Performance Evaluation of GPRS and Fiber as Transmission Medium for Social Care Systems

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Abstract

There is an extensive expansion of fiber infrastructure for high-speed broadband networks in Sweden, and Landskrona municipality is one of the leading examples. Owing to the superior capabilities of a fiber based network, a number of digital welfare services can be provided directly to residents and companies of the municipality. Social care is an example of a welfare service that can utilize the superior capabilities of a fiber based network. Currently, the social care system in Landskrona Municipality experiences extremely long delays. Deploying GPRS as the primary transmission medium for the social care system is one of the causes for the extremely long delays.

This report provides a thorough description of how the current social care system in Landskrona municipality can instead deploy fiber, to reduce the long delays experienced by the users of the service. Interestingly, performance evaluation of the results from this project show that there would be a significant reduction in the transmission network delay should GPRS be replaced with fiber.

Popular Science Summary

The point of this project was to evaluate the performance of GPRS and fiber as transmission medium for the social care systems. A social care system refers to a set of interdependent components interconnected through a communications system. The components are used to cater for the healthcare and security concerns of the elderly population. For instance, alarm units, sensors, alarm centers, alarm receivers, etc interconnected through a communications network. Because the number of people retiring in Europe is expanding, there is likely to be an increased burden on the working age group to provide for the services and care required by the ageing population. Hence, social care systems are likely to become an integral part of our everyday society because they are likely to substitute for the working age group.

Most European Countries have developed and deployed social care systems, but these systems are under severe stress and under-performing. Part of the problem has been that, this field has not benefited from the technological advancements and innovations. No innovations to adopt social care systems to the latest wireless communication systems for example 3G and LTE have been made. It is a shame that even with the technological advancements during the past 15 years, most societies to-date deploy GPRS as the transmission medium to route alarms from the alarm units to the alarm receivers.

Because GPRS has always been characterized by variable throughput and delays for packet transmissions, social care systems that use GPRS as the transmission medium always experience long transmission network delays. The delays arise due to the necessary retransmissions since alarm messages that are transmitted using GPRS easily get lost or damaged a long the way from the alarm units to the alarm center. In Sweden, the elderly population who are in need of social care services turn to the local municipality to claim for help. Many of the Swedish municipalities use Internet based social care systems. However, the transmission infrastructure for the social care service in most municipalities is based on GPRS. Hence, when an alarm is triggered, it may take more than 3 minutes before the telephone at the alarm receiver starts to ring. This is a serious problem because it leads to delay in the early intervention for patients in need of emergency assistance.

In a bid to solve this challenge, Landskrona municipality in collaboration with a company called Landskrona Energi AB developed interest in a project whose aim was to replace GPRS with fiber. This project developed a prototype that utilized the robust Internet connection of fiber, and a performance evaluation of the usage of GPRS and fiber networks for the social care service was established. Two alarm units were triggered simultaneously in different locations in the municipality. Each time the experiment was performed, the end to end transmission network delay (trigger to ring delay) over both GPRS and fiber networks was established. Hence, Figure 1 shows the comparison of the transmission network delay between GPRS and fiber networks from one of the locations in the municipality. The alarms were triggered at different time intervals. In the project, it was established that an alarm when transmitted using fiber will take an average of 2 seconds before the telephone starts to ring at the premises of the alarm receiver. However, the same alarm when transmitted using GPRS will take an average of 33 seconds. As showed in Figure 1, the transmission network delay over the GPRS network was found to be unstable because it was dependent on the behaviour of the radio channel characteristics.

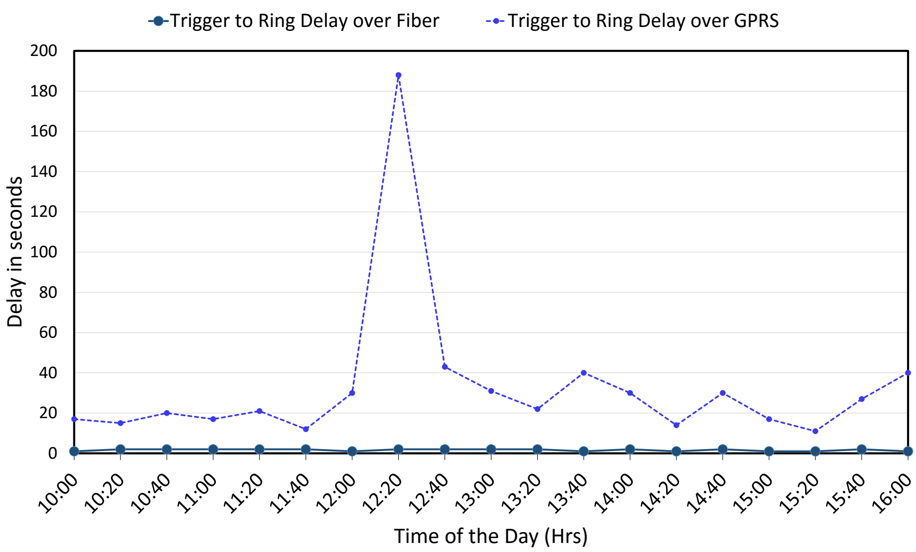

Figure 1: Comparison of the transmission network delay between GPRS and fiber networks.

