm [45] and LEO One [46] are examples of little LEOs.

Big LEOs typically orbit at a few thousand kilometers altitude and are some of the latest generation of communication satellites; they are particularly important as they support communication using small handheld sets. Big LEOs are operating at frequencies around 1-2 GHz and can support data rates up to a few megabits per second. Big LEOs offer data communication, voice, and positioning services. Iridium [47] and Globalstar [48] are the two largest and most active big LEOs.

Broadband LEOs are at an altitude around of ~1500 kilometers and they provide high-bandwidth data communications such as Internet access, videoconferencing, voice, and high-speed data services. Teledesic [49] is an example of a broadband LEO system.

4.4.1 Iridium

The Iridium LEO satellite, Figure 13, system is based on 66 satellites at an altitude of 780 km above the earth. The satellites are arranged into six planes and each plane consists of 11 satellites. The plane has a circular orbit and the planes are spaced with 31.6 degrees apart and the counter-rotating planes (one and six) are spaced with 22 degrees apart. To maximize the coverage area of the satellite and to improve the link quality, the minimum elevation angle to an earth station is 8.2 degrees. Seen from earth a satellite is within view on average approximately 10 minutes. Iridium offers low path delays and global coverage. Connections between the Iridium network and the public switched telephone network (PSTN) are provided via regional gateway installations that will handle call setup procedures and interface Iridium with the existing PSTN. The regional gateways are the terrestrial infrastructure that provides telephony services, messaging, and support to network operations. In today's Iridium system, there are more than one or two gateways. [51]

Each satellite is connected to its four neighboring satellites through inter-satellite links (ISL) and these ISLs provide flexibility in where the gateways can be located. The Iridium system offers two types of connections. One where a call originated from a mobile terminal call can be routed within the satellite network (Iridium to Iridium) and connected to any mobile terminal located anywhere. Second the call can be connected to or from the public network through gateways to the Iridium system.

4.4.2 Globalstar

The Globalstar system, Figure 13, has 48 low earth orbit satellites in eight planes. The constellation is designed for 100% single satellite coverage between ±70° latitude, and 100% two or more satellite coverage between 25° to 50° latitudes. To ensure avoidance of blocking and shadowing, up to three satellites may at any time be used to complete the call. Globalstar has implemented the CDMA-based frequency-sharing technology for the mobile link, Frequency Division Multiplexing (FDM) [51] is used for the feeder uplink, and Frequency Division Multiple Access (FDMA) [51] for downlink. CDMA was chosen to increase capacity on the mobile link through frequency re-use and voice activity detection. The Globalstar system provides interconnection to the PSTN/PLMN (Public Switched Telephone Network/Public Land Telephone Network) through gateways which will each interface a Mobile Switching Centers (MSC) for extension of terrestrial cellular call processing.

4.4.3 Teledesic

The Teledesic network design, Figure 13, consists of 288 satellites divided into 12 planes with 24 active satellites in each plane. Since the satellites are orbiting in a circular manner at an altitude of 1350 km from the satellite to earth, the same at all times, and so is the distance from each other. The planes are separated from each other with the same angular distance of (360/ (2 * the total number of satellites=288). The planes take the satellites over the geographic poles and they cross each other only over the North and South poles. The fleet of LEO satellites is arranged in such a way that, from any point on the surface at any time, at least one satellite is in line of sight. The goal of the Teledesic network is to have continuous global coverage and to provide wireless broadband services with fiber-like quality. The providers of Teledesic use the term "Internet-in-the sky" [52] for this service.

Each satellite has connectionless packet-oriented inter-satellite links to its eight neighboring satellites, and each satellite acts as a switch in a mesh network. All communication within the network is as streams of short, fixed length (512 bits) packets. Each inter-satellite link has a capacity of 155.52 Mbps. The Teledesic network could be described as a broadband LEO.

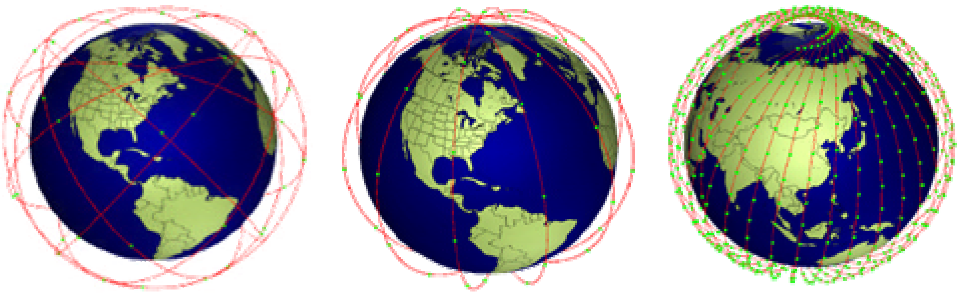

Figure 13. a) Globalstar constellation b) Iridium constellation c) Teledesic constellation, appears with permission of [53]

4.5 LEO Technology

All signals to and from a satellite are sent via a transponder. On average, satellites have between 24 and 72 transponders. Today a single transponder is able to handle up to 155 million bits of information per second. [54] With this huge capacity, satellite communication systems offer an ideal medium for transmitting and receiving almost any kind of content.

A complete satellite communication system also includes one or more ground stations and many remote terminal units (RTUs). The RTUs are designed to transmit fairly short-duration messages and for reliability, they can retransmit the same message. At the satellite this message is received by high-gain antennas. The loss of messages due to collisions is unlikely since the transmissions are infrequent and short. [54]

These satellites use a store and forward technique to provide communication services to users that are separated geographically. When a satellite is in sight it receives and stores messages from remote terminal units that are located in an orbit below this specific satellite. These messages are then later downloaded to another remote terminal unit in another part of the globe. Each user is able to send a message to another user by sending it as a file to the satellite and that is called uplinking. The message is stored onboard the satellite until it is scheduled for downlink. Due to this a full duplex service is provided with periodic access times when the satellites are visible.

When a satellite dips below the horizon, the call from the Iridium handset is handed off to the next satellite. Low earth orbit satellites utilize time division duplex; both uplink and downlink employ a TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access) mixture. The strength of a radio signal falls in proportion to the square of the distance traveled. For a satellite link, the distance is large and so the signal strength decreases before reaching its destination. For having continues satellite access and using less power the Time Division Duplex (TDD) is used in LEO which make the voice and data traffic delays nearly undetectable.

CDMA (Code Division Multiple Access) can also be used in LEO satellites which would result in higher capacity and higher quality of service and this is due to reduction in interference and multi path fading. This reduction of multipath fading occurs only in LEO small satellites, since these satellites use CDMA, which is a spread spectrum technique. [55]

In addition, the use of CDMA has other advantage such as soft handover, soft capacity, and no requirement of frequency management or assignments. [55]

4.6 LEO Architecture

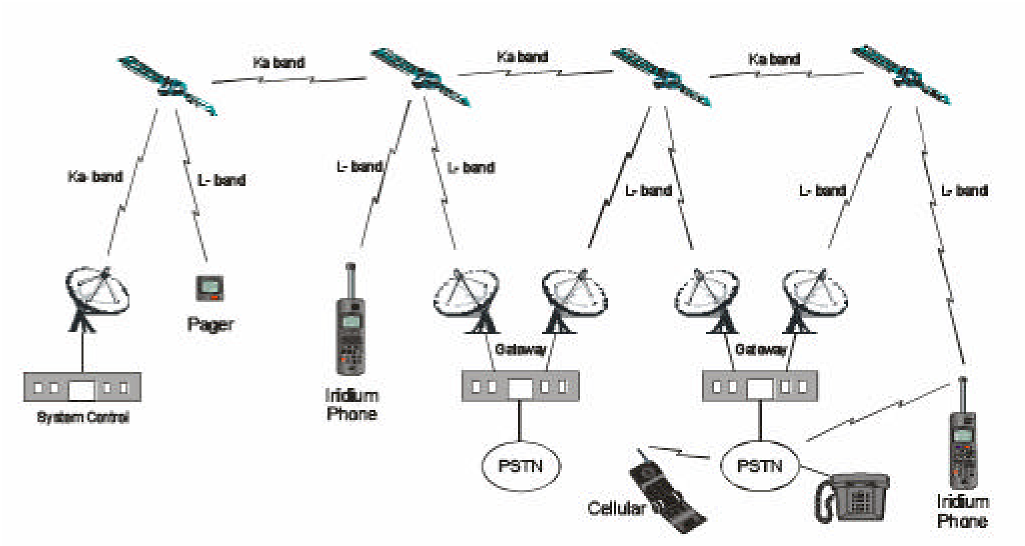

Figure 14. Satellite system overview, appears with permission of [53]

Making a call requires satellites, gateways, and user handsets. Intersatellite links are used between the satellites and to route network traffic. Regional gateways, on earth, will handle call setup procedures and interface satellite with the existing PSTN. The handsets may be dual-mode which makes it compatible with either a terrestrial cellular telephone network or the satellite network. The handsets are equipped with an antenna that requires line of sight to the satellite.

The low earth orbit satellite system uses a similar call processing architecture as the GSM. There are earth stations (ES) that implement a Mobile Switching Center (MSC) with the associated databases Equipment Identity Register (EIR), Home Location Register (HLR), and Visitor Location Register (VLR). For the low earth orbit satellite network there are additional functions that are not taken care of by traditional GSM Mobile Switching Center. Instead these are handled by the ES. Examples of these could be functions that control the feeder link, ES management subsystems and messaging controllers.

When a call is initiated the location of the mobile terminal (MT) is calculated by the satellite system, Figure 14. Associated with each ES is a location area which the ES controls. The location of the MT is used to assign the home (or visited, if the MT has roamed) ES which controls all aspects of the call. At the time of call-setup the ES chooses the connection between MT and the PSTN/PLMN. Based upon the MT's location and the location of the PSTN/PLMN a suitable connection would be established. Inter-satellite links (ISLs) are useful since the ES within a satellite footprint does not necessarily have to be used, since the call can be routed via the satellite network. Only the receiving ES has to be available to receive information and therefore (minimum) routing to ESs can be utilized.

4.7 LEO Advantages

Satellite networks (Big LEO's satellites (Teledesic)) have some of the same characteristics as, e.g. broadband channels and low delay and low error rates. All satellites do not have low error rates. Satellite channels show a higher bit-error rate (BER) than typical terrestrial networks. Typical bit error rates (BER) for a satellite link are approximately 1 error per 10 million bits (1 x 10^-7) or less frequent. Only Big LEO's satellites (Teledesic) have low error rates because of using advanced error control coding. For more information see [56]

Redundancy and reliability can be built more economically into the satellite network rather than the MT. Low earth orbit satellites are more efficient in its use of spectrum resources that GEO satellites because of their smaller footprint within which frequencies can be reused. [57]

A feature called spoofing [18] is provided in satellites, and that means that airtime is managed by seamlessly connecting and disconnecting a call when no data is transferred over the low earth orbit satellite system. The benefits of spoofing include increasing the phone's battery life time and seamlessly reconnect to the satellite system if a connection is dropped.

Because LEO satellites move in relation to the Earth, they provide continuous coverage of any point on Earth, thus naturally providing global coverage. [58}

4.8 LEO Disadvantages

The chance of no signal or dropped calls can occur because of the angle of transmission between user and satellite too is low or possibly obstructed by terrain when a mobile terminal and the satellites are located at the farthest point from each other and due to movement.

5 EDGE

Enhanced Data rates for GSM Evolution (EDGE) [59] is a digital mobile phone technology that acts as an enhancement to existing GSM and GPRS (General Packet Radio Service) networks. EDGE is also known as Enhanced GPRS. EDGE is a 3G technology that delivers broadband-like data speeds to mobile devices, 2 Mbps when stationary, 384 kbps when moving with good signal, and 144 kbps when moving fast/poor signal. EDGE makes it possible for users to connect to the Internet to send and receive data, including digital images, and web pages, etcetera, faster than an ordinary GSM/GPRS network.

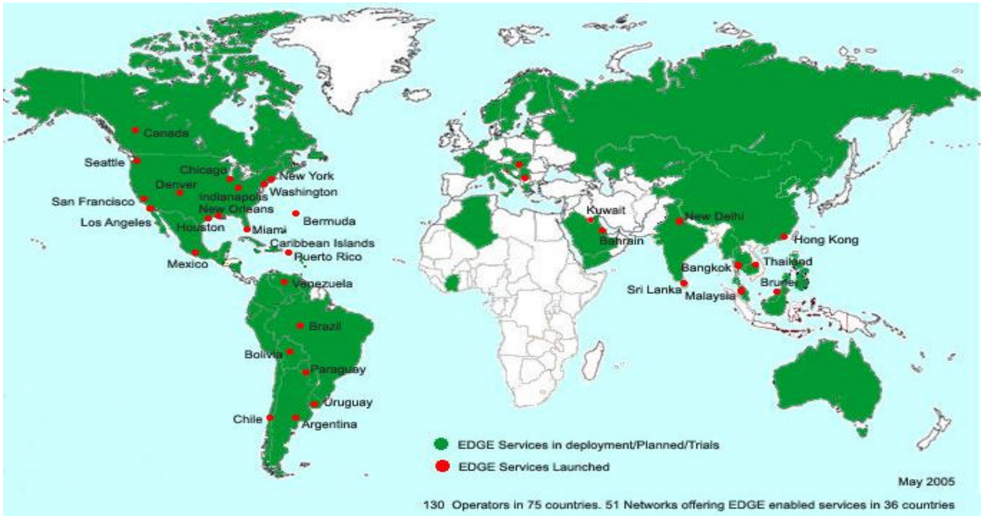

Figure 15. Red areas corresponds to where EDGE services already launched around the world and green to where services are in deployment or planned. Appears with permission of [60]

In Figure 15, the green area in the map is where EDGE services are planned or being deployed while the red is where EDGE services have already been launched. [59] As can be seen in Figure 15, the deployment of EDGE is supported by GSM operators in North America in an active manner. Countries that have already launched EDGE services include for example Canada, Chile, Kuwait, and Brazil.

5.1 EDGE Technology

EDGE is a digital mobile phone technology. It provides the GSM network capacity to handle services such as downloading information, exchanging email, and sending instant messages. EDGE uses the same TDMA (Time Division Multiple Access) frame structure, logic channel, and 200 kHz carrier bandwidth as the GSM networks of today. [61] EDGE can carry data with speed up to 236.8 kbps when utilizing four time slots. However, the theoretical data rate is 473.6 kbps if the used would get access to eight time slots. [62] EDGE can transmit three times as many bits as GPRS during the same period because of a new modulation scheme called 8-PSK. (For more information see [62] [63])

5.2 EDGE Architecture

The architecture of EDGE is similar to the GPRS architecture and requires no hardware changes to the GSM core network. However, each base station must be modified and upgraded. The base station requires a new transceiver unit (TRU) capable of handling EDGE modulation.

Additionally new mobile terminal hardware and software is necessary to utilize the new shift-keying scheme (8-phase shift keying), to encode and decode the signals. [64]

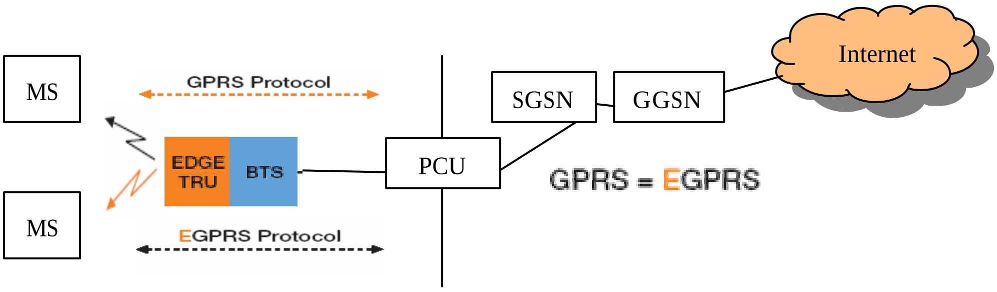

Figure 16. EGPRS Architecture [65]

As shown in Figure 16 the Base Transceiver System (BTS) provides transmission capability across the air interface to and from the mobile stations (MSs). The path is through an EDGE TRU. A Packet Control Unit (PCU) lies between the BTS and the SGSN (Serving GPRS Support Node), manages the radio related features.

The last part of the system is Gateway GPRS Support Node (GGSN), a network element that manages communication between the public Packet Data Networks and the SGSN through an IP-based backbone network. The GGSN provides IP connectivity between mobile users and public services such as Internet, Content Services Gateway (CSG), Wireless Application Protocol (WAP), and Multimedia Messaging Service (MMS). [64]

5.3 EDGE Advantages

With EDGE, operators can offer wireless data applications, including wireless multimedia, e-mail, and positioning services. Subscribers will also be able to browse the Internet on their mobile phones, personal digital assistants or laptops at a high speed. [64]

One advantage is that EDGE interoperates with GSM and GPRS, hence where there is not yet EDGE services available the system can fallback to GPRS and if necessary even dial service via GSM. EDGE also increase the capacity and triples the data rate of GPRS. The data rate has increased from maximum 115 kbps in GPRS to 384 kbps in EDGE. [65]

5.4 EDGE Disadvantages

Each EDGE base station has less coverage than a Digital 450 base station therefore more hardware are needed to implement an EDGE system. Thus, the cost of infrastructure development is much higher than some of the other networks. Clearly if a region does not have GSM coverage, then it is not going to have GPRS or EDGE coverage.

6 Digital 450

In 1970, Nordic telecommunications administrations, i.e., the Post, Telephone and Telegraph (PTT), specified an analogue mobile phone system, Nordic Mobile Telephony (NMT). [66] NMT is based on analog technology and is considered a first generation (1G) mobile cellular telecommunication system. There are two variants of NMT: NMT-450 and NMT-900. NMT-450, which uses the 450 MHz band, is at present used in many countries, for example in Sweden, Russia, Poland, and countries that are colored blue in Figure 17. The analog 450 system has been used in some urban areas and for subscribers living, traveling, and working in dense terrain such as the mountains or out at sea.

After many years of use, the existing NMT analog networks are migrating to a third generation, based on CDMA2000 technology, which is called Digital 450. This technology provides a significant increase in capacity, improved quality of service, and cost efficiencies. [67]

Figure 17. NMT450 Coverage [68] blue area: service in deployment/planned, beige area: no plans at the moment

Digital 450 provides wide area coverage and advanced services, such as high-speed data transfers. Some regions are using Digital 450 technology today, including Indonesia, the state of Hawaii, and Vietnam.

Digital 450 could be a promising technique for the northern part of Sweden where there is sparse GSM coverage, limited traffic, and few users. The implementation of this technique could cover most of the dense terrain in the forest area and thereby satisfying the communication demands of today.

The drawback of Digital 450 is that it requires special handsets and these do not work together with existing networks (specifically GSM and UMTS). [69] However, there are portable handsets that are GSM and CDMA compatible. For example, Motorola has developed a multi-mode handset called the Motorola A840 featuring both Digital 450 and GSM. [70] or [71]

6.1 *Digital 450 Technology*

Digital 450 is based on CDMA2000 technology, which is a 3G mobile telecommunication standard that uses CDMA (Code Division Multiple Access). CDMA is a flexible technology and can be used for a variety of applications. CDMA2000, the commercial broadband wireless technology, providing services such as voice, data, high-speed broadband, and advanced multimedia data services over 2x1.25 MHz channels, called CDMA carriers.

There are many different types of CDMA2000, as shown in Figure 18:

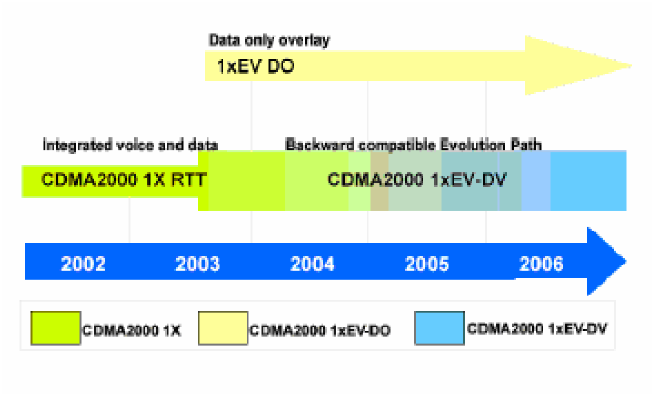

Figure 18. Evolution paths for CDMA2000, appears with permission of [68]

The first one shown above is CDMA2000 1x, sometimes known as 1xRTT. CDMA2000 1x is the core of 3G CDMA2000 technology. The term 1x is used to identify a version of CDMA2000 radio technology that operates with one pair of 1.25 MHz radio channels. CDMA2000 1xRTT (Radio Transmission Technology) is the basic layer of CDMA2000 that can support up to 144 kbps packet data speeds. The second is CDMA2000 1xEV (Evolution). This is the basic CDMA2000 1x, but with High Data Rate (HDR) capability. 1xEV is normally separated into two phases:

Phase 1 is CDMA2000 1xRTT (Radio Transmission Technology) which supports downlink (Forward Link) data rates up to 3.1 Mbit/s and uplink (Reverse Link) rates up to 1.8 Mbps. In addition, this traffic is carried in a radio channel devoted to high-speed packet data.