Besides the transmission network delay, the reluctance in picking up of a ringing telephone at the premises of the alarm receiver also contributed to the delay experienced by the social care system. However, this problem could not be solved by replacing one transmission network with another. Hence, this problem still exits. Packet loss measurements on the GPRS and fiber networks were performed. The idea was to determine why the networks experienced different magnitudes of delay. Two computers, one connected to fiber and the other connected to GPRS, were used to ping the Swedish University Computer Network (SUNET). Fiber incurred close to zero packet losses while GPRS incurred packet losses of more than 1 percent. Because fiber experienced transmission network delays between 1 and 2 seconds, the results generated from the project provided the justification why the switch from GPRS to fiber was necessary to improve on the performance of social care systems.

Dedication

To my beloved siblings
Rose, Robinson, Susan, Doreen, Paul, and Joseph for their love and support. Without forgetting my best friend ***Doryn Kanatukunda***, for bringing out the best in me. May the Lord Bless you All.

Tis Grace hath brought me safe thus far, And Grace will lead me home

Acknowledgments

Without a doubt, I would like to thank the Swedish Institute (SI) for having provided me with the scholarship to earn this master's degree. Additionally, I want to thank the following people for their tremendous help and effort throughout this project.

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List of Acronyms

3G	Third Generation
ACF	Admission Confirmation
ACK	Acknowledgement
ARQ	Admission Request
BSS	Base Station Subsystem
DHCP	Dynamic Host Control Protocol
DNS	Domain Name Service
GGSN	Gateway GPRS Support Node
GMSC	Gateway Mobile Switching Center
GPRS	Genaral Packet Radio Service
GSM	Global System for Mobile Communications
HLR	Home Location Register
ID	Identity
IP	Internet Protocol
ITU-T	ITU Telecommunication Standardization Sector (ITU-T)
LAN	Local Area Network
LTE	Long Term Evolution
NTP	Network Time Protocol
PBX	Private Branch Exchange
PSTN	Public Switched Telephone Network
RTP	Real Time Transport Protocol
SDP	Session Description Protocol
SIM	Subscriber Identity Module

SIP	Session Initiation Protocol
SGSN	Serving GPRS Support Node
SUNET	Swedish University Computer Network
TCP	Transport Control Protocol
UDP	User Datagram Protocol
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
URI	Uniform Resource Identifier
VOIP	Voice Over Internet Protocol
VPN	Virtual Private Network

Chapter 1
Introduction

The growing population and the increasing numbers of the elderly population living alone are leading to significant changes in the social and economic structure of our society. Advances in remote social care systems that transmit social alarms are on an increase. Many of the Swedish municipalities have already transited from the analog to the Internet based social care systems. However, the underlying transmission infrastructure for the social care service in some municipalities is still based on GPRS [1]. Hence, this project focuses on the feasibility study of replacing GPRS with fiber as the core transmissions infrastructure for the social care service in Landskrona Municipality.

1.1 Background

There is an extensive expansion of the infrastructure for high-speed broadband networks in Sweden, and Landskrona municipality is one of the leading examples of this. The main idea behind this expansion, is to establish a fiber to home infrastructure that enables digital services to be provided directly to residents and companies of the municipality regardless of their broadband subscription or location. As the owner of the fiber network in Landskrona municipality, as well as being one of its operators, Landskrona Energi AB is interested in utilizing the infrastructure's potential to improve the living standards of the municipality's inhabitants and companies through the provision of welfare services.

Social care is an example of such a welfare service that can utilize the robust Internet access provided by the fiber network. Currently, the social care system in Landskrona municipality is experiencing huge delays in the social care service. Hence, the Landskrona municipality authority responsible for elderly social care approached Landskrona Energi AB to help come up with a solution to this problem. The idea was to have social alarms transmitted via Landskrona Energi's fiber grid network instead of GPRS.

1.1.1 Landskrona Energi AB

Landskrona Energi AB is involved in this project because they are responsible for the city network in Landskrona municipality. The city network is one of the world's most modern broadband networks. The foundation of the network is made up of fiber optic cables that are distributed all the way to each of the buildings in the city. Currently, 80% of the households in Landskrona municipality have been connected to the fiber grid. However, the company's plan is to give all households the opportunity to be covered by the fiber grid by the year 2018.

1.2 Problem Statement

Generally, as the majority of the population gets older, the question about the quality of social care systems for the elderly emerges. A social care report in the United Kingdom (UK) cited that social care systems for the elderly were under severe stress and under-performing leading to higher costs, poorer health outcomes, and sicker patients [2]. In Landskrona municipality, the elderly population petitioned for help from the municipal authorities regarding the quality and the state of the social care system. Their main concern was, when triggered, the alarms delayed to reach the operators at the Alarm receiver. Hence, the wait for assistance from the operators at the Alarm receiver became unbearably long. Eventually, this challenge led to delays in early intervention for patients in need of emergency assistance.

Because GPRS is characterised by variable throughput and delays for packet transmission, there was a hypothesis that GPRS could be one of reasons why the current social care system was experiencing the extremely long delays. Hence, Landskrona Energi thought that by replacing the core transmission infrastructure with fiber, the challenge of delay could be solved. Fiber was chosen among other transmission alternatives for example 3G and LTE because the fiber infrastructure is readily available in Landskrona municipality.

In addition to the above challenge, the ambition of social care systems globally is changing and so is Landskrona Municipality's. For example, there exists a vision to have an automatic social care system that combines intelligent alarms with continuous real time monitoring of the user's activities. However, to achieve this vision and many others, the transmission infrastructure for the social care service has to be upgraded to a faster Internet access technology.

1.3 The aim of the project

The aim of this project was to illustrate that it is feasible to transmit social alarms over the fiber infrastructure, and thereby reduce the delays experienced by the current social care system. The idea was to have the alarms transmitted via a broadband connection across the Internet from the Alarm unit to the Alarm receiver.

1.4 Research Questions

In this project, the following research questions have been investigated:

- Why does the current social care system experience the extremely long delays?
- Will replacing the assumed weakest link (GPRS) with fiber help solve the problem of delay?
- By what measure in terms of reducing delay, would the social care system based on fiber perform better than the one based on GPRS?

1.5 Relevant Work

Over the years, there have been a number of projects that have been carried out in Sweden with an aim of improving social care technology and in particular digital security alarms. The projects have been carried out by some Municipalities in Sweden with support from the Swedish Government. The majority of the projects were aimed at transiting from traditional analog alarms to either mobile telephony or broadband IP based alarms [1].

The European Union too, funded a project called the Mobile social care that consisted of a consortium of universities, hospitals, and commercial companies aimed at developing innovative systems and services for social care networks using cellular transmission networks. This project carried out trials in four European countries on real-time monitoring systems and technical evaluations were made [3]. The main focus was on the performance of the communication infrastructure in terms of: availability, bandwidth characteristics, percentage of data loss, transmission delay, and jitter. In addition to the network performance, technical evaluations also assessed the communication infrastructure in terms of validity, accuracy, and time delays. The project concluded that although the UMTS networks are stable and functional, there were many barriers and technological details that need to be resolved before stable and viable m-health services could be introduced into the market. The problems that needed to be solved included restricted bandwidth, delay variations, delays in transmission, and handovers [3].

However, to the best of my knowledge, not so much work has been performed by the Industry to adopt the Alarm units to the latest wireless transmission technologies like 3G and LTE. Instead, this project aimed at reducing the transmission network delay experienced by the social care system through replacing GPRS with fiber.

1.6 Project Approach

The aim of this project was to evaluate the performance of the social care system by means of measurements rather than simulation or modelling. For this purpose, a measurements-based evaluation methodology was developed. In the project, a prototype of the social care system that is based on fiber was developed. A comparison of the performance of GPRS and fiber was established. During the implementation of the project, two alarm units were used to route alarms simultaneously over GPRS and fiber networks. One of the alarm units was connected to Landskrona Energi's fiber grid. The second alarm unit was configured to route alarms essentially over a GPRS network. Alarms were transmitted simultaneously, from the alarm units to the alarm receiver in Landskrona.

Measurement probes were used to record the Alarm Trigger time, Ringing time, and Alarm PickUp time for alarms transmitted using fiber. At the same time, the corresponding Alarm Trigger time, Ringing time, and Alarm PickUp time for the alarms routed using the GPRS network was estimated. The experiment was repeated in different locations within Landskrona municipality. Hence, with the results obtained from the measurements, a performance evaluation was established to determine the cause of the extreme delays experienced by the social care system.