The next phase is CDMA2000 1xEV-DV (Evolution-Data and Voice), which also supports downlink (Forward Link) data rates up to 3.1 Mbps and uplink (Reverse Link) rates of up to 1.8 Mbps, but can support 1x voice users, 1xRTT data users, and high speed 1xEV-DV data users within the same radio channel. [72]

6.2 Digital 450 Architecture

Digital 450 has a distributed architecture that consists of a Base Transceiver System (BTS), Base Station Controller (BSC), and Home Agent (HA), Authentication, Authorization and Accounting (AAA), and other associated interfaces. Digital 450 has the same architecture as an analog 450 network, but with some integration or enhancement of service applications.

The basic system architecture with Radio Access Network and the IP Core network of a CDMA20001x/CDMA2000-1xEV system are shown in Figure 19:

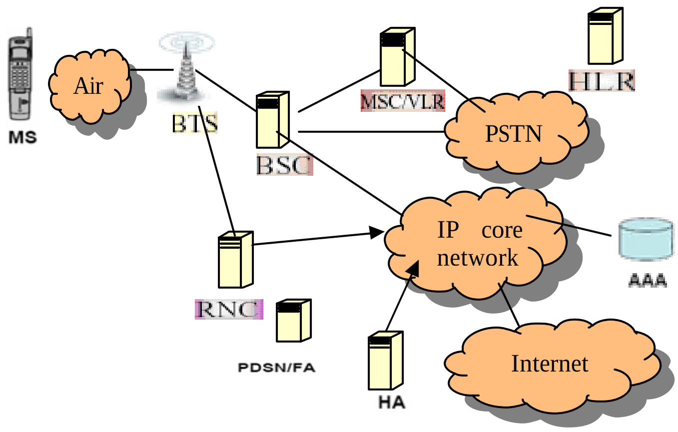

Figure 19. Typical IP core network of CDMA2000 [73]

In CDMA2000 system architecture, the mobile service area is covered by a set of Base Transceiver Systems, BTS. Each BTS is a unit that provides transmission capability across the air interface and is responsible for handing the calls to and from the Base Station Controllers (BSC) and the Radio Network Controllers (RNC), which are located in their coverage area or cells.

These BSCs are connected to Mobile Service Switching Centers (MSCs) by land or wireless links. An MCS is a telephone exchange configured specially for mobile applications. It interfaces the mobile stations (via a BTS) with the public switched telephone network. As shown in the Figure 19, there are two kinds of databases, the home location register (HLR) and the visitor location register (VLR) - these are used to support roaming. The AAA subsystem provides IP based authentication, authorization, accounting functions, and has an interface with the IP core.

Another unit, which has an interface with the IP core network, is the home agent (HA) that provides two main functions. It registers the current point of attachment of the user and forwards IP packets to and from the user. [69] This provides the same basic functionality as the home agent in Mobile IP.

CDMA2000 network is shifting towards a network where all components use IP protocols to provide transport for all types of bearers and signaling information.

6.3 Digital 450 Advantages

In CDMA2000, all devices can be active all the time, because network capacity does not directly limit the number of active units. While in a GSM network because of TDMA technology only a limited number of units can be active at the same time.

Another advantage of using Digital 450 is that due to the use of 450 MHz signals the base stations operating in this band can provide a wider coverage since each cell can cover a larger area. Since smaller numbers of cell-sites can serve larger numbers of phones, CDMA-based standards have a significant economic advantage over TDMA-based standards. [68] A consequence is that Digital 450 is a cost-effective way for countries with large rural areas to bring 3G services to the majority of their population.

6.4 Digital 450 Disadvantages

Digital 450 has some disadvantages compared to other technologies. The possibility of roaming is limited as 450 MHz only handsets cannot roam to other CDMA2000 networks outside the 450 MHz band or to other GSM- or WCDMA networks. Due to this, use of this technology alone is limited and can only be used in areas which support Digital 450. [73] As previously discussed, this could be solved by using multimode terminals.

7 Mobeel

Holmen Skog wants a reporting system where a continuous flow of valuable information could help management maintain up-to-date estimates (or even track in real-time) inventory, location information, sawmill needs, and facilitate optimization of transport solutions. This could help the industry to improve their productivity and performance.

Holmen Skog has requested an inventory of solutions that are available in the market today and an evaluation of each of these to determine the best solution. This solution should focus on the communication between forestry machines and between the production leader and these machines.

Holmen Skog chose the Mobeel solution based on the information that they had received from Skogforsk and Mobilassistenten, along with promises from an operator about deploying EDGE in the northern part of Sweden. Mobeel seemed to be a suitable solution both as a long term and short-term solution, therefore this thesis must include an evaluation of the Mobeel system.

7.1 Introduction to Mobeel

The two main purposes of Mobeel are to achieve a system that acts as an autonomous system, i.e., without requiring any interaction from the users. Moreover, the second purpose was to optimize the dataflow throughout the system, considering both storage capacity and power consumption of the phones.

As is illustrated in Figure 20, Mobeel is based on a router (Possio PX30) with Bluetooth equipment, P910 mobile phones and a web server. Data files are sent by Possio PX30, to and from the computer inside the harvester. Files are then stored in the operator's mobile phone. The transmission between the forest machinery and the mobile phone occurs via Bluetooth technique. As soon as the phone is brought to an area where GSM coverage is available, the files will automatically be transferred to the web server via the GPRS network.

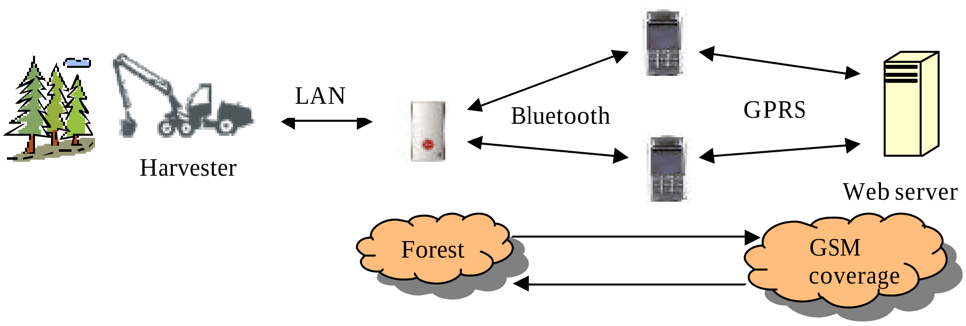

Figure 20. Description of Mobeel system

7.2 Holmen Skog Requirements

Holmen Skog became interested in the concept of Mobeel, but for this to be a workable product in the field some extensions were needed. After discussing preconditions, requirements, and needs we have concluded that the following extensions to Mobeel were necessary:

- To send productions files from both harvester and forwarder to the production leader.

- To send a production report from the forwarder to a production leader that in the future could be sent to SDC.

- To send a file containing GPS-tracks from a forwarder to a production leader, so that the logistics system can dispatch transport to the appropriate points to pick up logs.

- To establish a communication process between the harvester and forwarder, e.g., to send a GPS-track, so that the forwarder knows where there are logs to be collected.

7.2.1 Holmen Skog's Constraints and Limitations

Holmen Skog had constraints and limitations that were discussed for this thesis.

- The solution should only use limited amounts of memory on the forestry machines' computers – so as to avoid disturbing their daily work.
- Telia is to be the terrestrial mobile operator; as they have the best coverage of northern Sweden.

7.3 Mobeel Extended

To be able to fulfill the requirements and unmet needs the Mobeel solution required extensions. The following were considered for the extended version of Mobeel, see Figure 21.

- Installing a PX30 router in the forwarder and supplying the machine operator with a Mobeel equipped cellular telephone.
- To report the production information from the forwarder, by creating a production report which is a form created in XHTML, XML, and XSLT. Along with this production directives contain instructions from the production leader to the forwarder.

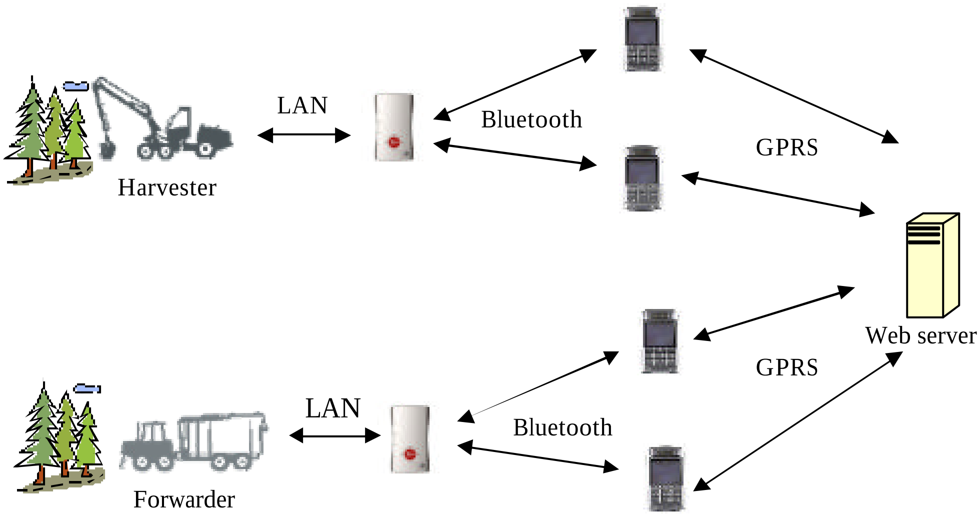

Figure 21. Description of extended version of the Mobeel system

7.4 Mobeel Software

Production files contain uncompressed data and are easily compressed. In the Mobeel software the compression method called ZIP is used. The ZIP format was developed by PKWare in 1989. Today this method is widely used. [74] ZIP reduces the size of a production file by a factor of two which makes the file transfer faster and cheaper. Additionally, the phone can store more files in a given amount of memory space.

Before the transfer of each file occurs, it is compressed, and then sent by the mobile to the appropriate destination. At the destination, each file is decompressed and stored in the correct directory.

A program installation was required, in order to instantly recognize and transmit new files in Timbermatic's prd directory. Because the Windows machine has built-in support and is able to connect to a Windows file server via the Server Message Block protocol (SMB) or its successor CIFS, this could be a viable procedure simply by installation of a program on the Timermatic. Due to the restrictions from specified in [10], no external programs were allowed to be installed in the Timbermatic computer.. The preferred option was to use the Java Common Internet File System (JCIFS) since it is an open source samba client and implements Server Message Block protocol (SMB) or CIFS.

After implementing this client, it was possible to connect the PX30 through an Ethernet – USB adapter to the local computer (i.e., Timbermatic 300) and also to send the new files immediately from prd directory to the PX30. (Note that it was not possible to connect the PX30 to the Timbermatic computer via the serial port).

7.5 Restriction of the Mobeel system

The version of the Mobeel application that is analyzed has restrictions and we have summarized the main issues here. For a more detailed view of the restrictions, refer to

- Files that exceed 500 kB cannot be sent by Mobeel
- The system can only handle production and apt files.
- The system does not support sending files with the letters 'å', 'ä', and 'ö' in the name.
- The phone's battery must be charged at all times and brought to work by the operator.

7.6 System Architecture

The Mobeel application periodically checks to see if it can reach the application server via the GPRS network. When there is connectivity, it starts its file transfer protocols. Every time a phone connects to the application server, it sends the data waiting to be sent and fetches files, which are destined for the computers in the forestry machines. Moreover, the phone sends a log file, which summarizes its activity. Once communication with the application server finishes, the phone waits 30 minutes before attempting to communicate again.

7.7 Acknowledgement

The receiving unit sends back acknowledgment packets to the sender to inform the sender that the data was received. There are two different acknowledgements in the Mobeel system, one acknowledgement (ACK) is from the phone and the other one is from either a Possio PX30 or the application server.

When a file is transferred to a mobile phone via Bluetooth or GPRS, then the phone sends an ACK back. This ACK is used to indicate that the file has been received by the phone. If the sender does not receive an ACK, then after a timeout occurs and the file will be retransmitted. See Figure 23 for the sequence of sending files and acknowledgements in Mobeel.

In the Timbermatic 300, the marked files are stored as a status file in a folder with the name "header". In this status file, the IMEI (International Mobile Equipment Identity), which is a unique number given to every single mobile phone [75], and a UNIX time stamp given in total of seconds [76] are stored. The UNIX time stamp indicates the date and time the file was received, e.g. 05/11/22@17:25 will generate the time stamp 1652304300.

See Figure 22 for an example:

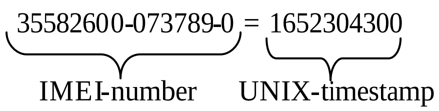

Figure 22. Structure of acknowledgement

A different type of acknowledgment occurs when the file is transferred from the phone to the PX30 or application server. In this case, the final ACK is sent to the phone to inform it that the file has reached its destination. Following a successful transfer, the mobile phones delete the file from its memory and saves the acknowledgment.

Then it sends a final ACK to the destination. When such an acknowledgment has reached the Possio PX30 or the application server it writes an additional time stamp with a punctuation mark following the previous UNIX-timestamp with the same IMEI number. For example: 35582600-073798-0=1652304300:1652311680. Afterward, PX30 and application server know that the file has been successfully transferred.

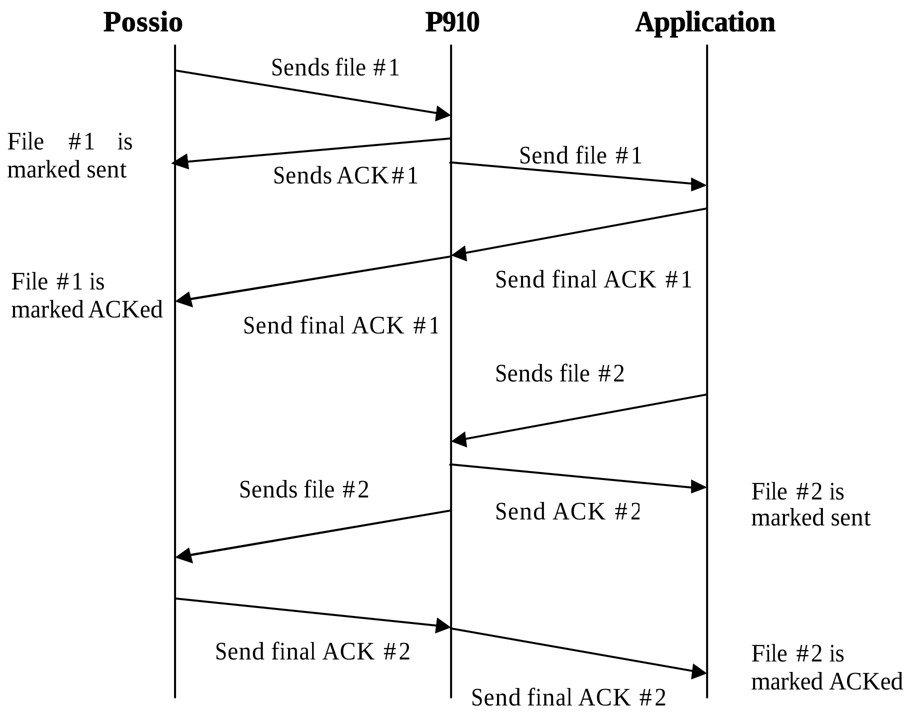

Figure 23. Sequence of sending files and acknowledgements in Mobeel

7.8 Web Server and Web Interface

The web interface presents a summary of all incoming and outgoing files. The web server is structured into two directories, one “IN” and one “OUT” directory. Files received via GRPS and phones will be stored in the “IN” directory. Here information about when the file was created, the size of the file, which phone sent the fle, and if the file is received or not will be stored.

When the production leader wants to send data to the phones they simply browse for the relevant files and place them in the appropriate “OUT” directory. When this has been done, the file will be shown in the “OUT” directory. The files name, size, and the time the file was placed in the “OUT” directory will be shown via the web interface. It is also possible to see which phone received the file, based upon the phone’s IMEI-number, what time the phone received the file, and if the file has reached its destination at the Possio PX30 (although this information will not be known until the phone is back in connection with the GPRS network after the shift is over) or not. Via the web interface, the user can send and erase files.

In the “IN” directory all files that have been sent by the forestry machines’ operators will be shown. Here it is also possible to see which phone received the file, based upon the phone’s IMEI-number and at what time the phone received the file, or when it reached its destination. It is also possible for production leader to download files and save them to a local disk.

7.9 Data Flow

To achieve the desired communication between the harvester, forwarder, and the production leader, various files have to be sent in the proper directions. This part of the thesis will explain the data flow and which the files are sent, their purpose, and sizes. An illustration of the flow of data between harvester, forwarder, and production leader is shown in Figure 24.

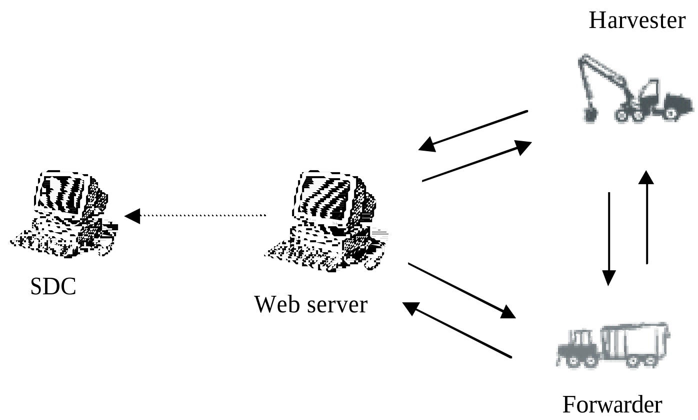

Figure 24. Data flow between harvester, forwarder, and production leader

In the following sections, a discussion about the flow of files in the extended version of Mobeel is covered. This flow is summarized in Table 1 below.

7.9.1 Production Leader to Harvester

From the production leader to the harvester, three different types of files are sent Adobe PDF [77], hdp, and apt. The **PDF-file** is typically 400-600 kB in size and contains instructions about the cutting operation such as cleaning, thinning, or regeneration felling. This document also provides maps and other relevant information for the operator of the harvester.

The **hdp-file** is around 400 kB and includes instructions about the cutting operation. This file is used by the navigation program in the harvester. The hdp extension stands for Holmen Data Packet and is an internally defined extension that represents the cutting operation.

The **apt-file** contains information about controlling bucking instructions, information about optimizing the cross-cutting procedure, and price matrixes per assortment. The size of the file is approximately 10 kB. The apt-file is part of a Nordic standardization developed by Skogforsk and is called the Standard for Forestry Data and Communication. StanForD. This defines a standardized file structure where the apt-file is included. [77]

7.9.2 Harvester to Production Leader

The harvester sends two prd-files, containing production information, to the production leader. These files are created in the harvester's production system. Information about each cut tree, the type of the tree, its volume, and taper can be found in a prd-file. The size of a prd-file is around 20-30 kB. The production file is created to meet the specific conditions that exist at each individual site. [79] The production file sent to the production leader contains only text and therefore it does not grow rapidly in size.

Furthermore, another file format called shp is sent between the harvester and the production leader. Shp is a vector image file that consists of three individual files that must be used together: filename.shp, filename.shx, and filename.dbf. The .shp file has the geographic coordinates for the map; the .shx file has the header information which describes the map, and the .dbf file has the attributes or data that goes with the map e.g. GPS-track. [80] These files are created by the navigation program in the harvester and will later be used by the forwarder's navigation program in order to follow the GPS-track created by the harvester.

7.9.3 Production Leader to Forwarder

The production leader sends an instruction file to the forwarder in XML format. The size of this file is around 1 kB. This file contains specific information for a site, e.g. the name of the field, the marking on the timber, pricelist used, machine number, and timber order number, assortment of timber, and information about the receiving mill where the timber should be shipped.

The production files (pdf and hdp) that are sent from the production leader to harvester are also sent from production leader to forwarder.

7.9.4 Forwarder to Production Leader

The forwarder operator fills in the forwarded volume for each day in a form. The information is saved in XML format into a file, that will later be sent to the production leader using Mobeel. This XML file is around 1 kB.

7.9.5 Harvester to Forwarder

The harvester's logged GPS-track, created by the navigation program, should be sent directly to the forwarder. The size of these files are as follow: the main *.shp file around 80-90 kB, index file: *.shx 100-120 kB and dBase file: *.dbf around 300 kB. At this moment it is not possible to send these files directly to the forwarder, the files have to go through the web server and manually be sent to the other operators' phone. See section 8.7.4 for a discussion of improvements about the web server.