1.7 Outline of project

The project is divided into six chapters. **Chapter 1** gives an introduction to the work that was performed in this project. It defines the background, describes the problem at hand, objectives of the project, and states the relevant work that has been carried out.

In **Chapter 2**, the current and proposed social care systems in Landskrona Municipality are presented. It presents the participants involved in the social care system chain, how the social alarms are activated, transmitted, processed, and logged.

In **Chapter 3**, a brief overview of the concepts of social care systems is given. Only parts relevant to this study are presented. The primary focus is on social care system components, the protocols and interfaces.

The experiments and measurements are presented in **Chapter 4**.

Chapter 5 presents the results from the measurements, and **Chapter 6** discusses conclusions and what could be done in the future.

Chapter 2

Social Care Overview in Landskrona

Swedish people have a statutory right to claim for services and care when needed [4]. Hence, whenever the elderly population are in need of social care services they turn to the local municipality to claim for help. This chapter gives an overview of the overall structure of the social care system in Landskrona Municipality.

2.1 Current Social Care System in Landskrona

The general architecture of the social care system in Landskrona municipality consists of 3 subsystems namely: an Alarm unit, an Alarm center, and an Alarm receiver. These subsystems are interconnected through a communications infrastructure. Hence, Figure 2.1 shows the general architecture of how the subsystems are interconnected to create the social care system.

The current social care system in Landskrona municipality deploys GPRS as the core telecommunications infrastructure to connect an Alarm unit to the Alarm center. A Public Switched Telephone Network (PSTN) is then used to connect the Alarm center to the operators at the Alarm receiver. Therefore, when an alarm is triggered by the Alarm unit, the user who triggered the alarm is able to communicate with the operators at the Alarm receiver.

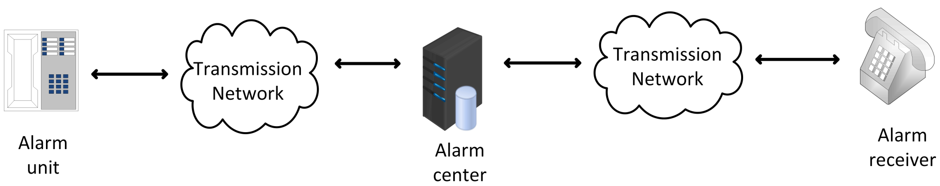

Figure 2.1: Architecture showing the social care system.

Figure 2.2 shows a detailed description of the social care system in Landskrona municipality. The social care system is deployed over a GPRS network where both data and voice are routed between the Alarm unit and the Alarm center. Alarm data is transmitted between the Alarm unit and the Alarm center over the GPRS core network as IP packets. However, the voice information is routed over a GSM channel dedicated solely to voice information.

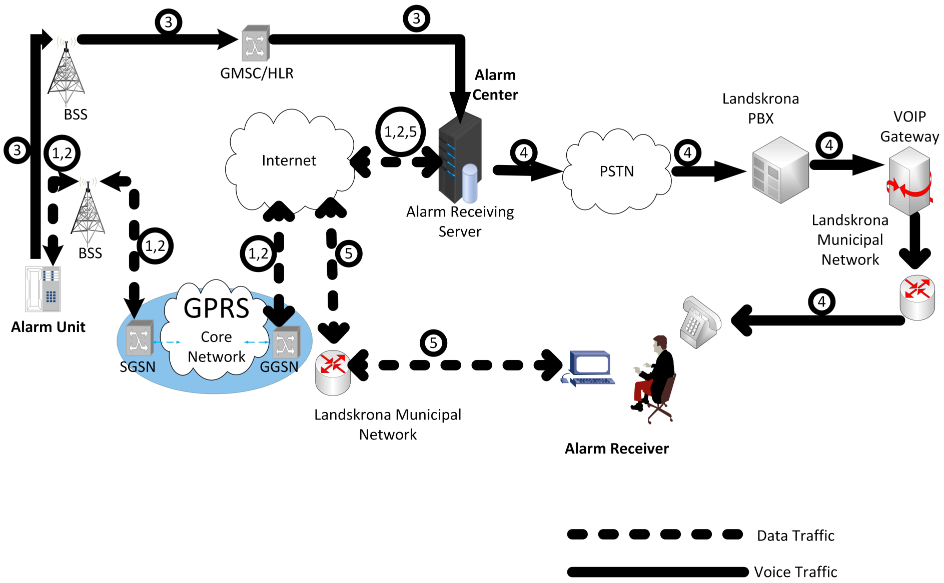

Figure 2.2: Architecture of Social care system using the GPRS network.

Figure 2.3 illustrates a time chart providing a brief explanation to the processes involved in Figure 2.2. Figure 2.3 explains the different processes involved in activating and servicing the alarms generated by the Alarm unit.

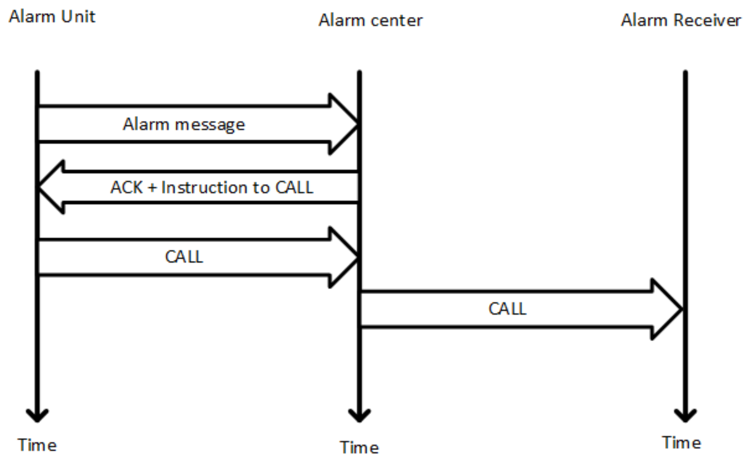

Figure 2.3: Time-chart showing the different process in activating and servicing of social alarms

2.1.1 Activating Alarms

The entire process shown in Figure 2.2 and Figure 2.3 starts with an alarm being generated by a manual trigger button that is located on the Alarm unit. The alarm could also be generated by an Alarm trigger or ambient sensors, for example heat and smoke sensors located at the User's home.

2.1.2 Alarm Processing

The Alarm unit sends the alarm message to the Alarm center through a GPRS connection illustrated by connection 1 in Figure 2.2. When the Alarm receiving server receives the alarm message, the alarm session is already active. From the received alarm message, the Alarm receiving server identifies the Alarm unit from which the alarm was triggered.

Using connection 2 as showed by Figure 2.2, the Alarm receiving server acknowledges receipt of the alarm message and at the same time instructs the Alarm unit to set up a telephone call. Using connection 3 in Figure 2.2, the Alarm unit calls a predefined number, which is the telephone number to the Alarm center. There is no direct connection between the Alarm unit and any third party, for example, the Police or even the Alarm receiver. The only direct link is between the Alarm unit and the Alarm center. Hence, all alarm traffic has to go through the Alarm center.

To check whether the alarm message and the telephone call came from the same Alarm unit, the Alarm receiving server matches the device ID to the SIM ID of the Alarm unit. When the matching is complete, the telephone call is routed to the Alarm receiver in Landskrona municipality over a PSTN network. However, the alarm message remains at the Alarm receiving server.

2.1.3 Alarm Processing to Landskrona

As illustrated by connection 4 in Figure 2.2, the call from the Alarm center is routed to the Alarm receiver through a Public Switched Telephone Network (PSTN). The call goes through the Private Branch Exchange (PBX) and the Voice over IP (VOIP) gateway, both located in Landskrona municipality. Eventually, the voice call from the Alarm unit arrives at the Alarm receiver as a VOIP call. Hence, from the time the Alarm unit generates the call, to the moment the operator at the Alarm receiver picks up the telephone, it is an active phone call where the user who triggered the alarm is on hold awaiting an operator's response.

At the same time, the alarm message is separately visible to operators at the Alarm receiver in Landskrona municipality. The operators are able to log into the Alarm center using a secure Virtual Private Network (VPN) connection over the Internet as illustrated by connection 5 in Figure 2.2.

2.2 Proposed Social Care System for Landskrona

The proposed architecture involves replacing the core transmission infrastructure from the Alarm unit to the Alarm center with fiber. Since most of the homes in the municipality have a fiber to home connection, it is worth exploiting the excellent capabilities of fiber so as to connect the users of the service to the Alarm center.