Table 1. Flow of files in the extended version of Mobeel

Files sent from	File name	Quantity	Approximate Size (kB)
Production leader - Harvester	*.pdf	1	400-600
	*.hdp	1	400
	*.apt	2	10
Harvester - Production leader	korspar.shp	1	80-90
	korspar.shx	1	100-120
	korspar.dbf	1	300
	*.prd	2	20-30
Production leader - Forwarder	*.xml	1	1
	*.pdf	1	400-600
	*.hdp	1	400
Forwarder - Production leader	*.xml	1	1
Harvester - Forwarder	korspar.shp	1	80-90
	korspar.shx	1	100-120
	korspar.dbf	1	300

7.10 Installation of Mobeel

The workflow of this thesis has included the Mobeel system. To accomplish this task, the first step was to install Mobeel in order to begin our evaluation. The hardware component of Mobeel consists of three Sony Ericsson P910 mobile phones, two Possio PX30, two Belkin USB 10/100 Ethernet Adapter, and two cross-over Ethernet cables.

7.10.1 *Configuration of the Sony Ericsson P910 Mobile Phones*

To establish a Bluetooth connection between the Possio PX30 and the Sony Ericsson P910 phone, the correct Bluetooth settings had to be configured. This requires that the phones are enabled for connecting to other Bluetooth units, after that the phones must paired with the Possio PX30. Next, the GPRS settings had to be configured. In this project a Telia Online subscription was used and the settings for GRPS were retrieved from Telia's web site. [81]

The Mobeel.sis file containing the Mobeel application was downloaded to the phone via Bluetooth, IR, or a serial cable to the phones. After that, the file was launched and installed on an external memory card. Mobilassistenten provided the Mobeel.sis file, including the code for Mobeel, to us. For debugging and control, the Mobeel application has a graphical user interface, that is enabled when launching the Mobeel.sis file.

Figure 25. Interface of Mobeel application, appears with permission of [10]

7.10.2 *Mobeel User Interface*

As illustrated in Figure 25, there are two fields: one for the received files from the machines and the other one for the files that has been sent to the Sveaskog. The name is not correct because the original Mobeel application was developed by Mobilassistenten for Sveaskog (another forest company in Sweden). Of course this should be replaced by Holmen Skog if Mobeel becomes a product in the future. If the phone is currently communicating with the Possio PX30 or the server, the square is marked orange and when a file is send or received completely then the square becomes green. The name of the files and the exact time when they are sent is displayed in the user interface.

There are two directories: GPRS_SERVER and MS_SERVER, in the phone that can be used for debugging purposes. GPRS_SERVER contains the files sent to the web server and the directory MS_SERVER contains files received from the web server. To be able to view this internal file structure on the phone, the SMAN program can be downloaded. SMan comes with a file manager, a task manager, and operations to display system information, a database manager, and much more as shown in the Figure 26. [82]

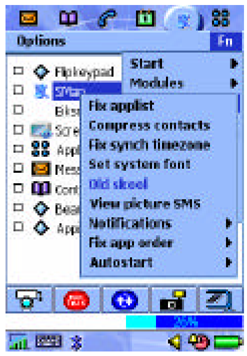

Figure 26. SMan interface

7.10.3 Installing of Samba Client to the Possio PX30

A configuration file, settings.ini, was created for the Mobeel application and is located in the Possio PX30. This file was written by Mobilassistenten and needs to be preconfigured in the Possio PX30 of the respective machine(s). Therefore, a version of this configuration file has to be created for each of the forestry machine with the correct values for the local variables, such as: login username and password. To perform modifications to these variables; Putty, an open source SSH client with remote file copying support, was used. The user terminal and the PX30 are connected via ssh and these machines are physically connected through an USB Ethernet adapter.

Important to note when making changes to the settings.ini file is that the user name and password in the Possio PX30 must the same as the administrator's name and password in the harvester's and forwarder's computer.

7.10.4 Installation in Harvester and Forwarder

First the Possio PX30 must be connected to the lighter socket (in order to get power), then it can be switched on. Via a cross-over network cable and a Belkin USB 10/100 Ethernet adapter, the Possio PX30 is connected to the Timbermatic computer. Next, the drivers for the USB Ethernet Adapter were installed in the Timbermatic computer and after that a new network connection was configured. The network connection in the forestry machines' computer was configured with a static IP-address and an appropriate file structure was created - that looks like this:

- C:\in
- C:\log
- C:\TIMBERMATIC FILES\Prd
- C:\TIMBERMATIC FILES\Prd\files
- C:\TIMBERMATIC FILES\Prd\files\header
- C:\TIMBERMATIC FILES\Prd\header

Directories C:\in, C:\TIMBERMATIC FILES\Prd, and C:\log are shared within the Timbermatic's network. C:\TIMBERMATIC FILES\Prd directory was also shared via this network. These directories should be shared, since the production files and other files in forestry machines' computer end up in Prd directory, subsequently these files will be sent via the mobile phone.

7.10.4.1 Installation Problems

We had some difficulties with the structure of directories due to the lack of information that we had received supplied by MobilAssistenten. In the Mobeel thesis it said that the C:\out directory was to be shared, but it turned out that the Possio PX30 was looking for the C:\TIMBERMATIC FILES\Prd directory.

7.11 Implementation of a Forward Report Application

Previously, the forward operator filled in a printed form at the end of each shift. Then the operator called an automatic voice response service ("hotline") and reported the forwarded volumes by entering data via the phone's keypad. This section will discuss the generation of a digital forwarding report written with Extensible Markup Language (XML) and Extensible style sheet language transformation (XSLT) that will replace the existing reporting procedure. The structure of this implementation consists of two forms: Forward Directive and Forward Report. The forward directive is implemented at the work station of the production leader and the forward report is implemented in the forwarder's computer.

The choice of using XML to construct the form for the forwarder was chosen since the data needs to be processed in various steps, see Figure 9:

1. The production leader fills in a form called a forward directive. The information entered in the form is saved as an XML file.
2. This XML file, XML 1, is then sent using Mobeel to the computer in the forwarder.
3. When the XML file arrives in the "IN" directory of Mobeel the forward report application extracts the information and creates a form for the forward report.
4. At the end of a shift the operator of the forwarder fills in the information concerning the volume of timber hauled, then this second XML file is automatically sent by Mobeel to the production leader.

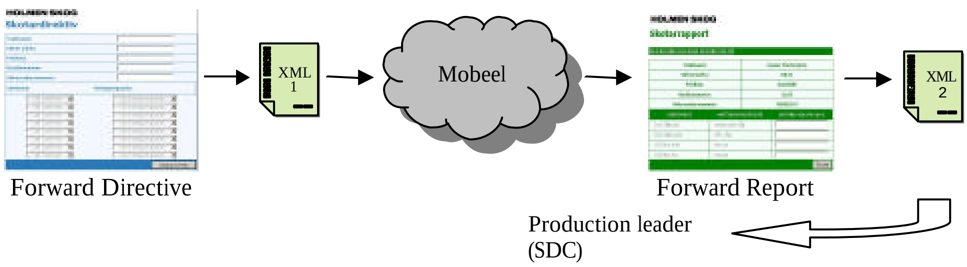

Figure 27. Course of events for creating a Forward Report

7.12 Extensible Markup Language

Extensible Markup Language (XML) is a language for documents containing structured information. It is derived from Standard Generalized Markup Language (SGML). This language is a general-purpose markup language and can be used to create special-purpose markup languages that are capable of describing different kinds of data. XML supports all kind of texts that is written in any of the world's alphabets, it also includes a method that signals what language and encoding is used.

An XML document consists of XML declaration and nested elements. Some of elements have attributes and contents. An element normally consists of two tags, a start tag and an end tag. In XML, it is possible to define personal (own) tag set and share them with others. XML documents must be well formed and valid to be correct. A well-formed document should agree with all of XML's syntax rules. For example, if a non-empty element has an opening tag with no closing tag, it is not well-formed. An XML document is valid when it complies with a particular scheme such as Document Type Definition (DTD). [83]

7.13 Extensible Style sheet Language Transformation

Extensible style sheet language transformation (XSLT) is an XML-based language for transforming XML documents into other XML documents. XSLT is designed to be used as part of XSL, which is a style sheet language for XML and also designed to be used independently of XSL. [84]

7.14 Extensible HyperText Markup Language

Extensible Hyper Text Markup Language (XHTML) is an extension of HTML and is defined as an application of the XML language. XML describes data and HTML displays it. XHTML is much stricter than HTML, all the elements that exist in HTML exist in XHTML and are combined with the syntax of XML. XHTML can be interpreted by XML and HTML browsers. [85]

The elements must be properly nested and the document must be well-formed. XHTML documents can utilize programs and scripts that support either the HTML Document Object Model or the XML Document Object Model (DOM). [86]

7.15 DOM

Document Object Model (DOM) is a platform or an application-programming interface that allows programs and scripts to access and update the document’s content, structure and style dynamically. It also binds different scripting languages together with HTML and other markup languages. [87]

7.16 MSXML DOM

MSXML DOM (Microsoft XML Document Object Model) is an XML parser that can access and manipulate XML documents. It loads or creates the document and thereafter the information and structures contained within the document can be accessed or manipulated. MSXML DOM is able to save the document back to an XML file, if necessary. [88]

7.17 Forward Directive

A forward directive is a form created to replace the existing spreadsheet (produced from a Microsoft Excel file) that the production leader previously printed and manually gave to the operator of the forwarder. The information in the forward directive is similar to that in the Excel file.

Figure 28. Forward Directive, for a larger figure refer to Appendix A

The production leader has the forward directive installed on his/hers computer and fills in the name of the forestry site, the marking of the timber, pricelist, machine number, and timber order number by typing on the keyboard. The timber assortment and delivery location are chosen from drop-down lists. In the timber assortment list information like birch, pine, spruce, and pulp can be found, while in the delivery location drop-down lists of different mills and industry locations are specified. The form for generating this forward directive is shown Figure 28.

When all the information is entered the production leader presses the button “Skapa Direktiv”, generating an order. The XML file is generated with the name Skotardirektiv_YYYY-MM-DD.xml. An example of such a file, Skotardirektiv_2005-11-8.xml, can be found in Appendix A. This file contains all the data entered within XML tags. Once the file is generated the production leader places this file on the web server and then the file is sent to the forwarder by the Mobeel application.

7.18 Forward Report

The computer in the forwarder receives the XML file in its C:\in directory. The forward report, such as that shown in Figure 29, can then be generated with the information in the recieved Skotardirektiv_YYYY-MM-DD.xml file. The forwarder operator can then see the static information entered by the production leader, but does not have possibility to change it, (as the operator does not need to change this data). The only thing the operator needs to do is to enter the forwarded volume and press the button “Skicka”, “Transmit”. Another XML document is then created called Skotarrapport_YYYY-MM-DD.xml and placed in the C:\TIMBERMATIC FILES\Prd directory and sent back to the web server. From there the information can be viewed by the production leader or in the future it could be sent directly to SDC. What should be noted is that the XML files of this implementation do not follow the XML standard

Figure 29. Forward Report, for a larger figure refer to Appendix A

developed by SDC. Converting them from this format to the SDC form at should be part of any future development of this system.

7.19 Generation of Forwarder Report

To understand the creation of the forward report several things have to be considered. A form (forward directive) was created, using XHTML, where the desired data was entered. The XHTML code has functions that loop through the form, collect the entered data and writing it to the specified XML file, Skotardirektiv_YYYY-MM-DD.xml. It is important to generate a well formed XML document so it can be read by the application on the forwarder side (i.e. the forward report).

To be able to read the information in the Skotardirektiv_YYYY-MM-DD.xml file a small transformation on the forwarder side needs to be applied. For this we use XSLT, which is an XML-based language to transform the incoming XML document to a second XML document (Skotarrapport_YYYY-MM-DD.xml). [89] To be able to do this transformation an XML parser (also called XML processor) from Microsoft is used, called MSXML 4.0, see Figure 30. This parser supports the DOM (Document Object Model), XPath, Schema, and XSLT implementation. [90] A DOM-based parser builds a tree structure containing the XML documents data in memory.

In the implementation of the forward report, we used the MSXML 4.0 parser, which we installed on the target machine along with a version of Internet Explore 5. In the Skotarrapport.html file the specific parser is invoked using JavaScript along with the XSL file, Skotarrapport.xsl. In the same HTML file, the XSL style sheet document created for the forwarder is loaded. Then the XHTML takes the information provided by the Skotardirektiv_YYY-MM-DD.xml file and creates the form, as in Figure 29. Then the operator of the forwarder provides his/hers information and the new information will be written to the new XML file, Skotarrapport_YYYY-MM-DD.xml.

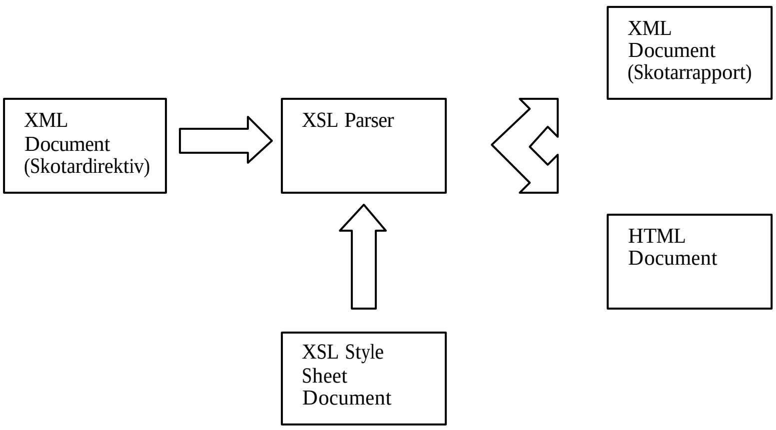

Figure 30. Transformation process of XML, XSL documents using a XSL Parser

8 Mobeel Evaluation

In this section, a discussion of the tests performed, along with the details of the implementation and evaluation of both the lab and field tests is presented.

8.1 Background of Tests

The testing and evaluation of Mobeel was done in different phases. The first phase included tests and evaluation of the system in a controlled lab environment, after this it was tested in a forest environment (i.e., in the field or in this case actually a forest). The field tests were performed over three weeks. The purpose of these tests was to retrieve relevant data to evaluate the system during actual use. The main purpose was to understand the flow of information between the management and the machines. The field test relevant information for our evaluation. The tested system was then extended to include the forwarder, and compared to the original version of the Mobeel system. This involved generating a forward report and send the result to the management. Relevant questions to be answered for this lab and field tests includes:

- How easy is the Mobeel application to use?
- How much GPRS-traffic is generated?
- What is the effective payload of the GPRS-traffic?
- How many files have been sent, received, and acknowledged properly?
- How was the distribution of sending/receiving files among the different telephones? (Keeping in mind that Mobeel tries to partner with all Mobeel equipped phones which are encountered)
- Does the flow of data follow the expected behavior?
- Etc.

The test has been performed in an area outside Junsele by an entrepreneur team called Resele Skog machine team. The team consisted of two harvester operators and one forward operator. The machines were equipped with the necessary hardware for each forestry machine and the operators were supplied with the Sony Ericsson P910 mobile phones.

For the lab and field tests, the Sony Ericsson P910 phones were identified in two different ways; by IMEI-number and a fictitious name as can be viewed in Table 2. The fictitious name was used to identify which machine operator had which phone and as a more user-friendly way of referring to the different handsets.

Table 2. Sony Ericsson P910 fictitious names and associated IMEI-number

Phone name	IMEI
Forwarder	35582600-073798-0
Forest	35582600-075610-5
Harvester	35582600-071845-1

In the rest of this section, we will discuss the performed lab and field tests.

8.2 Lab Test Setup

Before setting up the Mobeel solution in the forest machines, the system was tested in a lab environment. The purpose of these tests were to see how the system behaved, how stable it was, and if it was mature enough to be used in a forest environment.

The tests were implemented by uploading files to the web server http://generix.nufort.net/~mobeel/ to be sent to the machine's computer by Mobeel. A second test was performed to see how much GPRS traffic the Mobeel application utilizes when the phone is within GSM coverage. Five different test files were used, as specified in Table 3. In this lab test, the forestry machine computer was simulated by a DELL Latitude CPx laptop, Pentium III with a clock frequency of 500 MHz, 128 MB RAM, and running Microsoft's Windows 2000 operating system.

The files were sent by GPRS to the mobile phones, then by Bluetooth from the phone, to the Possio PX30 router, and finally through a local area network (via a USB-connection) to the laptop computer.

Table 3. Description of test files according to name, size, and file type

File name	Size (bytes)	File type
File1	19968	.doc
File2	200789	.dll
File3	421717	.jpg
File4	399200	.pdf
File5	391666	.hdp

The tests were divided into four different parts where the first three involved sending files from the web server to the field. The following sections will describe each of these lab tests in more detail.

8.2.1 Test 1

Test 1a included all three phones (Forwarder, Forest, and Harvester), one by one, being turned on to see if the Mobeel application in each phone would be able to send File1, File2, and File3.

Test 1b used two telephones at the same time (Forest and Harvester) to send File1, File2, and File3.

Test 1c used all three phones (Forest, Harvester, and Forwarder) at the same time to send File1, File2, and File3.

The purpose of the first test was to see if the Mobeel application would be able to send files with different types and sizes. For Test 1a, Test 1b, and Test 1c three arbitrary files were chosen. The test included one, two, or three active handsets to see how the system behaved.

8.2.2 Test 2

Test 2a used all three phones (Forest, Forwarder, and Harvester), one by one, to transfer files File4 and File5.

Test 2b used two telephones (Forest and Harvester) at the same time sending File4 and File5 sequentially.

Test 2c used all three phones (Forest, Harvester, and Forwarder) at the same time sending File4 and File5 sequentially.

The purpose of Test 2a, Test 2b, and Test 2c was to see how the system behaved with one, two, or three active handsets, which phone will perform the transmission of files, which phone will acknowledge the transfer and so on. File4 and File5 were chosen specifically to represent the planned path (traktpaket) that the production leader is sending, to simulate a regular workflow.

8.2.3 Test 3

Test 3a used all three phones (Forest, Forwarder, and Harvester), one by one, to transfer the files File3, File4, and File5.

Test 3b used two telephones (Forest and Harvester) at the same time sending File3, File4, and File5.

Test 3c used all phones (Forest, Harvester, and Forwarder) sending File3, File4, and File5.

The purpose of Test 3a, Test 3b, and Test 3c was to see if the system could handle sending and receiving large files at the same time. The different tests are performed with one, two, or three active handsets.

8.2.4 Test 4

The fourth test was to investigate the Mobeel application's consumption of GPRS capacity when the phone(s) was (were) in an area with sufficient GSM coverage. This test showed how much GPRS traffic the Mobeel application consumed during a period of several hours, on different days, without sending any actual files.

8.2.5 *Result and Evaluation of Lab Tests*

Details view of the results of these tests is found in Appendix B.

When sending the five files one by one using all the phones in Test 1a, Test 2a, and Test 3a the Mobeel application appears to be stable, it transfers and acknowledges the files within 1 to 11 minutes. The tables also show that about 62.5% of the files are received within three minutes, which is a good result. The theoretical time required to transfer the file would be according to Table 4 of maximum 1.3 minutes (assuming the worst case scenario of allocating one time slot with a bit rate of 43.05 kbps) – assuming that the link was operating at the maximum theoretical throughput and that there were no other sources of delay or overhead.

Table 4 Theoretical time required to transfer the files sequentially

File name	Size (bytes)	Transfer time 43.05 kbps (allocating 1 time slot)	Transfer time 86.1 kbps (allocating 4 time slots)	Transfer time 172.2 kbps (allocating all eight time slots)
File1	19968	3.7 s	1.8 s	0,9 s
File2	200789	37.2 s	18.6 s	9.3 s
File3	421717	78.4 s	39.2 s	19.6 s
File4	399200	74.2 s	37.1 s	18.6 s
File5	391666	72.8 s	36.4 s	18.2 s

Test 1b, Test 2b, and Test 3b sent the five specified files by using two of the phones. The results from this test show that all sent files are acknowledged by the Possio PX30 within four minutes. Transferring the files from the Possio PX30 to the Timbermatic (or another attached PC) via the USB/Ethernet is no issue since the speed via cable is significantly higher than the GPRS bit rate.

Test 1c, Test 2c, and Test 3c used all three phones to send files at the same time, here we observed a bit different results compared to the previous tests. Test 1c showed that it took almost one hour to acknowledge that the three files had been successfully sent. While, Test 2c and Test 3c, showed that all files were received within three to six minutes.

We deliberately tried to send files with extensions other than the approved files (hdp-, apt, and prd files).

During the test, we observed that the Mobeel application tries to connect to the application server every 30 minutes, to establish a connection and to transfer any pending files. This could be a major drawback of the Mobeel system due to the high cost for what are generally unnecessary connection setups. Test 4 was performed to measure how much "unnecessary" GPRS-traffic was generated in these cases where there was not transfer of any files. The results of Test 4 are shown in Table 5.

Table 5. Results from Test 4, where the phone has suitable GSM coverage, but did not send any files.

Date	Time	Sent data (kB)	Received data (kB)
2005-10-21	17.09-18.09	100	34.5
	18.09-19.09	100	37.4
	19.26-20.26	100	36.0
2005-10-22	12.28-13.28	100	35.4
	13.40-14.40	100	35.8
	14.42-14.52	100	35.6
2005-10-23	09.50-10.00	100	35.8
	10.00-10.10	100	36.0
	10.10-10.20	100	37.4

The measurements for Test4 were performed on three different days and during three different times of the day. The amount of traffic sent is always 100 kB and the average amount of the received traffic is roughly 36 kB (35.99 kB). This means that during a 24-hour period when the phone is in constant GSM coverage the Mobeel application will transfer almost 3.2 MB (3264 kB) just connecting to the GPRS server (but without any user data being transferred!).

We also tried to stress the system by overloading it by sending quite large files (File4 and File5). When the amount of data to be sent reached a total of 2-3 MB the Mobeel application became unstable and gave the error message, "User code 11" or "Orsakskod 11". See section 8.7.4 for further information about this error message.

From these tests, we conclude that the Mobeel system works stably in a lab environment (if the restrictions of the system are considered). One important observation was the amount of data used to periodically connect to the web server, which will contribute to the costs of using this system.

Based on these lab experiments, we concluded that Mobeel is fairly easy to use when it is working properly. Although when problems are encountered, such as "User code 11"/"Orsakskod 11", the users of the system are expected to have sufficient experience to solve them.

8.3 Field Test Setup

In this section, a presentation of the field-test is presented along with the specific conditions concerning each of the different tests.

8.3.1 Task of Production Leader

The production leader was instructed to create a planned path (.prd- and .hdp files) every second day and to generate a forward directive each day. The task of the production leader was to place these files on the web server to be sent by the Mobeel application. The production leader was also instructed how to handle files that are received by the web server.

The planned path was considered fictitious since it was created only for the purpose of generating a flow of information and to familiarize the production leader familiar with the Mobeel system. Although the planned path was not actually used by the machine operators, it contained the same information as a "real" planned path would.

8.3.2 Task of Forwarder Operator

The operator of the forest machines were instructed how to handle the hardware used by Mobeel. Prior to starting any of the experiments, we spent a couple of weeks learning how to use the application before the test started. The task of the forward operator was to create a forward report each day (see section 7.11). Once the forward report was generated, the Mobeel application would perform the transfer of information to the production leader.

8.3.3 Task of Harvester Operator

The operator of the harvester also had a couple of weeks to learn how to use the Mobeel application. The task of the harvester operator was to manually produce production files at the end of each day. The operators were instructed how to generate the production files, see Appendix D. Previously these files were generated only when the operator confirmed that the site they were working on was finished, this is called in swedish "traktavslut".

8.4 Results and Evaluation of Field Tests

In this section, the results and evaluation of transferring files will be presented. This evaluation is split into an evaluation of the in(put) and out(put) directories of the web server and the GPRS traffic generated via this application.

8.4.1 Results and Evaluation of In Directory

In Appendix C presented details of all the files received in the "IN" directory of the web server. In this table the specific details of the files are also presented. It will be from those details we have achieved this evaluation of the received files. The most positive result is that *all* files are being sent, received and acknowledged by the Mobeel system.

Table 6 shows, a summary of the number of acknowledged files within a specific time interval. From Table 6 we can see that almost 44 % of the files were sent, received, and acknowledged within four hours. Roughly, 69% of the files sent from phones to the in directory are received and acknowledged within 24 hours. This seems to be a reasonable amount of data and a time perspective that meets the expectations of Holmen Skog. However, this also shows that the rest, i.e., 31% of the files or 12 files, required more than 24 hours to be transferred.

Three out of these twelve files were part of the forward report procedure. These three files were received within four to five days. This has a natural explanation since the files were created at the end of the shift on Friday evening. The transmission of the files to the mobile phone had not occurred by the time that the forest machine was turned off for the weekend. In other words, the Possio PX30 did not poll the out directory of the forestry machine's computer before that computer was turned off. Therefore the files are were subsequently sent on Monday, Tuesday, or even Wednesday depending on the operator's work schedule.

Table 6. Summary of acknowledged files of in directory

In Directory		
Time interval (h)	**Acknowledged files**	**Percentage (%)**
0 – 4	17	43.59
4 – 8	0	0.00
8 – 12	3	7.69
12 – 24	7	17.95
> 24	12	30.77

Seven of the twelve files sent to the in directory during the test period were recognized as "old" files (i.e., previously received). See Appendix C the files send on 2005-11-14 and 2005-11-23 are recognized as old. Thqere are many conceivable scenarios why this happened. One is that these files were sent by the Mobeel application previously, and when the acknowledgements were removed from the web server, the Mobeel application did not understand that it had already sent the file and therefore did a retransmission. Another scenario could be that the operator of the machines has manipulated or moved files to the out catalogue, C:\TIMBERMATIC FILES\Prd, thus they would automatically be transmitted. The only information known about these files is the date when they are created and received. Therefore, we do not know the exact date/time when they were sent, the only thing we know is that from created to received it took between 52 and 166 days.

In Figure 31, the distribution of transfer times for the in directory of the web server is shown. This gives an easily visualized version of the previous discussion. From this figure, we can see the dates when the files are sent and the approximate transfer times. For more details about the transfer of these files, refer to Appendix C.

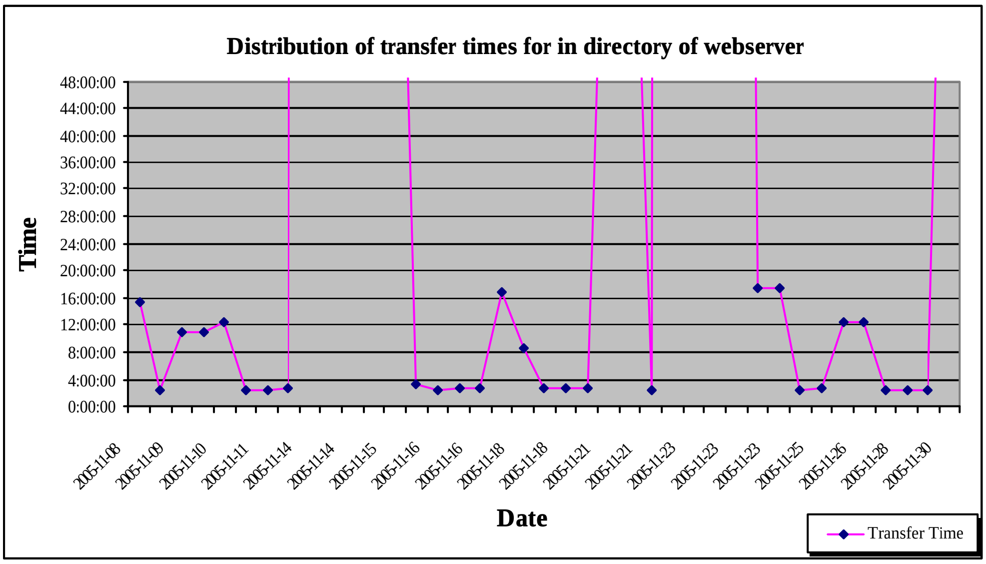

Figure 31. Distribution of transfer times for in directory of web server

Table 7 shows the distribution in kilobytes of the transfer that each phone made each day. It also shows the total GPRS traffic, in kilobytes, for the in directory. Here we can conclude that Harvester and Forest phones have almost the same load of GPRS traffic, while the Forwarder phone is consuming only 1.7% of the total GRPS traffic for the in directory. This occurs because the Forwarder phone is only transferring forward reports of roughly 1 kB each day, while the other phones are sending production files that vary between 24 – 72 kB.

Table 7. Distribution of kilobytes transferred by each phone and the total traffic for in directory

Date	Forwarder Size of file (kB)	Harvester Size of file (kB)	Forest Size of files (kB)	Total GPRS traffic (kB)
2005-11-08	2.07	0.00	0.00	2.07
2005-11-09	0.00	24.75	0.00	24.75
2005-11-10	1.04	0.00	24.90	25.93
2005-11-11	0.00	49.98	0.00	49.98
2005-11-14	0.00	0.00	59.39	59.39
2005-11-15	1.04	0.00	22.77	23.80
2005-11-16	1.04	48.57	0.00	49.60
2005-11-17	1.04	0.00	0.00	1.04
2005-11-18	0.00	74.20	0.00	74.20
2005-11-21	3.10	0.00	0.00	3.10
2005-11-23	0.00	0.00	55.80	55.80
2005-11-24	0.00	0.00	25.97	25.97
2005-11-25	0.00	24.64	0.00	24.64
2005-11-26	0.00	0.00	71.54	71.54
2005-11-28	0.00	0.00	24.13	24.13
2005-11-30	0.00	24.66	0.00	24.66
Total (kB)	**9.32**	**246.80**	**284.49**	**540.61**

8.4.2 Results and Evaluation of Out Directory

In Appendix C a detailed view of the files sent from the out directory of the web server are presented. In the Table 8, a summary of the files sent by GPRS from the out catalogue of the web server can be found. The time it has taken to complete the transfer (i.e., sending, receiving and acknowledging) the files differs from the time it took for the in directory. Here we can see that 68% of the files are acknowledged within four hours. Moreover, as much as 76% of the files are sent and received within eight hours. Only 24% of files have been acknowledged later than 24 hours, but the important fact is that all files have been sent and received and acknowledged. This is confirmed with Figure 32 that shows the distribution of transfer times for the out directory of the web server. Here we can see that all files except one was received and acknowledged within 32 hours, while the majority of the files are transferred within four to eight hours.

Table 8. Summary of acknowledged files of out directory

Out Directory		
Time interval (h)	**Acknowledged files**	**Percentage (%)**
0 – 4	17	68.00
4 – 8	2	8.00
8 – 12	0	0.00
12 - 24	0	0.00
> 24	6	24.00

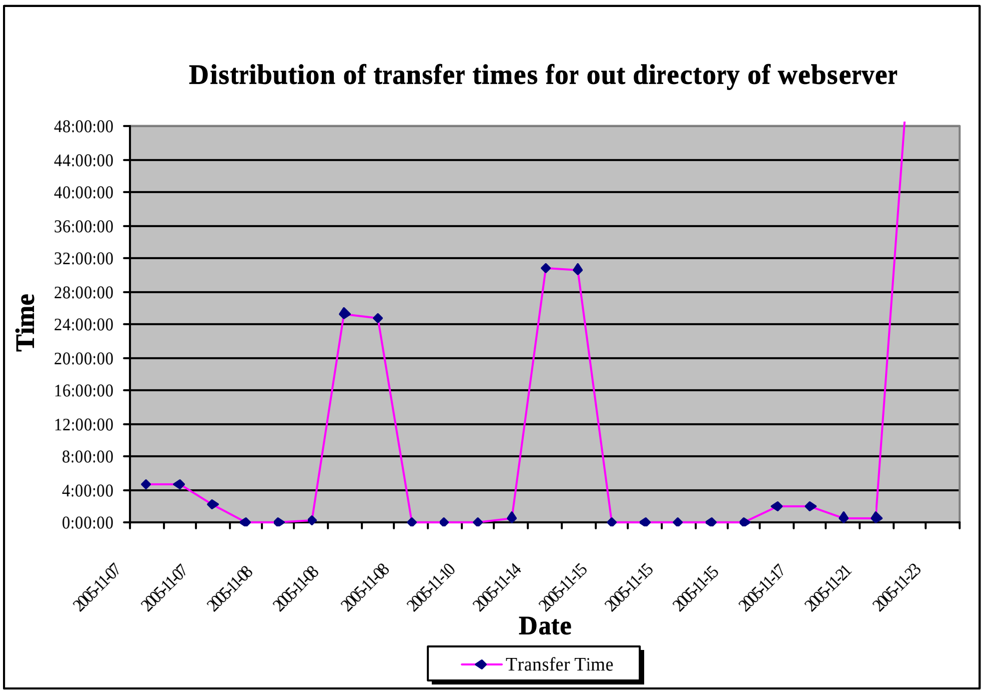

Figure 32. Distribution of transfer times each day for out directory of web server

Table 9 shows the transfer in kilobytes transferred by each phone and the total traffic for the out directory.

Table 9. Distribution of kilobytes transferred by each phone and total traffic for out directory

Date	Forwarder Size of file (kB)	Harvester Size of file (kB)	Forest Size of files (kB)	Total GPRS traffic (kB)
2005-11-07	0.00	0.00	724.38	724.38
2005-11-08	1.64	0.00	742.78	743.60
2005-11-10	0.82	0.00	726.71	727.53
2005-11-14	696.40	0.00	0.00	696.40
2005-11-15	28.49	0.00	695.86	724.35
2005-11-17	0.00	0.00	306.26	306.26
2005-11-21	696.25	0.00	696.25	696.25
2005-11-23	0.00	290.69	0.00	290.69
Total (kB)	**1423.60**	**290.69**	**3892.24**	**4909.47**

Here we can see that the Harvester phone has a lot less activity compared to the other two. The Harvester phone has sent approximately 290 kB while the Forwarder is almost five times as active and the Forest telephone is about 10 times more active. This might have several explanations, but for this particular test we think that the explanation is human error, perhaps the operator forgot to turn on his phone, it was forgotten at home, etc. Hence this would result in a less effective system and erroneous results could be outcome.

8.4.3 Results and Evaluation of In and Out Directory

This section will summarize our evaluation of the in and out directory. A satisfying aspect of the present solution is that almost 72% of the files are received and acknowledged within 24 hours, see Table 10. In Figure 35 a summary of the distribution of transfer times for the two directories are shown. Table 11 shows that the GPRS traffic needed for transferring the files to/from the in and out directories of the web server is 5450 kB.

Table 10. Summary of acknowledged files of in- and out directory

In and Out Directory		
Time interval (h)	**Acknowledged files**	**Percentage (%)**
0 – 4	34	53.13
4 – 8	2	3.13
8 – 12	3	4.69
12 – 24	7	10.94
> 24	18	28.13

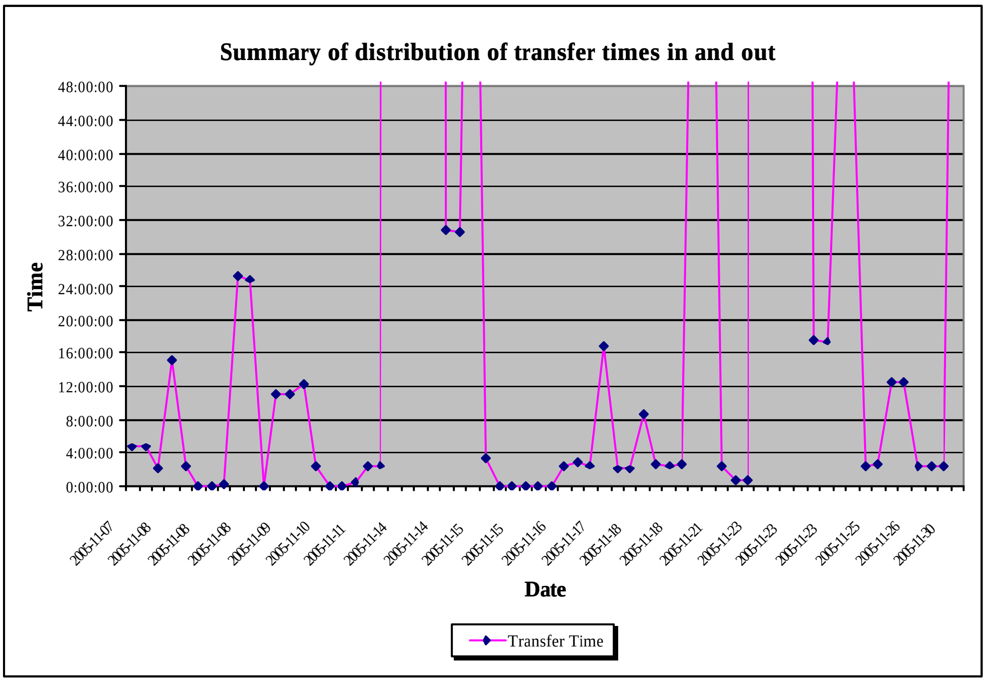

Figure 33. Summary of distribution of transfer times for in and out directories

Table 11. Needed GPRS traffic for transfer of files

Sum of GPRS traffic sending files	
Size of retrieved files to in directory	541 kB
Size of sent files from out directory	4909 kB
Total size of files sent by GPRS	5450 kB

It should be noted that the actual total amount of GPRS traffic needed for transferring files will actually be less than 5450kB for a month since the production leader only needs to send the hdp and pdf files when the machine team moves to a new forestry site.

In conclusion, it is obvious that the Mobeel solution can handle sending and receiving files from and to the forestry machines. The time to get acknowledgments differs from one minute to sometimes days, but the important fact is that all files are transferred and have been acknowledged.

8.4.4 Results and Evaluation of Total GPRS Traffic

According to the invoice and specifications from Telia concerning the GPRS traffic, see Appendix C. During the test period, a total of 93.6 MB of GPRS traffic was transferred. In Table 12, a summary of the total transferred GPRS traffic, according to invoice from Telia, is shown itemized by phone.

Table 12. Total used GPRS traffic by each phone according to Telia invoice

Phone	Received (kB)	Sent (kB)	Total traffic used (kB)
Forwarder	4906	10138	15044
Harvester	6170	18988	25158
Forest	12894	42764	55658
Sum of used GPRS (kB)	**23970**	**71889**	**95860**

According to Table 11 the total size of transferring files during the test period is 5450 kB, but the according to the invoice from Telia 93,6 MB (95860 kB) of GPRS traffic was sent, see Table 12.

To be able to estimate how much overhead (i.e., TCP- and IP headers) are generated for sending the actual files. We contacted Telia a numerous of times to learn the Maximum Transmission Unit (MTU) [91] of their GPRS network, but unfortunately they did not share this information. To determine this we could either do a MTU discovery, but unfortunately the Mobeel system was still in use in the forest or we could calculate the overhead for various MTU sizes (see Table 13). In these calculations, we have assumed the user sent data to be 5450 kB, TCP- and IP headers equal to 20 bytes, and the total generated GPRS traffic to be 95860 kB. We calculated the number of packets that 5450 kB would generate with the different packet sizes. The amount of transferred data that would constitute of headers, and the percentage of the transport information that would constitute the total GPRS traffic.

Table 13. MTU calculations

Packet size (MTU)	Number of packets	Total amount of headers (kB)	Headers / total GPRS traffic
100	93014	3633	3.79%
300	21465	838	0.87%
500	12133	474	0.49%
700	8456	330	0.34%
900	6490	254	0.26%
1100	5265	206	0.21%
1300	4430	173	0.18%
1500	3823	149	0.16%

From this table we can see that the best performance is achieved by a GPRS network when sending large packets. This means that the overhead of headers decreases when the packets are larger, which is obvious. The best performance with a GPRS network is reached when the MTU is set to 1500 [92], interesting to notice, though, is that the overhead is below one percent as long as the packet size is higher than 266 bytes, see Figure 34. We can relatively safely assume that the MTU is higher than 266 bytes, this would end up in the worst-case scenario, for sending the files, of a overhead approximately about 1%. This means that 1% of the generated traffic (sending files) constitutes of transport overhead (TCP- and IP headers) while the rest 93,3% (94,3%-1%) is used by the Mobeel application by continuously searching the application server via GPRS, see Figure 35.