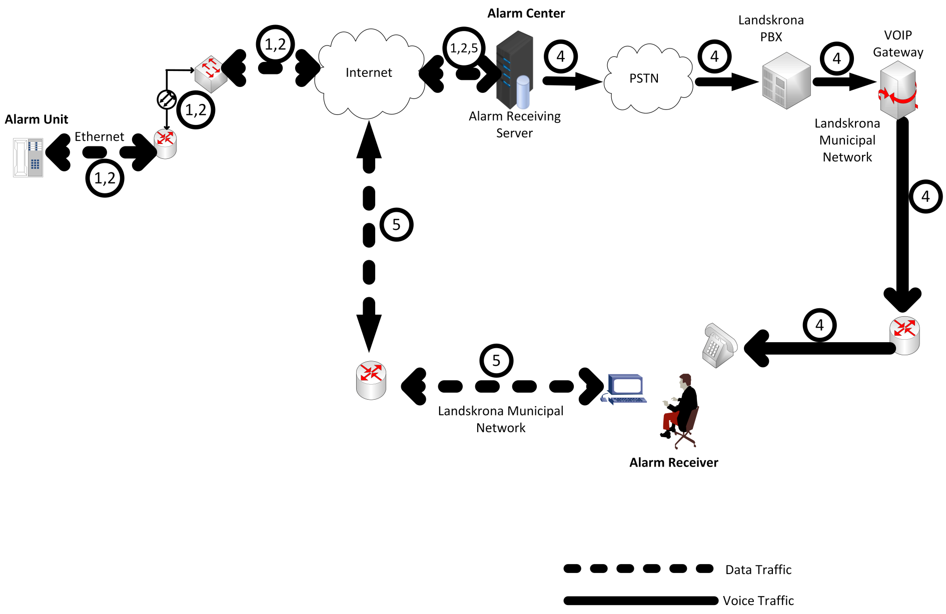

Figure 2.4: Proposed social care system using Fiber

The proposed social care system eliminates connection 3, which is used to separately route voice traffic from the Alarm unit to the Alarm center. Instead, both voice and data traffic from Alarm unit to the Alarm center will be routed over the same connection. The rest of the architecture and processes of the current architecture illustrated by Figure 2.2 is the same as for the proposed architecture illustrated by Figure 2.4.

2.3 Participants

A number of stakeholders are involved in the providing of social care services for the elderly population in Landskrona Municipality. Figure 2.5 shows the different stakeholders involved in the social care service in Landskrona Municipality. The stakeholders have independent roles to play in each of the activities illustrated in Figure 2.2. They have to work, hand in hand to ensure that the social care system runs smoothly.

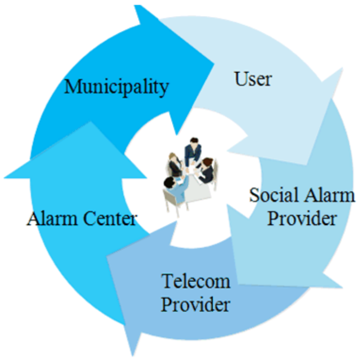

Figure 2.5: Participants in the social care service

2.3.1 User

Users are the elderly population who utilize the social care service. Each User is availed with an Alarm trigger (wearable device), Alarm unit, and a group of ambient sensors installed in and around the home. Using a manual button on either the Alarm trigger or the Alarm unit, the Users can trigger alarms in case they need help from the operators at the Alarm receiver. The alarms could also be triggered by the sensors installed around the User's home. Figure 2.6 illustrates an Alarm unit that is used to trigger alarms.

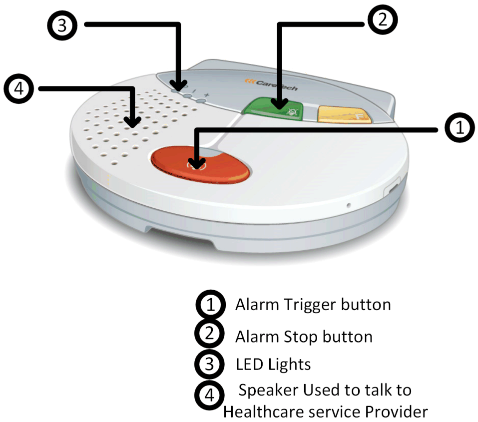

Figure 2.6: Alarm Unit used to trigger Alarms

2.3.2 Social Alarm Provider

In reference to Figure 2.5, the Social Alarm Provider is the supplier of the social care hardware and software. Doro Care AB is the social alarm provider in Landskrona municipality. Figure 2.6 illustrates an Alarm unit that is supplied by the Social Alarm Provider.

Prior to installing an Alarm unit at the home of the User, the Social Alarm Provider measures the GPRS signal strength that is received by the unit. The aim of measuring the GPRS signal strength is to determine whether the Alarm unit receives the threshold of -83 dBm, which is required for the Alarm unit to operate effectively [5]. In case the signal strength that is received by the Alarm unit is higher than the required threshold, the Social Alarm Provider will go ahead and install the Alarm unit at the premises of the User. In case the GPRS signal strength is lower than the required threshold, an external antenna is connected to the Alarm unit to improve on it's signal reception.