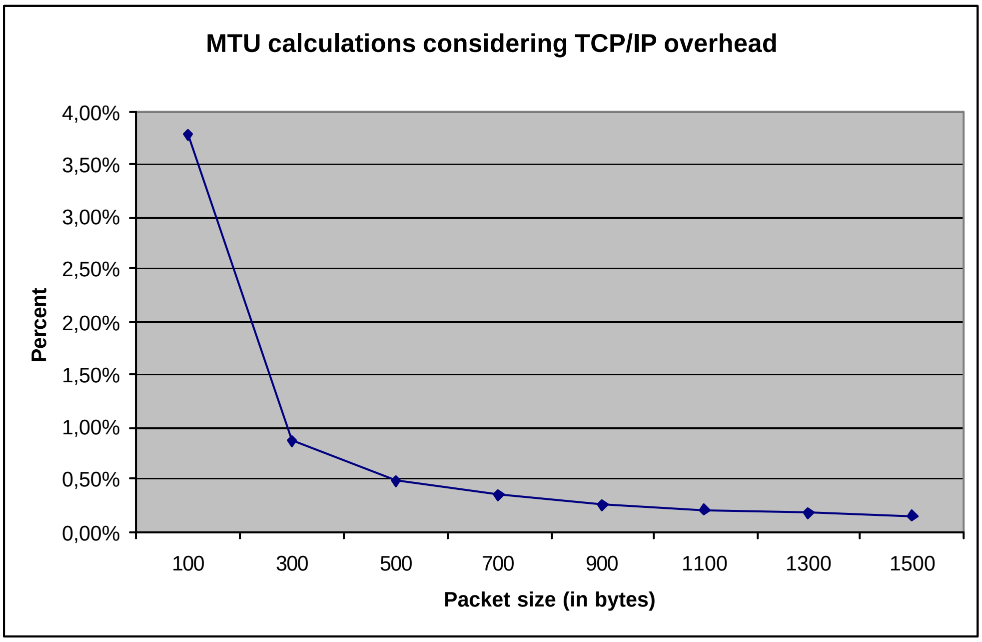

Figure 34 Percentage of generated GPRS traffic that consists of TCP / IP headers

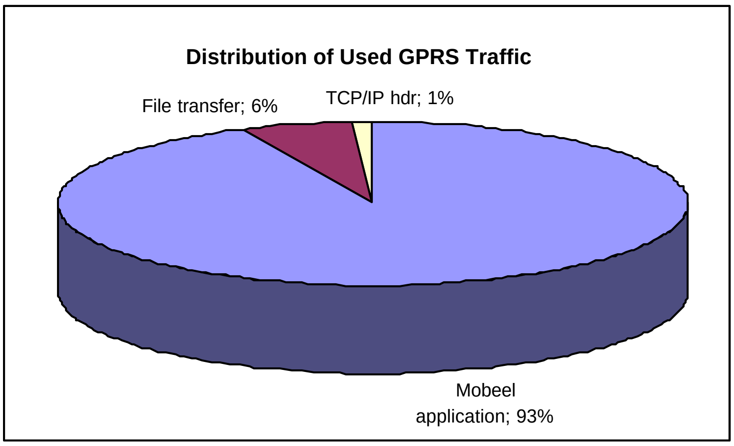

Figure 35. Distribution of GPRS traffic for Mobeel application, file transfer and TCP/IP headers

An interesting measure is to look at the effective payload of transferred files since it gives information about the real utilization of the GPRS traffic. The effective payload is described with Equation 1. This equation describes the percentage of the total generated GPRS traffic relative to the total size of the desired files sent.

$$Effective\_Payload = \frac{Total\_File\_Size}{Total\_Used\_GPRS\_Traffic}$$

Equation 1 describing the effective payload

The effective payload can be calculated for each phone and for the whole system. The effective payload for each phone is specified in Table 14. The effective payload per phone is under 10 %, which is a quite low utilization for the system. The systems total effective payload is approximately 5.7%, which is considered low. This means that more than 90% (approximately 93%) of the GPRS traffic is redundant traffic generated by the application.

Table 14. Effective payload per mobile phone

Phone	Forwarder	Harvester	Forest	System
Effective Payload (%)	9.52	2.14	7.50	5.7

What should be noticed in this discussion is that the effective payload is highly dependent on the number of mobile phones in the system and by the size of the transferred files. Also, note that more files were sent and received during the test period than would be transferred in a normal working period. Therefore, the real effective payload of this system would be even lower than that calculated in Table 14. Refer to section 8.7.4 for suggestions on how this can be improved.

8.4.5 Results and Evaluation of Planned Path

Sending the planned path is done by the production leader and includes the .hdp and .pdf files. The transfer of these files are specified in a detailed view in Appendix C. The summarized information about how the planned path files that have been acknowledged within a certain time interval can be found in Table 15. An interesting thing to notice is that 50 % of the files are received and acknowledged by the operator's phones within one hour. This indicates that the GSM-coverage in the site is sufficient for the Mobeel application to transfer the files nearly immediately.

In 18.75% of the transfers, the files have been received within 5 hours. The explanation for this could be that the operators have been in GSM coverage (home, on the way to work, or in a GSM covered forestry site). When they arrive at work or when the Possio PX30 is searching for files to send or receive the files are transferred to the machine computer and acknowledged. In 37.5% of the times the files were transferred in one minute. Thus, we assume that the operators have been in a GSM coverage area and have actually been sitting in the machines when receiving the files.

31.25 % of the times the transfer and acknowledgements have not been performed within 24 hours, which probably indicates the lack of GSM-coverage in the field.

Distribution of transfer times for the planned path is illustrated in Figure 36.

Table 15. Summary of acknowledged planned path files

Planned Path		
Time interval (h)	**Acknowledged files**	**Percentage (%)**
< 1	8	50.00
< 5	3	18.75
24	5	31.25

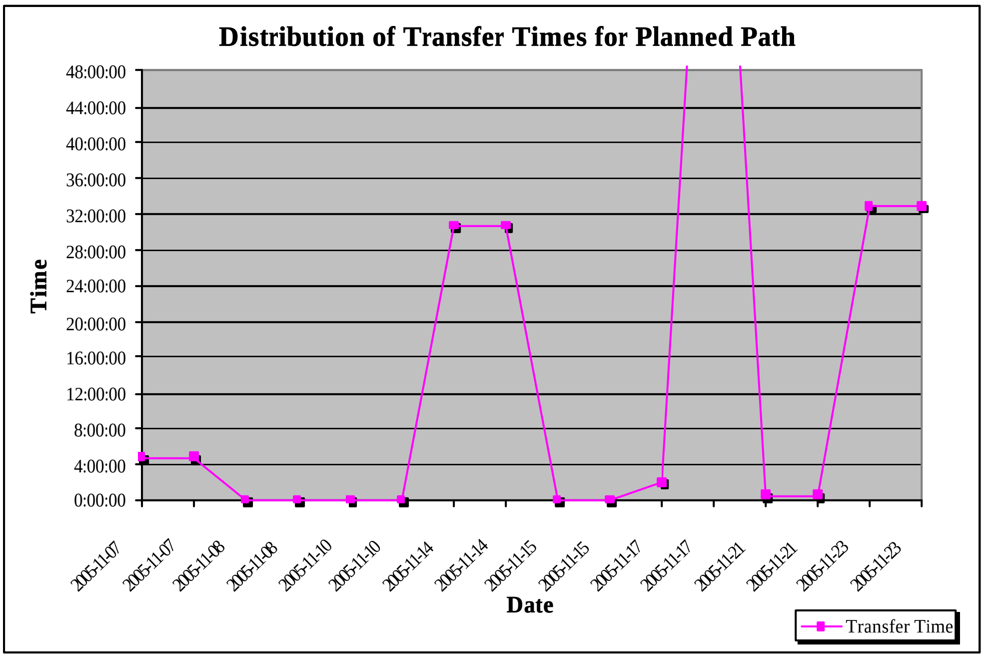

Figure 36. Distribution of transfer times for planned path files

8.4.6 Results and Evaluation of Production Files from Field

In this section, the result and evaluation of transferring the production files is presented. The production files are sent from the field to the production leader by the Mobeel application. For this test, the files were manually generated everyday by the operator of the harvester [Appendix A] and the result of the transfer is summarized in Figure 15. The summary covers the whole test period. A detailed view of the sent production files can be found in Appendix C.

It is interesting to note the time it takes the system to perform the sending, receiving, and acknowledgements: In 56% of the case, the time from the creation of a file until it is acknowledged varies from two to three hours, see Figure 15. In 91.3 % of the time, the files are received and acknowledged within 24 hours. This is a nice result and if it is analyzed we can conclude that the working routines of the operator matters. If the files were created just before the end of a shift, then the application might not be able to transfer the files before the machine is turned off. This implies that the file would be sent 8-12 hours later depending on the night rest of the operator. This is also shown in Figure 15 since almost 22% of the files are received eight to twelve hours later. The two files received within 12 to 24 hours can also be explained by a longer night rest. See Figure 37 for a visible view of the distribution of times for the different files.

There exists two files that are not received within the period of 24 hours, the first file was received after 15 days 22 hours and 22 minutes later, while the second was received 5 days 11 hours and 33 after it was sent. The explanation of this might be that the web server was down for a while, which we know is true for the second file.

Table 16. Summary of acknowledged of production files

Production Files		
Time interval (h)	**Acknowledged files**	**Percentage (%)**
0 – 4	14	60.87%
4 – 8	0	0.00%
8 – 12	5	21.74%
12 – 24	2	8.70%
> 24	2	8.70%

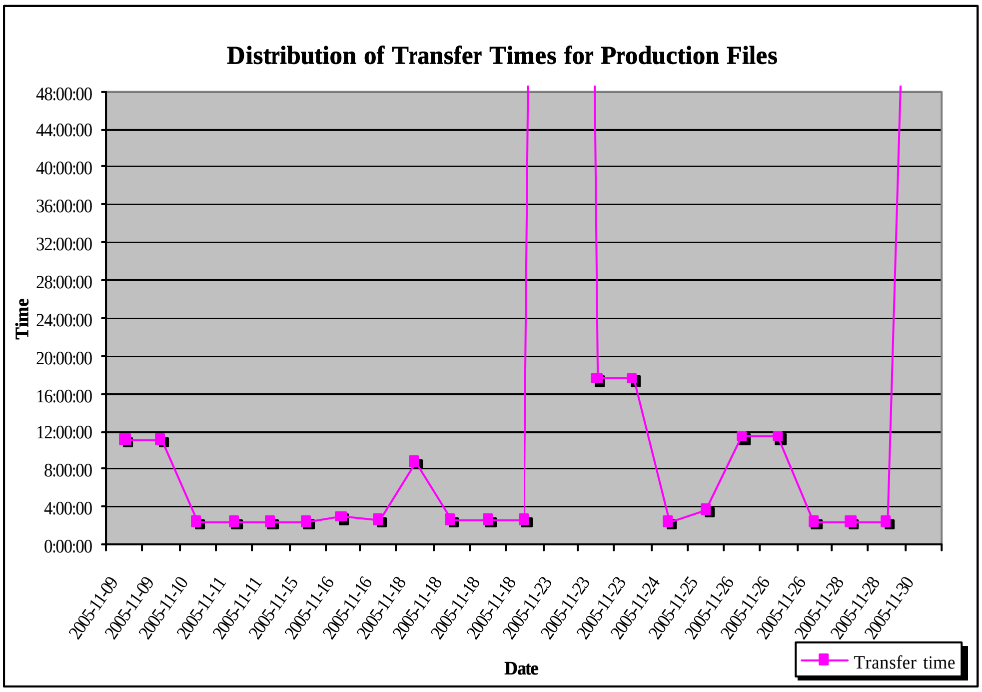

Figure 37. Distribution of transfer times for production files from the field

8.4.7 Results and Evaluation of Forward Report

The diffusion of time when sending the forward report is totally depending on the work routines of the operator of the forwarder. When files are sent from the machine depends on when the operator creates the file. The most convenient time of generating the forward report is at the end of the working shift since this is the time when the operator knows the quantity of the timber load.

The time that the file actually will be sent from the forwarder depends on if operator generates the forward report as the last thing he does before turning off the machine. This means that the delivery of the file from the Possio PX30 to the phone will not be executed until the following morning or early noon when the operator starts the machine again. Of course, there is always a small possibility that the Possio PX30 will perform the polling for new Bluetooth-units before the operator turns off the machine

The file information for the forward reports can be found in Appendix C. Table 17 contains a summary of the acknowledged forward reports and from this we can draw the conclusion that Mobeel is getting the job done. Files are being sent, and they will be received and acknowledged. Within a time span of 24 hours two thirds of the files are received. An explanation for the files that are not received within the 24-hour period could be that they are created late on Friday evening and has not been picked up by the phone before the operator has turned off the machine and left the forestry site. Therefore, the files has been sent on the following Monday, Tuesday or Wednesday depending on how the working schedule. The three files it concerns are acknowledged after the weekend.

Table 17. Summary of acknowledged of forward reports

Forward Report		
Time interval (h)	**Acknowledged files**	**Percentage (%)**
0 – 4	3	33.33%
4 – 8	0	0.00%
8 – 12	0	0.00%
12 – 24	3	33.33%
> 24	3	33.33%

Sending the forward directives was not performed during this test, since the Mobeel application cannot send XML files to the field.

8.5 Conclusions from Tests

Our conclusion based on the lab- and field tests were that the files are sent, received, and acknowledged roughly as expected. In the field tests almost 90% of files are sent and received in 24 hours therefore Mobeel may be a suitable solution, as it meets the performance needs articulated by Holmen Skog. The drawback is that the utilization of the whole system is very low. The system's total effective payload ended up in approximately 5.7% which can be considered very low. The utilization depends on various factors, the number of active phones, how often GSM coverage is available etcetera. From this test, we have observed more than 90% (approximately 93%) of the GPRS traffic is redundant traffic generated by checking for updates from the application server. As a result, for future implementation this has to be carefully considered as a critical problem for future development of the Mobeel software.

8.6 Evaluation of Costs of Mobeel

Our cost evaluation assesses how much the Mobeel solution will cost per month for a machine team including three machine operators. Three different cost studies performed:

- Initial investment costs for purchasing the hardware for the Mobeel system.
- Comparing the costs of different monthly subscriptions provided by Telia and suggest the best subscription for using Mobeel.
- Evaluating costs using the invoice Holmen Skog received from Telia for the test period.

For the cost calculation the Swedish value tax (called moms) will be included in all prices. If Holmen Skog is purchasing these items, they can exclude this 25%.

8.6.1 Initial Investment Costs

The initial investment cost includes purchasing the mobile phones, two Bluetooth equipped routers, two TP-cables, two Belkin USB 10/100 Ethernet Adapters, and two Sony Ericsson P910 chargers for the machine (12V or 24V). The investment costs are summarized in Table 18.

Figure 38. Belkin F8T030 Bluetooth Access Point

For the testing of Mobeel the Possio PX30 was used as the Bluetooth equipped router, but this is no longer available. Therefore, a substitute needs to be found if this system should be implemented. One alternative would be to choose the Belkin F8T030 Bluetooth Access Point Figure 38 router which is Bluetooth enabled and can cope with cold temperatures (-5°C - +50°C). [93] Another alternative would be to use the MIIPS II, Mobile Internet IP Server, [94] by Fält Communications AB which can be equipped with Bluetooth, is approved for being installed in machines and can handle -30°C - +70°C, see Figure 39. A calculation of initial investment costs for the Mobeel system can be found in Table 18.

Figure 39. MIIPS II - Mobile Internet IP Server

Table 18. Initial investments for the Mobeel system

Mobeel equipment	Quantity	Company	Cost (SEK)	Total Cost (SEK)
Sony Ericsson P910	3	Telia [95]	4295	12885
Belkin F8T030 Bluetooth Access Point	2	Mycom.se [93]	1474	2948
MIIPS II equipped with Bluetooth	2	Fält Communications AB [94]	6500	13000
TP-cables (CAT-5, UTP, cross-over, 3 meters)	2	Clas Ohlson [96]	59	118
Belkin USB 10/100 Ethernet Adapter	2	inWarehouse [97]	239	478
Sony Ericsson P910 Charger for machine (12V/24V)	2	Clas Ohlson [98]	79	158
Total initial investment cost (Belkin F8T030)			**16587 SEK**	
Total initial investment cost (MIIPS II)			**26639 SEK**	

The total initial investment cost for the Mobeel system will approximately be between 16587 – 26639 SEK depending on the choice of router.

8.6.2 Comparisons of Monthly Subscriptions

Telia provides numerous types of monthly subscriptions that can be bought by companies. For this comparison, we have focused on Telia Connect, Telia Jobbmobil, and Telia Online.

When using GPRS with Telia it is possible to add a GPRS subscription called Telia Online, see Table 19 for a payment plan, to an existing Telia subscription. Alternatively, it is possible to subscribe for Telia Connect if you *only* wish to send GPRS traffic with your phone.

Table 19. Telia Online payment plan

	Online 3	Online 10	Online 50	Online 150	Online 450
Prepaid amount (MB)	3	10	50	150	450
Cost per month (SEK)	24	60	240	480	720
Exceeding traffic SEK/MB	> 3MB 8 SEK	> 10MB 6 SEK	> 50MB 4.80 SEK	> 150 MB 3.20 SEK	> 450MB 1.60 SEK

The operators in the machine team that was involved with this test already had a private monthly subscription with Telia. The cheapest way for the entrepreneurs is then to add a Telia Online subscription for sending GPRS. Another reasonably priced option is to sign up for Telia Jobbmobil for making phone calls and Telia Online subscription for sending

GPRS data. The Telia Jobbmobil is considered a suitable subscription for Mobeel. The difference between Telia Jobbmobil and Telia Connect can be observed in Table 20.

Table 20. Summary of subscription: Telia Jobbmobil and Telia Connect

Subscription	Telia Jobbmobil	Telia Connect
Subscription cost to operator	99 SEK/month	40 SEK/month
Opening fee per phone call	0.49 SEK	0.30 SEK
Bluetooth cost	0 SEK	0 SEK
GPRS transfer cost (>50 MB)	4.80 SEK/MB	4.80 SEK/MB
Conversation fee (Telia)	0.69 SEK/min	10 SEK/min
Conversation fee (other)	1.29 SEK/min	10 SEK/min

8.6.3 *Evaluation of Costs*

When evaluating the costs we are assuming that all members of a machine team would have a monthly Telia Jobbmobil subscription extended with Telia Online as the GRPS subscription. Within the Telia Online subscription, a choice must be made based on how much data will be sent every month. This choice depends of course on how much GPRS data transfer will occur.

Here, we base our calculations on the fact of total transferred files within one month and the usage GPRS traffic using Mobeel. These calculations are estimations since the exact amount of data varies on a monthly basis. In Table 21 an approximation of the sent files each month are estimated. How many times a certain file are sent and the file sizes are approximated since it depends factors like, the forestry site the machines are working on and sizes of maps etc.

Table 21. Estimate of files to be sent each month

Files sent from	File name	Quantity	Frequency	Approx. Size (kB)	Total per month on average (kB)
Production leader to harvester	*.pdf	1	2 per month	400-600	1000
	*.hdp	1	2 per month	400	800
	*.apt	2	1 per month	10	40
Harvester to production leader	Korspar.shp	1	2 per month	80-90	170
	Korspar.shx	1	2 per month	100-120	220
	Korspar.dbf	1	2 per month	300	600
	*.prd	2	every day	20-30	1050
Production leader to forwarder	*.xml	1	2 per month	1	2
	*.pdf	1	2 per month	400-600	1000
	*.hdp	1	2 per month	400	800
Forwarder to production leader	*.xml	1	every day	1	21
Harvester to forwarder	Korspar.shp	1	2 per month	80-90	170
	Korspar.shx	1	2 per month	100-120	220
	Korspar.dbf	1	2 per month	300	600
Total size of sent files					**6693**

Based on this we can estimate the monthly cost of using Mobeel. This estimate includes using the subscriptions Telia Jobbmobil and Telia Online.

Table 22. Estimated monthly cost of using Mobeel

	Monthly cost (SEK/month)	Total (3 operators) (SEK/month)
Telia Jobbmobil	99	297
Telia Online 50 MB	240	720
Total cost	**1017 SEK**	

In this case Telia Online 50 is chosen, since it can send 50 MB of data per subscription. This gives a total of 150 MB/month for the machine team to send, exceeding the pot of

50 MB costs 4.80 SEK/MB for the user. Regardless of the number of bytes sent a cost of (99+240) 339 SEK per phone and month is used.

By considering the existing invoice that Holmen has received from Telia, we were able to estimate the approximated GPRS traffic generated by Mobeel including sending approximately 5 MB (5450 kB) of data. Therefore we estimate a rough monthly cost for using Mobeel to be around 1000 - 1200 SEK per month for the whole machine team with the assumption that no failure/retransmission of data transfers is needed.

8.7 Evaluation of Mobeel System

There exist different problems with the existing Mobeel system. In this section, a specification of the problems will be stated and a discussion of possible improvements will be considered to produce a stable and user-friendly system. This section is divided into subsections that focus on the Mob eel hardware and software.

8.7.1 Existing Problems with Mobeel Hardware

There exists problems with the Mobeel hardware, in this section we will discuss the Possio PX30 and the Sony Ericsson P910 phones.

8.7.1.1 Possio PX30 Router

During the test period, a few problems with the PX30 router were encountered. The router sometimes is unstable and occasionally even stops functioning. One reason might be the movement of the forestry machines affecting the hardware. To avoid this unstable behavior the remedy the test period was to restart the router once or twice during a day. The operator of the machines restarted the machine manually by removing the power cord and place it back again. Rebooting the Possio PX30 could also be done by turning off the power to the machines.

Moreover, the PX30 can only be used indoors since the operating temperature range is between +5°C to +40°C. Due to the cold winters in northern Sweden, the router must tolerate temperatures that is below zero degrees. The Possio PX30 is no longer being produced and as stated in section 8.6.1 two possible replacements have been found; Belkin F8T030 Bluetooth Access Point by Belkin and MIIPS II by Fält Communications AB. The advantage of the Belkin F8T030 is of course he price, but the MIIPS II is probably a better choice when it comes to temperatures and endurance in a forest environment.