2.3.3 Telecom Provider

The Telecom Provider supplies the infrastructure onto which the GPRS network is accessed. The Alarm unit contains a sim-card of the Telecom provider through whose network, the alarm data and voice are routed.

2.3.4 Alarm Center

This is a location where events and data from the Users' homes are collected and analyzed by the Alarm receiving server. The Alarm center is supplied by the Social Alarm Provider. In this project, the Alarm center is located in Malmö city.

2.3.5 Municipality

The Municipality authorities provide social care services to the elderly population. In Landskrona municipality, this is primarily done through Landskrona Stad Omsorgsförvaltning. As illustrated by Figure 2.7, Landskrona Stad Omsorgsförvaltning has a monitoring center located in Landskrona municipality with operators who can access the Alarm center remotely over the Internet. The operators handle the incoming alarm calls and take up actions, which in the most cases consist of dialing the care provider team and letting them know about the alarm.

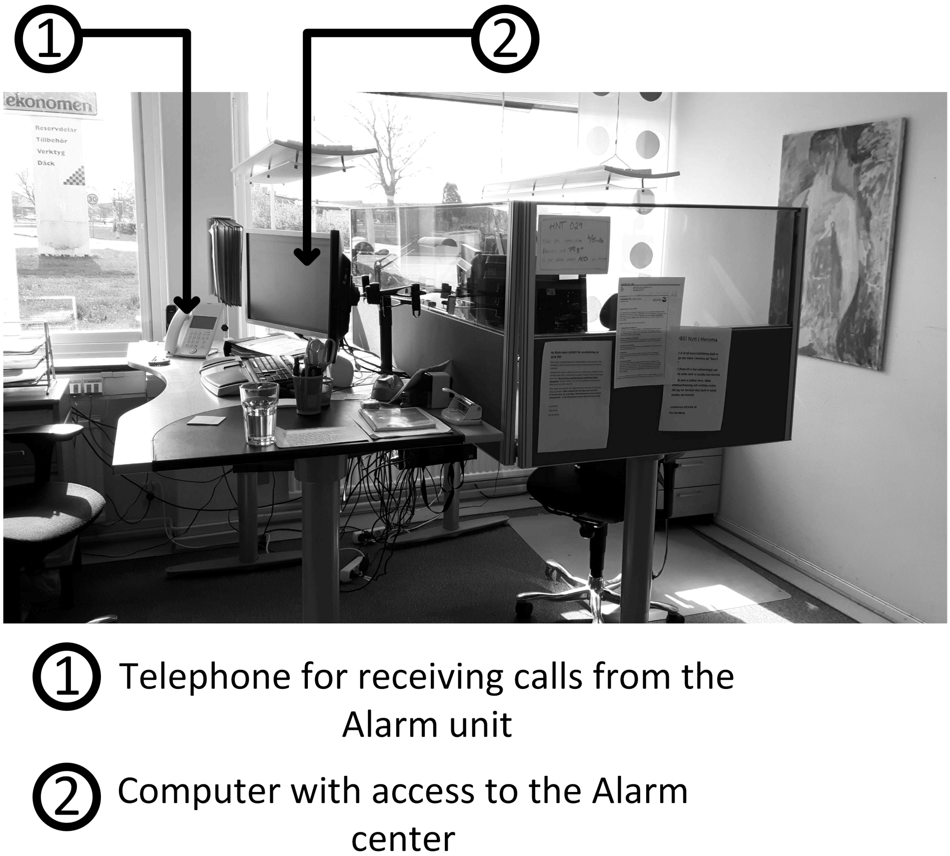

Figure 2.7: Monitoring center for social alarms

Chapter 3

Social Care Systems

Social care systems have been established so as to reduce face to face discussions between the doctors and patients as well as shortening hospital stays. Decent social care systems require that, healthcare information be captured and delivered in an efficient way in respective of whether the patients are in their own homes, aged facility or in a hospital.In addition to an efficient and reliable social care system, security concerns for the elderly people have to be improved both objectively and subjectively. A widely adopted system in Europe to respond to the fore-mentioned needs is the introduction of social alarms [6]. This chapter gives an understanding of what information is required for the design and implementation of social care systems for people living independently. Hence, this chapter focuses on social care system components, the protocols and interfaces for transmitting alarms over the fiber network.

3.1 Components

The general architecture for social care system is composed of sub-systems that acquire data from the user's home, transfer this information to a remote Alarm center in a reliable and unobtrusive way.