8.7.1.2 Sony Ericsson P910

The Sony Ericsson P910 handsets consume a lot of battery when used by the Mobeel system. The reason for this is hat the Mobeel system requires that both Bluetooth and GPRS are activated at all times. This implies that the operators need to supervise that the phones are charged at all times. Additionally, the operator needs to take their phone to work each day. This implies that this system can be exposed to the human. For example, the phone(s) might be forgotten/left at home or be uncharged. Phones can also be lost or fail to operate.

From time to time, the software inside the mobile phones needs to be upgraded. To upgrade the software, the phones have to be sent to a mobile service centre. The updating process can take anywhere from one day up to one month. This implies that important information will not be sent during this period.

8.7.2 Suggested Improvements of Mobeel Hardware

The PX30 router is no longer available on the market, therefore the PX30 router needs to be replaced by a Bluetooth equipped wireless router that is more stable (both software and hardware-wise) and can tolerate temperatures below zero degrees and endure vibration. The Belkin F8T030 Bluetooth Access Point or the MIIPS II were suggested as possible replacements for the Possio PX30. (see section 8.6.1)]

The problem of broken phones implies that there must exist some kind of backup system. Human errors and the upgrading procedure can be solved by having a backup system in the form of extra phones with Mobeel installed. This might be an expensive solution for entrepreneurs to have extra phones that are rarely used. An additional complication is the problem of having subscriptions for these backup phones; thus there needs to be an account for each of these backup phones, prepared subscriptions for these phones, or some time of group account for multiple phones.

The battery problem can be solved by changing the Mobeel application to only activate the phone when it is about to send or receive files. This the operating time for a given battery charge will be extended and the GPRS traffic can also be reduced (by reducing the unnecessary traffic). The drawback is that the system will not always be able to receive files whenthe operator is within GSM coverage.

8.7.3 Existing Problems with Mobeel Software

The most critical problem lies with the Mobeel application itself. During the testing period, the Mobeel application terminated suddenly without any visible reason and the Symbian operating system returned the error message “User code 11” or “Orsakskod 11”. A possible explanation is operations in the Mobeel application might move or copy data to a 16-bit alternative descriptor that causes the length of that descriptor to exceed its maximum length. This can occur during any of the copying, appending, or formatting functions, specifically, by the Insert(), Replace(), Fill(), Fillz(), and ZeroTerminate() descriptor functions or the SetLength() function. [99] Since the Mobeel software of belongs to Mobilassistenten, we did not have the authority to change their code.

Another essential problem concerns sending files from the production leader. When a file is sent from the production leader all of the phones that are connected via GPRS can/will receive the files. At the moment no consideration is made concerning if the file is destined for the forwarder or harvester. This implies that a lot of unnecessary GPRS traffic is generated and unnecessary files are received in the in directory of the machines.

Furthermore, the Mobeel application can send any file (any format) from the machine to the production leader. But when it comes to sending files from the production leader to the machines, Mobeel can only handle production files (prd, hdp, and apt). What actually happens is that all the files are sent and acknowledged by the system, but files are other than these production files not readable when it arrives in the machine. This was tested by having the production leader sent forward directives (in xml format) to machines, unfortunately the XML application/operator was not able to read the contents of the file.

The maximum size of a file that can be sent by Mobeel is currently 500 kB. However, there are some files that exceed this maximum size, as these files contain quite large maps that needed to be sent to the machines.

Another limitation is that files that is supposed to be sent by Mobeel cannot contain the letters å, ä, and ö in the file name. If the file name contains any of these letters the files will not be sent and received correctly by the Mobeel system. Mobeel needs to support this since the production leader's application and the application in Timbermatic supports the usage of å, ä, and ö.

Moreover, it is important to consider that each phone sends the same received file even if the file has reached the server or the router earlier by one of these phones. Thus, if one phone receives some files and then before sending any files, it is taken home. Later (perhaps even a week later), when this phone comes to the GPRS coverage it sends all the files it has buffered that are not acknowledged. This will lead to the server receiving leading to an unnecessarily old files, which is unnecessary. Additionally, this will cause a lot of GPRS traffic leading to an unnecessarily higher expense.

One of the Holmen requirements, was to transfer data directly from harvester to forwarder and vice versa is not solved with the existing Mobeel solution.

Today, it is not possible to make an emergency call (112), when there is no GSM coverage.

In the existing version of Mobeel no security aspects has been considered besides the security implemented in the underlying link layers (such as Bluetooth's link layer encryption). Nor is there any integrity in the existing Mobeel solution (i.e., there is no check of any corruption or alteration of the files). The files, which belong to Holmen Skog, can be downloaded by anyone because Mobeel sends the file without any encryption. In addition, the web server is currently open to anyone to access at http://www.generix.nufort.net/~mobeel/.

The XML file generated from the Forward report application is at the moment not compatible with the XML structure required by the SDC and can therefore not be sent directly to this database.

8.7.4 Suggested Improvements to the Mobeel Software

To resolve the problems of "User code 11" or "Orsakskod 11" the problem needs to be identified within the Mobeel source code and changes needs to be made to resolve this problem. When changing in the source code the functionalities of sending files with different extensions, using the Swedish letters (å, ä, and ö), and sending files bigger than 500 kB should be considered. Mobeel should be able to send and receive any kind of file format, not only the prd and apt, but also XML files.

Some kind of selection needs to be implemented to discern what phone a file is destined for and what phone should receive the file when the file it is put on the web server? The web server needs to distinguish between phones belonging to the harvester and phones belonging to the forwarder. Therefore, the Mobeel solution needs to have only activate the phones that the files are actually destined for. This will reduce the amount of GPRS traffic and only the files relevant for each machine will be received at each machine.

Security should be considred, for example, some kind of encryption of the files and at least a password should be required before accessing the web server.

The generation of the XML file from the forward report application needs to compatible with SDC. Furthermore, transfering files directly from harvester to forwarder and vice versa needs to be implemented.

9 Future Alternatives

When considering alternatives to the Mobeel system we have previously discussed EDGE, Digital 450, and Low Earth Orbiting satellites. EDGE is currently being in deployed in Sweden. Digital 450 is in the start up phase and at the moment no one really knows when EDGE or Digital 450 will be available for service in the northern part of Sweden. Therefore, we consider LEO as an interesting alternative to the Mobeel system. In the following discussion, we will consider using low earth orbiting satellites to achieve the desired communication.

9.1 LEO

There are plenty of different systems to choose from when discussing LEO, we have considered using Globalstar, Iridium, and Teledesic [see section 4] since they provide the required services. Iridium seems to be the best alternative based on a thesis called *"Satellittelefoner - ett realistiskt framtidsalternativ för svenskt skogsbruk"* by Kristofer Fröjd and Mattias Ehnhage, Royal Institute of Technology, performed on the behalf of Skogforsk. [9] In their thesis, three different systems (Inmarsat, Globalstar, and Iridium) are tested, for voice traffic, in the forests of northern part of Sweden where there is dense woodland and difficult terrain. Inmarsat and Globalstar did not show adequate satellite coverage while Iridium had sufficient coverage. Iridium was able to deliver communication and data services to and from remote areas where no other form of communication was available. The voice- and data transmission tests were performed at a speed of 9.6 kbps.

Figure 43. Iridium coverage map, Yellow: Iridium world satellite coverage Orange: Iridium world roaming coverage Green: coverage not yet available, appears with permission of [108]

This satellite system would be able to provide all the services that Mobeel achieves, along with many features. The satellite system could be implemented using a satellite phone, see Appendix E. A satellite system, using a satellite phone, can provide delivery of files in real time and enable emergency calls (112). This system would also enable direct communication between the forestry machines even when they are separated geographically. The restriction of sending less than 500 kB with Mobeel is no longer an issue. The system requires minimal user interaction, it could be permanently mounted in each forestry machine, and might therefore be a more reliable system.

A drawback with satellite communication is the cost of voice calls that still is quite expensive compared to the GSM network. (For more details of costs see section 9.1.2) Thus, this system would primarily be used for sending data and in emergencies it could be used for voice traffic.

9.1.1 Iridium Data Services

To communicate using the Iridium system, the forestry machines needs to be equipped with an Iridium satellite phone. Following this the operators would be able to establish connections to the Internet or a corporate network from almost anywhere in the forest, and thereby it would allow them to transfer files. [100]

Iridium offers two types of services to transfer data: Dial-Up Data or Direct Internet Data.

The first alternative, Dial-Up Data Service provides dial-up connectivity through an Iridium phone to a computer, a company network/LAN, or an Internet Service Provider (ISP). This service offers a data rate of up to 2.4 kbps. The Dial-Up Data service works as a modem and connect the call through the public switched telephone network (PSTN). To use Dial-Up Data Service the forestry machine's PC would be connected to a data-capable Iridium phone [104]. The phone should have a Subscriber Identity Module (SIM) card that is intended for data. [101]

The second alternative is the Direct Internet Data Service and offers connectivity from a PC, through an Iridium phone equipped with a SIM card prepared for data transmission [102], directly to the Internet through dedicated servers at the Iridium gateway. This service utilizes compression that results in a typical data rate of 9.6 kbps, but the transfer rate depends on the content of the files; graphics and images might result in lower throughput. The Direct Internet Data Service is able to connect and disconnect the Iridium phone when no data is being transferred. This feature is called spoofing, which reduces airtime charges and improves the phone's battery life. Additionally because the phone could be permanently mounted in the forestry machine – it would be able to automatically charge its battery from the vehicles power system.

If the Iridium system would be implemented in the forestry machines, the Direct Internet Data service is a suitable choice since the data rate of 9.6 kbps corresponds to the same transmission rate as often occurred when using GPRS. The only disadvantage is that communication software needs to be installed on the computers of the forestry machines. We cannot see that installing such applications would disturb the daily work of the Timbermatic computer. Worth mentioning is that a California company already has implemented this software for the Timbermatic and by default Timbermatic are providing Inmarsat as the satellite provider. [6]

9.1.2 Iridium Investment Costs

In this section, costs associated with an implementation of an Iridium satellite system are considered. To implement the necessary communication system two portable satellite phones and two Iridium Data Kits are needed. See Appendix E for details of the suggested 9505A Portable Satellite Phone and the Iridium Data Kit.

In the following discussion the costs are presented in US dollars, which have been converted into Swedish Kronor (SEK) with the estimation that 1 US dollar corresponds to approximately 8 SEK. As of the January 19, 2006, 1 US dollar is equal 7.68 SEK. [103]

The satellite phones can be obtained new, pre-owned, or by renting them.

The first option is to buy a new satellite phone, data kit, and SIM card activation – this would cost 25624 SEK [104] [105]. Another alternative is to buy a pre-owned satellite phone along with a new data kit – together with an activation fee this would cost approximately 9824 SEK for each set. [105] [106] The third possibility is to rent a satellite phone, which would cost around 1520 SEK per month [107] for more details see Figure 21. However, renting a phone would not be a suitable strategy if the phones are to be used for a long period of time.

What should be noted is that three mobile phones are required for the Mobeel system, while only two phones are necessary when implementing a satellite system. This is explained by the possibility that the satellite phones would be stationary in the machines.

Table 23. Possible solutions for buying new, pre-owned, or rental equipment for the Iridium system

9505A Portable Satellite Phone	Cost ($)	Cost (SEK)	Total cost
Iridium phone [104]	$1,395.00	11160	**25624 SEK**
SIM card activation fee [105]	$53	424	
Data Kit [105]	$180	1440	
Iridium phone (pre owned) [106]	$995.00	7960	**9824 SEK**
SIM card activation fee [105]	$53	424	
Data Kit [105]	$180	1440	
Iridium phone (renting/monthly) [107]	$189.99	1520	**1520 SEK/month + 1864 SEK**
SIM card activation fee [105]	$53	424	
Data Kit [105]	$180	1440	

9.1.3 Comparison of Costs for Mobeel and Iridium

In the Mobeel system, the initial investment costs would approximately be 25624 SEK, and would include three mobile phones, wireless Bluetooth routers, twisted pair cables, etc. The total cost of the Mobeel solution is 16587 to 26639 SEK, see section 8.6.1 for details about the initial investment cost of Mobeel.

Table 24. Initial investment cost for Iridium and Mobeel

Solution	Total cost
Iridium (9505A Portable Satellite Phone)	25624 SEK
Iridium (pre owned)	9824 SEK
Mobeel	16587 or 26639 SEK

As shown in Table 24, the initial investment cost for pre-owned Mobeel is lower than buying Mobeel package.

To be able to transfer data and voice traffic, a monthly subscription or prepaid plan is needed. There are lots of different monthly subscriptions and pre-paid plans. An example of a basic plan involves a monthly subscription fee, and a cost for transferring data and voice traffic see Table 25. In this basic plan, a cost of approximately 240 SEK/month is applied along with 9.6 SEK/min for voice- and data services. [105] This could be compared to the subscription fee of Mobeel that is 99 SEK/month and the GPRS transfer cost is, at the moment, 6 SEK/MB, see Table 26. In the case of Iridium the alternative of choosing pre paid minutes could be used, then there is no monthly subscription fee and the per minute rate for data- and voice services will be a little cheaper. For more information about this pre-paid alternative, refer to Appendix E

Table 25. Subscription costs of Iridium, example of a basic plan [105]

Iridium Subscription		
Subscription cost to operator	$30.00	240 SEK/month
Opening fee	0	0 SEK
Data transfer cost	$1.20	9.6 SEK/min
Conversation fee (PSTN)	$1.20	9.6 SEK/min

Table 26. Subscription costs of Mobeel

Telia Subscription	
Subscription cost to operator	99 SEK/month
Opening fee	0.49 SEK
GPRS transfer cost (>10 MB)	6 SEK/MB
Conversation fee (Telia)	0.69 SEK/min
Conversation fee (other)	1.29 SEK/min

A great advantage by using Iridium is that only the amount of data transferred will be charged for. Compare this to the Mobeel solution where money is spent for sending files and the GPRS traffic generated for the Mobeel application to poll the web server. (See section 8.4.4 for the evaluation of GPRS traffic)

In the field tests the amount of capacity actually used for sending files was approximately 5450 kB for three weeks, see Table 11. For one month, assuming the same load of traffic going back and forth to the forest, would result in roughly 7 MB of data each month, including transport information like TCP/IP headers, etc.

To transfer 7 MB the with Direct Internet Data service of data rate of 9.6 kbps takes approximately 12.5 minutes. The cost per minute using Iridium is approximately 9.6 SEK/minute and the result would be a cost of 122 SEK/month. The total cost for both machines with a monthly subscription will be approximately 600 SEK for sending the required files. However, by using the pre-paid minutes, there is no need for paying a subscription fee and the cost per minute would be cheaper than 9.6 SEK/minute. By choosing the Iridium solution and providing pre-paid minutes, it is possible to save around a lot of money each month. If the satellite system were used with pre-paid minutes then an evaluation of the exact pattern of the data transfers should be considered in detail; as the time required to send data is dependent on setting up and tear down calls.

10 Future Work

First, a decision, based on the work of this thesis, needs to be made by Holmen Skog. If they choose to go with the Mobeel system some new hardware and software development needs to be considered. As mentioned in section 3.3.2 and 8.6.1 a new wireless Bluetooth equipped router that can tolerate temperatures below zero degrees and endure vibration needs to be found. When it comes to the development of the software, issues like sending different file types, reducing the GPRS costs, making the forward report application XML file compatible with the SDC database, and making a distinction for different phones when it comes to the web server are issues that all need to be addressed. In addition, a careful consideration of end-to-end security and integrity needs to occur.

A possible solution to reduce the investment cost of Mobeel would be to implement this system without the Bluetooth equipped router. This would be solved by equipping the Timbermatic computer with a USB Bluetooth dongle and an application that would move the files from the Windows PC to the cellular phone using Bluetooth. This would be possible by installing drivers of the dongle and software that moves the files to the mobile phones. This would be far less expensive than having to use the existing router, but then the restrictions of not installing applications in the Timbermatic needs to be revised. Although if the restriction of installing software in the machine computer is persistent then it would be interesting to see if the router could be exchanged to use a low power Mini-ITX (and soon a nano-ITX) which is a single board computer systems.

Furthermore, we would recommend evaluating the possibility of using the existing satellite system inside the Timbermatic for sending files. If this is working properly, it might be interesting, when purchasing new forestry machines, to have the correct hardware implemented depending on what satellite system is going to be used.

11 Conclusion

There exists a lot of critical problems in the present Mobeel solution that should be fixed before any future implementation of this system in practice. The present Mobeel solution is not ready to be used at the moment; therefore we cannot recommend its use. Rather one of the alternative solutions is recommended. Currently EDGE and Digital 450 are not available yet in Holmen Skog's area, in northern of Sweden. When these alternative solutions will be available is not known.

The final suggested solution is Iridium satellite. The initial investments needed the Iridium solutions (pre-owned and prepaid air time) are roughly the same as the Mobeel solution. By choosing Iridium's direct internet data service, the monthly cost of the satellite solution will be much lower than Mobeel. Furthermore, by buying prepaid minutes the monthly cost could be reduced even further.

With Iridium data could be transferred at any time – so that the production leader and even SDC could always have up to date information while GSM-coverage is not needed. Using the Iridium system also avoids problems of phones, user interaction, and overcomes the problem with communications between machines. Finally, the safety advantage of emergency calls would be available where the GSM coverage is not satisfying.

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13 Appendices

13.1 Appendix A

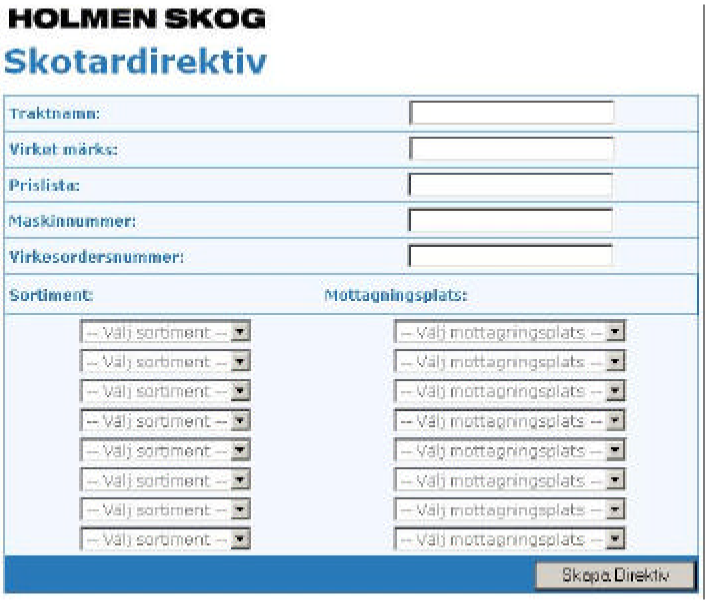


Figure 44 The Forward Directive Form

Figure 45 The Forward Report Form

A1 Forward Directive

Skotardirektiv_2005-11-8.xml


```
<?xml version="1.0" encoding="ISO-8859-1"?>
<skog>
<title></title>
<traktnamn>Ingvar Westergren</traktnamn>
<virketmarks>875</virketmarks>
<prislista>hso0408</prislista>
<maskinnummer>3129</maskinnummer>
<VONUM>78965438</VONUM>
<ISSTE>011 Sågt tall</ISSTE>
<mottagningsplats>Holmsunds såg</mottagningsplats>
<ISSTE2>012 Sågt gran</ISSTE2>
<mottagningsplats2>Vilh. såg</mottagningsplats2>
<ISSTE3>100 Mav barr</ISSTE3>
<mottagningsplats3>Husum</mottagningsplats3>
<ISSTE4>103 Mav löv</ISSTE4>
<mottagningsplats4>Husum</mottagningsplats4>
<ISSTE5></ISSTE5>
<mottagningsplats5></mottagningsplats5>
<ISSTE6></ISSTE6>
<mottagningsplats6></mottagningsplats6>
<ISSTE7></ISSTE7>
<mottagningsplats7></mottagningsplats7>
<ISSTE8></ISSTE8>
<mottagningsplats8></mottagningsplats8>
<M3TVOLT>||textfield4.8||</M3TVOLT>
</skog>
```

A2 Forward Report

Skotarrapport_2005-11-8.xml

<?xml version="1.0" encoding="ISO-8859-1" ?>
<skog>
<title />
<traktnamn>**Ingvar Westergren**</traktnamn>
<virketmarks>**875**</virketmarks>
<prislista>**hso0408**</prislista>
<maskinnummer>**3129**</maskinnummer>
<VONUM>**78965438**</VONUM>
<sortiment1>**011 Sågt tall**</sortiment1>
<mottagningsplats1>**Holmsunds såg**</mottagningsplats1>
<M3TVOLT1 />
<sortiment2>**011 Sågt tall**</sortiment2>
<mottagningsplats2>**Vilh. såg**</mottagningsplats2>
<M3TVOLT2>**12**</M3TVOLT2>
<sortiment3>**100 Mav barr**</sortiment3>
<mottagningsplats3>**Husum**</mottagningsplats3>
<M3TVOLT3>**156**</M3TVOLT3>
<sortiment4>**103 Mav löv**</sortiment4>
<mottagningsplats4>**Husum**</mottagningsplats4>
<M3TVOLT4>**36**</M3TVOLT4>
<sortiment5 />
<mottagningsplats5 />
<M3TVOLT5 />
<sortiment6 />
<mottagningsplats6 />
<M3TVOLT6 />
<sortiment7 />
<mottagningsplats7 />
<M3TVOLT7 />
<sortiment8 />
<mottagningsplats8 />
<M3TVOLT8 />
</skog>

13.2 Appendix B

Appendix B contains results of lab test; Test 1a, Test 1b, Test 1c, Test 2a, Test 2b, Test 2c, Test 3a, Test 3b, and Test 3c.

B1 Test 1a

Test 1a used one telephone *at the time* sending files File1, File2, and File3. Test 1a included all the phones (Forest, Forwarder, and Harvester).

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File1	19968	2005-10-21 11:37	2005-10-21 11:43 **2005-10-21 12:32**	5 min	11 min
File2	200789	2005-10-21 12:40	2005-10-21 12:40 **2005-10-21 12:41**	0 min	1 min
File3	421717	2005-10-21 12:43	2005-10-21 12:44 **2005-10-21 12:53**	1 min	9 min

Table Result of Test 1a using phone Forest

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File1	19968	2005-10-21 14:02	2005-10-21 14:02 **2005-10-21 14:04**	0 min	2 min
File2	200789	2005-10-21 14:06	2005-10-21 14:06 **2005-10-21 14:08**	0 min	2 min
File3	421717	2005-10-21 14:08	2005-10-21 14:09 **2005-10-21 14:10**	1 min	1 min

Table 27 Result of Test 1a using phone Forwarder

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File1	19968	2005-10-21 14:23	2005-10-21 14:24 **2005-10-21 14:31**	1 min	8 min
File2	200789	2005-10-21 14:35	2005-10-21 14:35 **2005-10-21 14:37**	0 min	2 min
File3	421717	2005-10-21 14:39	2005-10-21 14:40 **2005-10-21 14:41**	1 min	2 min

Table 28 Result of Test 1a using phone Harvester

B2 Test 1b

Test 1b used two telephones (Forest and Harvester) *at the same time* sending File1, File2, and File3.

File Name	Size (bytes)	Sent	Phone (IMEI) Delivered ACKED	Transfer to phone	Time to ACKED
File1	19968	2005-10-21 14:54	35582600-075610-5 **2005-10-21 14:55** **2005-10-21 14:57**	1 min	3 min
			35582600-071845-1 **2005-10-21 14:56** **2005-10-21 14:58**	2 min	4 min
File2	200789	2005-10-21 14:58	35582600-071845-1 **2005-10-21 14:58** **2005-10-21 14:59**	0 min	1 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:00**	0 min	2 min
File3	421717	2005-10-21 15:00	35582600-075610-5 **2005-10-21 15:00** **2005-10-21 15:01**	0 min	1 min
			35582600-071845-1 **1970-01-01 01:00** **2005-10-21 15:02**	0 min	2 min

Table 29 Result of Test 1b using phone Forest and Harvester

B3 Test 1c

Test 1c used all phones (Forest, Harvester, and Forwarder) sending File1, File2, and File3.

File Name	Size (bytes)	Sent	Phone (IMEI) Delivered ACKED	Transfer to phone	Time to ACKED
File1	19968	2005-10-21 13:02	35582600-075610-5 **2005-10-21 13:03**	1 min	0 min
			35582600-071845-1 **2005-10-21 13:51**	49 min	0 min
			35582600-073798-0 **2005-10-21 13:58** **2005-10-21 13:59**	56 min	57 min
File2	200789	2005-10-21 13:02	35582600-075610-5 **2005-10-21 13:03**	1 min	0 min
			35582600-071845-1 **2005-10-21 13:51**	49 min	0 min
			35582600-073798-0 **2005-10-21 13:58** **2005-10-21 13:59**	56 min	57 min

File3	421717	2005-10-21 13:02	35582600-075610-5 **2005-10-21 13:03**	1 min	0 min
			35582600-071845-1 **2005-10-21 13:51**	49 min	0 min
			35582600-073798-0 **2005-10-21 13:58** **2005-10-21 13:59**	56 min	57 min

Table 30 Result of Test 1c using phones Forest, Harvester, and Forwarder

B4 Description of Test 2a

Test 2a used one telephone *at the time*, sending files File4 and File5. Test 2a includes all the phones (Forest, Forwarder, and Harvester).

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File4	399200	2005-10-21 13:00	2005-10-21 13:00 **2005-10-21 13:02**	0 min	2 min
File5	391666	2005-10-21 13:00	2005-10-21 13:00 **2005-10-21 13:02**	0 min	2 min

Table 31 Result of Test 2a using phone Forest

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File4	399200	2005-10-21 14:11	2005-10-21 14:12 **2005-10-21 14:13**	1 min	2 min
File5	391666	2005-10-21 14:12	2005-10-21 14:12 **2005-10-21 14:13**	0 min	1 min

Table 32 Result of Test 2a using phone Forwarder

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File4	399200	2005-10-21 14:42	2005-10-21 14:42 **2005-10-21 14:44**	0 min	2 min
File5	391666	2005-10-21 14:42	2005-10-21 14:42 **2005-10-21 14:44**	0 min	2 min

Table 33 Result of Test 2a using phone Harvester

B5 Description of Test 2b

Test 2b used two telephones (Forest and Harvester) sending File4 and File5.

File Name	Size (bytes)	Sent	Phone (IMEI) Delivered ACKED	Transfer to phone	Time to ACKED
File4	399200	2005-10-21 15:04	35582600-071845-1 **2005-10-21 15:05** **2005-10-21 15:06**	1 min	2 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:07**	0 min	3 min
File5	391666	2005-10-21 15:04	35582600-075610-5 **2005-10-21 15:04** **2005-10-21 15:05**	0 min	1 min
			35582600-071845-1 **1970-01-01 01:00** **2005-10-21 15:06**	0 min	2 min

Table 34 Result of Test 2b using phones Forest and Harvester

B6 Description of Test 2c

Test 2c used all phones (Forest, Harvester, and Forwarder) sending File4 and File5.

File Name	Size (bytes)	Sent	Phone (IMEI) Delivered ACKED	Transfer to phone	Time to ACKED
File4	399200	2005-10-21 15:20	35582600-071845-1 **2005-10-21 15:20** 2005-10-21 15:22	0 min	2 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:23**	0 min	3 min
			35582600-073798-0 **1970-01-01 01:00** **2005-10-21 15:23**	0 min	3 min
File5	391666	2005-10-21 15:20	35582600-071845-1 **2005-10-21 15:20** **2005-10-21 15:22**	0 min	2 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:23**	0 min	3 min
			35582600-073798-0 **1970-01-01 01:00** **2005-10-21 15:23**	0 min	3 min

Table 35 Result of Test 2c using phones Forwarder, Harvester, and Forest

B7 Description of Test 3a

Test 3a used one telephone at the time, sending files File3, File4, and File5. Test 3a included all the phones (Forest, Forwarder, and Harvester).

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File3	421717	2005-10-21 13:40	2005-10-21 12:44 **2005-10-21 12:48**	4 min	8 min
File4	399200	2005-10-21 13:40	2005-10-21 13:43 **2005-10-21 12:46**	3 min	6 min
File5	391666	2005-10-21 13:40	2005-10-21 12:43 **2005-10-21 12:46**	3 min	6 min

Table 36 Result of Test 3a using phone Forest

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File3	421717	2005-10-21 14:14	2005-10-21 14:16 **2005-10-21 14:18**	2 min	4 min
File4	399200	2005-10-21 14:14	2005-10-21 14:16 **2005-10-21 14:18**	2 min	4 min
File5	391666	2005-10-21 14:14	2005-10-21 14:16 **2005-10-21 14:18**	2 min	4 min

Table 37 Result of Test 3a using Forwarder

File Name	Size (bytes)	Sent	Delivered ACKED	Transfer to phone	Time to ACKED
File3	421717	2005-10-21 14:45	2005-10-21 14:47 **2005-10-21 14:48**	2 min	3 min
File4	399200	2005-10-21 14:45	2005-10-21 14:45 **2005-10-21 14:48**	0 min	3 min
File5	391666	2005-10-21 14:45	2005-10-21 14:45 **2005-10-21 14:48**	0 min	3 min

Table 38 Result of Test 3a using phone Harvester

B8 Description of Test 3b

Test 3b used two telephones (Forest and Harvester) sending File3, File4, and File5.

File Name	Size (bytes)	Sent	Phone (IMEI) Delivered ACKED	Transfer to phone	Time to ACKED
File3	421717	2005-10-21 15:07	35582600-071845-1 **2005-10-21 15:08** **2005-10-21 15:09**	1 min	2 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:10**	0 min	3 min
File4	399200	2005-10-21 15:07	35582600-071845-1 **2005-10-21 15:08** **2005-10-21 15:09**	1 min	2 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:10**	0 min	3 min
File5	391666	2005-10-21 15:07	35582600-071845-1 **2005-10-21 15:08** **2005-10-21 15:09**	1 min	2 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:10**	0 min	3 min

Table 39 Result of Test 3b using phones Forest and Harvester

B9 Description of Test 3c

Test 3c is using all phones (Forest, Harvester, and Forwarder) sending File3, File4, and File5.

File Name	Size (bytes)	Sent	Phone (IMEI) Delivered ACKED	Transfer to phone	Time to ACKED
File3	421717	2005-10-21 15:33	35582600-073798-0 **2005-10-21 15:37** **2005-10-21 15:39**	4 min	6 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:39**	0 min	6 min
			35582600-071845-1 **1970-01-01 01:00** **2005-10-21 15:39**	0 min	6 min
File4	399200	2005-10-21 15:33	35582600-073798-0 **2005-10-21 15:37** **2005-10-21 15:39**	4 min	6 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:39**	0 min	6 min

			35582600-071845-1 **1970-01-01 01:00** **2005-10-21 15:39**	0 min	6 min
File5	391666	2005-10-21 15:33	35582600-073798-0 **2005-10-21 15:37** **2005-10-21 15:39**	4 min	6 min
			35582600-075610-5 **1970-01-01 01:00** **2005-10-21 15:39**	0 min	6 min
			35582600-071845-1 **1970-01-01 01:00** **2005-10-21 15:39**	0 min	6 min

Table 40 Result of Test 3c using phones Forest, Harvester, and Forest

13.3 Appendix C

C1 Files Received to IN Directory on the Web Server

Date	File name	Size (bytes)	Created	Phone (IMEI) ACKED	Elapsed time
2005-11-08	Skotarrapport_2005-11-7_1.xml	1063	2005-11-07 21:02	35582600-073798-0 **2005-11-08 12:18**	15:16:00
	Skotarrapport_2005-11-8_1.xml	1061	2005-11-08 21:14	35582600-073798-0 **2005-11-08 23:33**	2:19:00
2005-11-09	Ingvar Westergren051108_2.prd	25348	2005-11-08 23:00	35582600-071845-1 **2005-11-09 10:04**	11:04:00
	Ingvar Westergren051108_1.prd	0	2005-11-08 23:06	35582600-071845-1 **2005-11-09 10:04**	10:58:00
2005-11-10	Skotarrapport_2005-11-9_1.xml	1060	2005-11-09 19:14	35582600-073798-0 **2005-11-10 07:32**	12:18:00
	Ingvar Westergren051109_1.prd	25497	2005-11-09 22:00	35582600-075610-5 **2005-11-10 00:19**	2:19:00
2005-11-11	Ingvar Westergren051110_1.prd	25563	2005-11-10 22:28	35582600-071845-1 **2005-11-11 00:48**	2:20:00
	Ingvar Westergren051111_1.prd	25616	2005-11-11 13:29	35582600-071845-1 **2005-11-11 15:51**	2:32:00
2005-11-14	Bj?rnstockmyran_X7043236_Y1591493export_1.hdp	5024	2005-09-23 10:33	35582600-075610-5 **2005-11-14 21:03**	1258:30:00
	test4_1.hdp	0	2005-06-02 13:24	35582600-075610-5 **2005-11-14 21:14**	3991:50:00
	lill rocksjon_1.prd	28689	2005-07-07 11:03	35582600-075610-5 **2005-11-14 21:13**	3154:10:00
	byvattnet_1.prd	27098	2005-07-21 12:18	35582600-075610-5 **2005-11-14 21:16**	2816:58:00
2005-11-15	Skotarrapport_2005-11-10_1.xml	1060	2005-11-10 19:22	35582600-073798-0 **2005-11-15 17:07**	117:45:00
	C Nordlund mfl 051114_1.prd	23314	2005-11-14 22:21	35582600-075610-5 **2005-11-15 00:39**	3:17:00
2005-11-16	Skotarrapport_2005-11-15_1.xml	1060	2005-11-15 21:56	35582600-073798-0 **2005-11-16 00:14**	2:18:00
	Ingvar Westergren051115_1.prd	25765	2005-11-15 22:02	35582600-071845-1 **2005-11-16 00:52**	2:50:00
	C Nordlund mfl051115_1.prd	23969	2005-11-15 22:21	35582600-071845-1 **2005-11-16 00:51**	2:30:00
2005-11-17	Skotarrapport_2005-11-16_1.xml	1060	2005-11-16 19:26	35582600-073798-0 **2005-11-17 12:09**	16:43:00
2005-11-18	Ingvar Westergren051117_1.prd	25956	2005-11-17 16:46	35582600-071845-1 **2005-11-18 01:24**	8:38:00
	Helen Almroth_gallring051117_2.prd	23792	2005-11-17 22:48	35582600-071845-1 **2005-11-18 01:24**	2:36:00
	Helen Almroth_gallring051117_1.prd	0	2005-11-17 22:53	35582600-071845-1 **2005-11-18 01:24**	2:31:00
	Helen Almroth051118_1.prd	26231	2005-11-18	35582600-071845-1	2:36:00

			14:00	**2005-11-18 16:36**	
2005-11-21	Skotarrapport_2005-11-17_1.xml	1060	2005-11-17 16:15	35582600-073798-0 **2005-11-21 20:54**	100:39:00
	Skotarrapport_2005-11-18_1.xml	1060	2005-11-18 14:11	35582600-073798-0 **2005-11-21 20:54**	102:43:00
	Skotarrapport_2005-11-21_1.xml	1056	2005-11-21 18:43	35582600-073798-0 **2005-11-21 21:01**	2:18:00
2005-11-23	test12_1.hdp	4172	2005-08-18 18:27	35582600-075610-5 **2005-11-23 20:13**	2305:46:00
	testing1_1.hdp	3010	2005-09-20 14:13	35582600-075610-5 **2005-11-23 20:24**	1542:11:00
	Bodberget_X7048817_Y1587737export_1.hdp	0	2005-09-20 14:55	35582600-075610-5 **2005-11-23 20:19**	1541:24:00
	Ingvar Westergren_1.prd	25228	2005-11-07 21:51	35582600-075610-5 **2005-11-23 20:13**	382:22:00
	Helen Almroth_gallring051122_2.prd	24730	2005-11-22 23:07	35582600-075610-5 **2005-11-23 16:40**	17:33:00
	Helen Almroth_gallring051122_1.prd	0	2005-11-22 23:11	35582600-075610-5 **2005-11-23 16:39**	17:28:00
2005-11-24	Helen Almroth051123_1.prd	26598	2005-11-23 22:39	35582600-075610-5 **2005-11-24 00:57**	2:18:00
2005-11-25	Helen Almroth_gallring051124_1.prd	25234	2005-11-24 22:45	35582600-071845-1 **2005-11-25 01:22**	2:37:00
2005-11-26	C Nordlund mfl_gallring051125_1.prd	24220	2005-11-25 22:02	35582600-075610-5 **2005-11-26 10:28**	12:26:00
	C Nordlund mfl051125_1.prd	24505	2005-11-25 22:06	35582600-075610-5 **2005-11-26 10:28**	12:22:00
	C Nordlund mfl051126_1.prd	24529	2005-11-26 11:35	35582600-075610-5 **2005-11-26 13:54**	2:19:00
2005-11-28	C Nordlund mfl051128_1.prd	0	2005-11-28 21:37	35582600-075610-5 **2005-11-28 23:57**	2:17:00
	C Nordlund mfl051128_2.prd	24707	2005-11-28 21:39	35582600-075610-5 **2005-11-28 23:57**	2:18:00
2005-11-30	Helen Almroth_gallring051125_1.prd	25252	2005-11-25 09:29	35582600-071845-1 **2005-11-30 21:02**	131:33:00

C2 Files Sent From OUT directory of the web server

Date	File name	Size (bytes)	Created	Phone (IMEI) Delivered ACKED	Elapsed time
2005-11-07	Trakt_051107_X7043890_Y1580647.hdp	339480	2005-11-07 10:51	35582600-075610-5 **2005-11-07 10:52** **2005-11-07 15:34**	4:42:00
	Trakt_051107_X7043890_Y1580647_SAvv.pdf	401448	2005-11-07 10:53	35582600-075610-5 **2005-11-07 10:53** **2005-11-07 15:34**	4:41:00
	Skotardirektiv_2005-11-7.xml	839	2005-11-07 13:27	35582600-075610-5 **2005-11-07 13:27** **2005-11-07 15:34**	2:07:00
2005-11-08	Trakt_11.08_X7043915_Y1580806_SAvv.pdf	400852	2005-11-08 10:42	35582600-075610-5 **2005-11-08 10:43** **2005-11-08 10:44**	0:01:00
	Trakt_11.08_X7043915_Y1580806.hdp	357257	2005-11-08 10:43	35582600-075610-5 **2005-11-08 10:45** **2005-11-08 10:46**	0:01:00
	Skotardirektiv_2005-11-8.xml	839	2005-11-08 12:03	35582600-073798-0 **2005-11-08 12:03** **2005-11-08 12:17**	0:14:00
	Skotardirektiv_2005-11-9.xml	823	2005-11-08 23:04	35582600-075610-5 **2005-11-08 23:04** **2005-11-10 00:17**	25:13:00
	Skotardirektiv_2005-11-88.xml	839	2005-11-08 23:28	35582600-075610-5 **2005-11-08 23:29** **2005-11-10 00:17**	24:48:00
	Skotardirektiv_2005-11-888.xml	839	2005-11-08 23:36	35582600-073798-0 **2005-11-08 23:36** **2005-11-08 23:37**	0:01:00
				35582600-075610-5 **1970-01-01 01:00** **2005-11-10 00:17**	0:41:00
2005-11-10	Trakt_11.10_X7044331_Y1580668_SAvv.pdf	400129	2005-11-10 10:07	35582600-075610-5 **2005-11-10 10:08** **2005-11-10 10:09**	0:01:00
	Trakt_11.10_X7044331_Y1580668.hdp	344020	2005-11-10 10:08	35582600-075610-5 **2005-11-10 10:09** **2005-11-10 10:10**	0:01:00
	Skotardirektiv_2005-11-10-10.xml	839	2005-11-10 11:19	35582600-073798-0 **2005-11-10 11:19** **2005-11-10 11:50**	0:31:00
2005-11-14	Trakt_11.14_X7046182_Y1587121_SAvv.pdf	384773	2005-11-14 10:26	35582600-073798-0 **2005-11-14 10:26** **2005-11-15 17:07**	30:41:00
	Trakt_11.14_X7046182_Y1587121.hdp	328344	2005-11-14 10:29	35582600-073798-0 **2005-11-14 10:29** **2005-11-15 17:07**	30:38:00

2005-11-15	Trakt_11.15_X7044367_Y1581015_SAvv.pdf	402532	2005-11-15 10:51	35582600-075610-5 **2005-11-15 10:52** **2005-11-15 10:53**	0:01:00
	Trakt_11.15_X7044367_Y1581015.hdp	310027	2005-11-15 10:53	35582600-075610-5 **2005-11-15 10:54** **2005-11-15 10:55**	0:01:00
	Skotardirektiv_2005-11-15.xml	762	2005-11-15 17:03	35582600-073798-0 **2005-11-15 17:04** **2005-11-15 17:07**	0:03:00
	aa.doc	27648	2005-11-15 17:10	35582600-073798-0 **2005-11-15 17:11** **2005-11-15 17:13**	0:02:00
	Skotardirektiv_2005-11-15-15.xml	762	2005-11-15 17:12	35582600-073798-0 **2005-11-15 17:13** **2005-11-15 17:14**	0:01:00
2005-11-17	Trakt_6_X7044130_Y1581561_SAvv.pdf	0	2005-11-17 13:23	35582600-073798-0 **2005-11-17 13:23** **2005-11-17 15:21**	1:58:00
				35582600-075610-5 **1970-01-01 01:00** **2005-11-21 15:27**	2:04:00
	Trakt_11.17_X7044130_Y1581561.hdp	313607	2005-11-17 13:25	35582600-075610-5 **2005-11-17 13:25** **2005-11-21 15:27**	2:02:00
2005-11-21	Trakt_11.21_X7043959_Y1581614_SAvv.pdf	400915	2005-11-21 11:38	35582600-073798-0 **2005-11-21 14:52** **2005-11-21 15:25**	0:33:00
				35582600-075610-5 **1970-01-01 01:00** **2005-11-21 15:27**	0:35:00
	Trakt_11.21_X7043959_Y1581614.hdp	312048	2005-11-21 11:40	35582600-073798-0 **2005-11-21 14:52** **2005-11-21 15:25**	0:33:00
				35582600-075610-5 **1970-01-01 01:00** **2005-11-21 15:27**	0:35:00
2005-11-23	Trakt_8_X7043903_Y1581761_SAvv.pdf	0	2005-11-23 16:16	35582600-071845-1 **2005-11-23 16:31** **2005-11-25 01:22**	56:51:00
	Trakt_11.23_X7043903_Y1581761.hdp	297671	2005-11-23 16:17	35582600-071845-1 **2005-11-23 16:31** **2005-11-25 01:22**	56:51:00

C3 Transferred File GPRS Traffic (Web Server)

Date	IN directory (bytes)	OUT directory (bytes)
11/7/2005	0	741767
11/8/2005	2124	761449
11/9/2005	25348	0
11/10/2005	26557	744988
11/11/2005	51179	0
11/12/2005	0	0
11/13/2005	0	0
11/14/2005	60811	713117
11/15/2005	24374	741731
11/16/2005	50794	0
11/17/2005	1060	313607
11/18/2005	75979	0
11/19/2005	0	0
11/20/2005	0	0
11/21/2005	3176	712963
11/22/2005	0	0
11/23/2005	57140	297671
11/24/2005	26598	0
11/25/2005	25234	0
11/26/2005	73254	0
11/27/2005	0	0
11/28/2005	24707	0
11/29/2005	0	0
11/30/2005	25252	0
in bytes	553587	5027293
in kB	540.6123047	4909.46582
Total GPRS traffic	**5450 kB**	

Table 41 Total GPRS traffic of transferred files per day, weekends are specified in purple

C4 GPRS Specification Received from Telia

Date	Forwarder (bytes)	Harvester (bytes)	Forest (bytes)
11/7/2005	0	712514	3564655
11/8/2005	1731152	1379527	3674092
11/9/2005	2348882	1869765	3527129
11/10/2005	1652849	3402751	1830409
11/11/2005	968743	1181871	3483437
11/12/2005	0	1332315	3364982
11/13/2005	0	886222	3348602
11/14/2005	0	2486461	2927448
11/15/2005	1690397	2171628	2641452
11/16/2005	0	2184272	1933311
11/17/2005	2115908	1492730	2373553
11/18/2005	1177063	1386059	0
11/19/2005	0	906307	0
11/20/2005	0	357986	0
11/21/2005	0	1358616	2306871
11/22/2005	764291	2337193	3792593
11/23/2005	1123525	222808	1486945
11/24/2005	1832170	89182	2235410
11/25/2005	0	255	3544590
11/26/2005	0	931	3779235
11/27/2005	0	0	1106725
11/28/2005	0	2725	1919114
11/29/2005	0	0	2729595
11/30/2005	0	0	1423145
in bytes	15404980	25762118	56993293
in kB	15043.93	25158.32	55657.51
Total GPRS traffic used by phones	**95859.76 kB**		

Table 42 GPRS specification received from Telia, weekends are specified in purple

C5 Planned Path Sent to Field

Date	File name	Size (bytes)	Created	Phone (IMEI) Delivered ACKED	Elapsed time
2005-11-07	Trakt_051107_X7043890_Y1580647.hdp	339480	05-11-07 10:51	35582600-075610-5 **2005-11-07 10:52** **2005-11-07 15:34**	4:42:00
	Trakt_051107_X7043890_Y1580647_SAvv.pdf	401448	05-11-07 10:53	35582600-075610-5 **2005-11-07 10:53** **2005-11-07 15:34**	4:41:00
2005-11-08	Trakt_11.08_X7043915_Y1580806_SAvv.pdf	400852	05-11-08 10:42	35582600-075610-5 **2005-11-08 10:43** **2005-11-08 10:44**	0:01:00
	Trakt_11.08_X7043915_Y1580806.hdp	357257	05-11-08 10:43	35582600-075610-5 **2005-11-08 10:45** **2005-11-08 10:46**	0:01:00
2005-11-10	Trakt_11.10_X7044331_Y1580668_SAvv.pdf	400129	05-11-10 10:07	35582600-075610-5 **2005-11-10 10:08** **2005-11-10 10:09**	0:01:00
	Trakt_11.10_X7044331_Y1580668.hdp	344020	05-11-10 10:08	35582600-075610-5 **2005-11-10 10:09** **2005-11-10 10:10**	0:01:00
2005-11-14	Trakt_11.14_X7046182_Y1587121_SAvv.pdf	384773	05-11-14 10:26	35582600-073798-0 **2005-11-14 10:26** **2005-11-15 17:07**	30:41:00
	Trakt_11.14_X7046182_Y1587121.hdp	328344	05-11-14 10:29	35582600-073798-0 **2005-11-14 10:29** **2005-11-15 17:07**	30:38:00
2005-11-15	Trakt_11.15_X7044367_Y1581015_SAvv.pdf	402532	05-11-15 10:51	35582600-075610-5 **2005-11-15 10:52** **2005-11-15 10:53**	0:01:00
	Trakt_11.15_X7044367_Y1581015.hdp	310027	05-11-15 10:53	35582600-075610-5 **2005-11-15 10:54** **2005-11-15 10:55**	0:01:00
2005-11-17	Trakt_6_X7044130_Y1581561_SAvv.pdf	0	05-11-17 13:23	35582600-073798-0 **2005-11-17 13:23** **2005-11-17 15:21**	1:58:00
				35582600-075610-5 **1970-01-01 01:00** **2005-11-21 15:27**	2:04:00
	Trakt_11.17_X7044130_Y1581561.hdp	313607	05-11-17 13:25	35582600-075610-5 **2005-11-17 13:25** **2005-11-21 15:27**	98:02:00
2005-11-21	Trakt_11.21_X7043959_Y1581614_SAvv.pdf	400915	05-11-21 11:38	35582600-073798-0 **2005-11-21 14:52** **2005-11-21 15:25**	0:33:00
				35582600-075610-5 **1970-01-01 01:00** **2005-11-21 15:27**	0:35:00
	Trakt_11.21_X7043959_Y1581614.hdp	312048	05-11-21 11:40	35582600-073798-0 **2005-11-21 14:52** **2005-11-21 15:25**	0:33:00

				35582600-075610-5 **1970-01-01 01:00** **2005-11-21 15:27**	0:35:00
2005-11-23	Trakt_8_X7043903_Y1581761_SAvv.pdf	0	05-11-23 16:16	35582600-071845-1 **2005-11-23 16:31** **2005-11-25 01:22**	32:51:00
	Trakt_11.23_X7043903_Y1581761.hdp	297671	05-11-23 16:17	35582600-071845-1 **2005-11-23 16:31** **2005-11-25 01:22**	32:51:00

C6 Production Files From Field

Date	File name	Size (bytes)	Created	Phone (IMEI) ACKED	Elapsed time
2005-11-09	Ingvar Westergren051108_2.prd	25348	2005-11-08 23:00	35582600-071845-1 **2005-11-09 10:04**	11:04:00
	Ingvar Westergren051108_1.prd	0	2005-11-08 23:06	35582600-071845-1 **2005-11-09 10:04**	10:58:00
2005-11-10	Ingvar Westergren051109_1.prd	25497	2005-11-09 22:00	35582600-075610-5 **2005-11-10 00:19**	2:19:00
2005-11-11	Ingvar Westergren051110_1.prd	25563	2005-11-10 22:28	35582600-071845-1 **2005-11-11 00:48**	2:20:00
	Ingvar Westergren051111_1.prd	25616	2005-11-11 13:29	35582600-071845-1 **2005-11-11 15:51**	2:22:00
2005-11-15	C Nordlund mfl 051114_1.prd	23314	2005-11-14 22:21	35582600-075610-5 **2005-11-15 00:39**	2:18:00
2005-11-16	Ingvar Westergren051115_1.prd	25765	2005-11-15 22:02	35582600-071845-1 **2005-11-16 00:52**	2:50:00
	C Nordlund mfl051115_1.prd	23969	2005-11-15 22:21	35582600-071845-1 **2005-11-16 00:51**	2:30:00
2005-11-18	Ingvar Westergren051117_1.prd	25956	2005-11-17 16:46	35582600-071845-1 **2005-11-18 01:24**	8:38:00
	Helen Almroth_gallring051117_2.prd	23792	2005-11-17 22:48	35582600-071845-1 **2005-11-18 01:24**	2:36:00
	Helen Almroth_gallring051117_1.prd	0	2005-11-17 22:53	35582600-071845-1 **2005-11-18 01:24**	2:31:00
	Helen Almroth051118_1.prd	26231	2005-11-18 14:00	35582600-071845-1 **2005-11-18 16:36**	2:36:00
2005-11-23	Ingvar Westergren_1.prd	25228	2005-11-07 21:51	35582600-075610-5 **2005-11-23 20:13**	404:22:00
	Helen Almroth_gallring051122_2.prd	24730	2005-11-22 23:07	35582600-075610-5 **2005-11-23 16:40**	17:33:00
	Helen Almroth_gallring051122_1.prd	0	2005-11-22 23:11	35582600-075610-5 **2005-11-23 16:39**	17:29:00
2005-11-24	Helen Almroth051123_1.prd	26598	2005-11-23 22:39	35582600-075610-5 **2005-11-24 00:57**	02:18:00
2005-11-25	Helen Almroth_gallring051124_1.prd	25234	2005-11-24 22:45	35582600-071845-1 **2005-11-25 01:22**	03:37:00
2005-11-26	C Nordlund mfl_gallring051125_1.prd	24220	2005-11-25 22:02	35582600-075610-5 **2005-11-26 10:28**	11:26:00
	C Nordlund mfl051125_1.prd	24505	2005-11-25 22:06	35582600-075610-5 **2005-11-26 10:28**	11:22:00
	C Nordlund mfl051126_1.prd	24529	2005-11-26 11:35	35582600-075610-5 **2005-11-26 13:54**	02:19:00

2005-11-28	C Nordlund mfl051128_1.prd	0	2005-11-28 21:37	35582600-075610-5 **2005-11-28 23:57**	02:20:00
	C Nordlund mfl051128_2.prd	24707	2005-11-28 21:39	35582600-075610-5 **2005-11-28 23:57**	02:18:00
2005-11-30	Helen Almroth_gallring051125_1.prd	25252	2005-11-25 09:29	35582600-071845-1 **2005-11-30 21:02**	131:33:00

C7 Forward Reports Received From Field

Date	File name	Size (bytes)	Created	Phone (IMEI) **Recieved**	Elapsed time
2005-11-08	Skotarrapport_2005-11-7_1.xml	1063	2005-11-07 21:02	35582600-073798-0 **2005-11-08 12:18**	15:16:00
	Skotarrapport_2005-11-8_1.xml	1061	2005-11-08 21:14	35582600-073798-0 **2005-11-08 23:33**	2:19:00
2005-11-10	Skotarrapport_2005-11-9_1.xml	1060	2005-11-09 19:14	35582600-073798-0 **2005-11-10 07:32**	12:18:00
2005-11-15	Skotarrapport_2005-11-10_1.xml	1060	2005-11-10 19:22	35582600-073798-0 **2005-11-15 17:07**	117:45:00
2005-11-16	Skotarrapport_2005-11-15_1.xml	1060	2005-11-15 21:56	35582600-073798-0 **2005-11-16 00:14**	2:18:00
2005-11-17	Skotarrapport_2005-11-16_1.xml	1060	2005-11-16 19:26	35582600-073798-0 **2005-11-17 12:09**	16:43:00
2005-11-21	Skotarrapport_2005-11-17_1.xml	1060	2005-11-17 16:15	35582600-073798-0 **2005-11-21 20:54**	100:39:00
	Skotarrapport_2005-11-18_1.xml	1060	2005-11-18 14:11	35582600-073798-0 **2005-11-21 20:54**	78:43:00
	Skotarrapport_2005-11-21_1.xml	1056	2005-11-21 18:43	35582600-073798-0 **2005-11-21 21:01**	2:18:00

13.4 Appendix D

Information is retrieved from the reference manual of Timberjack.

Timberjack Tillv nr ver 1.0-

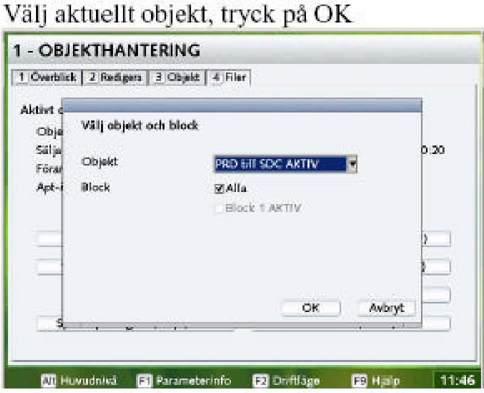
Att sända PRD fil till SDC

Spara produktionen till mappen PRD genom att:

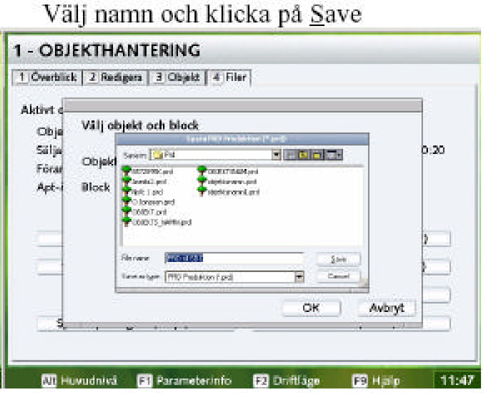
Välj 1 OBJEKTHANTERING, 4 FILER

Vänster klicka på Spara produktion (*.prd)

Välj aktuellt objekt, tryck på OK



Välj namn och klicka på Save



Om objektet är klart går det att markera det som avslutat på fliken Objekt. Utnyttjas det även i SDC:s system se att avverkningen är klar.

13.5 Appendix E

Iridium Service:

- I-LINX Basic Airtime/Post Paid Plan
- Voice Services
- Iridium to PSTN $1.20
- Iridium to Iridium $0.85
- Iridium to Inmarsat $10.00
- Iridium to Personal Mailbox Access $1.20
- SMS Message (per message) $0.65
- Data Services
- Iridium to Iridium Circuit Switched Data $1.20
- Iridium to PSTN Circuit Switched Data $1.20
- Iridium to Iridium Direct Internet Server $1.20
- Activation Fee $49.95
- Subscription Fee
- Handset (SIM Card) $30.00
- Voicemail (Optional) $10.00
- I-LINX Basic Iridium Airtime/Pre-Paid Plan
- Pre-Paid Service
- 75 min e-voucher (No activation fee) 1 month expiry $90.00
- 500 min e-voucher (No activation fee) 12 month expiry $600.00
- Add Minutes; 50 minute e-voucher $60.00
- Extend Expiry; One Month e-voucher $35.00

Information is found at [105] and [117]

E1 9505A Portable Satellite Phone

- Price: $1,395.00
- Price: €1,154.00
- 9505 Pre-Owned Portable Satellite Phone
- Price: $995.00
- Price: €834.00
- Includes:
- Includes 9505A Phone
- AC Travel charger & plug kit
- High Capacity Battery
- Antenna Adapter
- Portable Auxiliary Antenna
- Auto Adapter
- Earpiece
- Leather Case
- User's Guide
- 1 year warranty
- Data Capable (use your satellite phone to transmit and receive data with an optional RS232 adapter)

E2 Iridium Data Kit (for 9505A)

- Price: $220.00 USD
- It contains the hardware and software required for establishing an Iridium data call with a 9505A Portable Phone.
- Data Kit includes:
- Data Adapter
- Serial Cable (9-pin M/F)
- Stand
- Iridium World Data Services CD
- Neoprene carrying case
- Features
- Data Adapter - attaches to a 9505A Portable Phone and provides a connection for a serial cable.
- Stand - Supports the 9505A Portable Phone and allows the antenna to be oriented in a vertical position.
- Serial Cable - connects the Data Adapter to a computer serial port.
- Iridium World Data Services CD - Contains all software and documentation required to install and configure Iridium World Data Services on your computer. Documentation includes user guides, troubleshooting guides and application notes.

E3 Iridium 9505a - Internet to Go Package

Iridium 9505a - Internet To Go Package [Includes Handset, AC Charger, DC Charger, Leather case, Magnet Antenna, Antenna Adapter, 1 Battery, Data Kit, and Hands free Earpiece] [$1,625.00]

Information found at [118]

E4 Iridium Rental Phones

All Rentals Include:

- Motorola 9500 or 9505 Iridium satellite phone with battery
- Additional 1900 Mah Lithium Ion battery
- AC Charger (100-240VAC)
- Soft Carry Case
- User Manual & Quick Start Guide

	One Week	Two Weeks	Three Weeks	Monthly	Daily
Iridium 9500	$39.99	$79.98	$119.97	$159.96	$20.00
Iridium 9505	$89.99	$129.99	$169.99	$189.99	$45.00
Rate Per Minute	$1.80	$1.80	$1.80	$1.80	$1.80

Additional Weeks over 1 Month are Available at $47.50 per week.

Information found at [119]

E5 Iridium Prepaid Airtime Plans

Minutes	Valid For	Price	Per Minute Rate
75	One Month	$159	$2.12
500	One Year	$745	$1.49
3000	Two Years	$3,750	$1.25
5000	Two Years	$5,650	$1.13

E6 Monthly Subscription Plans

Plan	Amount	Minutes included	Per rate minute
Basic plan	$32.95	No Minutes Included	$1.49min**
Standard plan	$62.95	20 Minutes Included	$1.39min**
Traveler plan	$142.95	100 Minutes Included	$1.15min**
Value plan	$272.95	250 Minutes Included	$0.99min**

**EMERGENCY PLAN: Optional Service enabling activation for immediate use, but with less calls volume. [120]

13.6 Appendix F

F1 Acronym List

AAA	Authorization, Authentication and Accounting
API	Access Programming Interface
BER	Bit Error Rates
bps	Bits per second
BS	Base Station
BSC	Base Station Controller
BSS	Base Station System
BTS	Base Transceiver System
CDMA	Code Division Multiple Access
CSG	Content Services Gateway
DOM	Document Object Model
DTD	Document Type Definition
EDGE	Enhanced Data rates for GSM Evolution
EIR	Equipment Identity Register
ES	Earth Stations
EV	Evolution
EV-DV	Evolution-Data and Voice
FDM	Frequency Division Multiplexing
FDMA	Frequency Division Multiple Access
FHSS	Frequency Hopping Spread Spectrum
GEO	Geostationary Orbit Satellites
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service (2.5G)
GPS	Global Positioning System
GSM	Global System for Mobile communications (2G)
GTP	GPRS Tunnel Protocol
HA	Home Agent
HDR	High Data Rate
HLR	Home Location Register
HTTP	HyperText Transfer Protocol
IMEI	International Mobile Equipment Identity
IP	Internet Protocol
ISL	Inter-Satellite Link
ISP	Internet Service Provider
JCIFS	Java Common Internet File System
JVM	Java Virtual Machine
kbps	Kilo Bits per second
L2CAP	Logical Link Control and Adaptation Protocol
LAN	Local Area Network
LEO	Low Earth Orbiting satellites
MEO	Medium Earth Orbit Satellites
MMS	Multimedia Messaging Service
MS	Mobile Station
MSC	Mobile Switching Center
MSXML DOM	Microsoft XML Document Object Model
MT	Mobile Terminal

MTU	Maximum Transmission Unit
NMT	Nordic Mobile Telephony
OSGi	Open Services Gateway initiative
PCU	Packet Control Unit
PDA	Personal Digital Assistant
PLMN	Public Land Mobile Network
PSTN	Public Switched Telephone Network
PTT	Post, Telephone and Telegraph
QoS	Quality of Service
RF	Radio Frequency
RFCOMM	Radio Frequency Communications Protocol
RNC	Radio Network Controllers
RTT	Radio Transmission Technology
RTU	Remote Terminal Unit
SDC	Skogs Data Central
SDP	Service Discovery Protocol
SEK	Swedish Kronor
SGML	Standard Generalized Markup Language
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SMS	Short Message Service
TCP	Transmission Control Protocol
TCS	Telephony Control Protocol Specification
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
UDP	User Datagram Protocol
USB	Universal Serial Bus
VLR	Visitor Location Register
VLR	Visitor Location Register
WAP	Wireless Application Protocol
WISP	Wireless Internet Service Providers
XML	Extensible Markup Language
XSLT	Extensible Style Sheet Language Transformation

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