3.1.1 Alarm Trigger

Alarm Trigger is a portable alarm transmitter intended to be used together with an Alarm unit. This unit can be worn by the wrist or as a necklace with a panic button [7]. The user pushes a panic alarm button which generates an alarm signal in case they need immediate help. After pressing the manual button, an alarm is sent to the home Alarm unit which passes the alarm information to the Alarm center.

3.1.2 Sensors

Sensors are installed in and around the user's house to generate a group of alarms. The sensors are designed to collect different types of data, providing information on the patient's environment and activities. Some of the sensors installed in the house include smoke sensors, intruder sensors, and fire sensors.

3.1.3 Alarm Unit

In [8], an Alarm unit is defined as a personal alarm or a telephone based unit that directs for help to your home in an emergency situation. It serves as extra protection in your home to provide re-assurance and support especially if you

- Live alone
- Are infirm or disabled
- Recently left hospital
- Have been victimized
- Are a victim of burglary
- Live in an area with high crime levels

An Alarm unit is activated by pressing a manual button located on either the Alarm unit itself or on the Alarm trigger. However, it can also be activated by the sensors installed around the user's home. The Alarm unit sends these details to a 24-hour Alarm center or directly to the Alarm receiver, where an operator assesses the situation and sends emergency services if required [8].

3.1.4 Alarm Center

This is a 24-hour operational center with a secured server which collects the events and data from the Users' homes. The Alarm center can be independent of the Alarm receiver or they could be collocated. This depends on the type of contract that exists between the Municipal authorities and the Social Alarm Provider. The Alarm center decodes the alarm information (for example the Alarm ID and Alarm type) and establishes a two–way conversation between the user's Alarm unit and either the operator at the Alarm receiver or Alarm center.

Alarm Types

The information received at the Alarm center can be categorized into Technical and Non-Technical Alarms. As shown by Table 3.1, each of the alarms is allocated an Alarm ID, a description name, and grouped in to whether a speech connection between the Alarm unit and the Alarm receiver is required or not. The Alarm ID informs the recipient of the cause of the alarm.

Alarm types that require a speech connection between the Alarm unit and Alarm center are called Non-Technical Alarms. As illustrated by Table 3.1, when such alarms are triggered, the Alarm center establishes a speech connection to the Alarm unit to find out more details about the alarm [5].

However, Technical alarms do not require a speech connection between the Alarm unit and Alarm receiver. When these alarms go off, they are serviced by the Social Alarm Provider without approval from the user. It is their responsibility as the Social Alarm Provider to take proper action, all according to internal procedures defined for each type of alarm type.

Table 3.1: Types of Alarms Programmed by Doro Care AB

Alarm ID	Description (s)	Speech
2	System alarm	No
9	Smoke alarm	Yes
10	Emergency alarm	Yes
17	Battery alarm central unit	No
26	Test alarm	No
32	Fire alarm	Yes
35	Door alarm	No

3.1.5 Alarm Receivers

The Alarm unit can be programmed to communicate with as many as 10 recipient contacts. The recipient contacts consists of a relative's SIP telephone, mobile telephone, or the monitoring center. The primary responsibility of receiving alarms and acting on the alarm calls, lies with the operators at the monitoring center though the relatives who own SIP telephones and mobile phones are informed when an alarm has been made [5].

3.2 Interfaces and Protocols

The different options in parsing data, alarm protocols, and transfer media are very essential in building up different service functions for the alarm analysis. Many Social Alarm Providers have an installed a base of Alarm units, which require specific receiving software and allow for specific transmission technologies. These requirements have to be supported at all times. Session Initiation Protocol (SIP) and H.323 are examples of the protocols, that are used in the communication chain between the Alarm unit and the Alarm receiver.

3.2.1 SIP

The Session Initiation Protocol is a signalling protocol used for setting up, modifying, and terminating real-time sessions over an IP data network [9]. In this project, SIP is used for setting up and terminating real-time sessions between the Alarm unit and Alarm center while the Real-Time Transport Protocol (RTP) is used to send media files between the Alarm unit and the Alarm center.

SIP is chosen because it runs on top of the User Datagram Protocol (UDP) for performance reasons [9]. Hence, this allows the Alarm unit to send the alarm packets to the Alarm center as fast as possible without having to consider the reliability of delivering alarms to the Alarm center. The guarantee of delivering alarm messages is performed by the Alarm receiving server that forces an ACK message back to the Alarm unit.

Overview of SIP Functionality

This section introduces a basic overview of how SIP works. Figure 3.1 is an example of communication between two users, Tom and Clare using SIP. In this example, Tom uses an Alarm unit that supports SIP applications to call Clare on her SIP phone over the Internet.

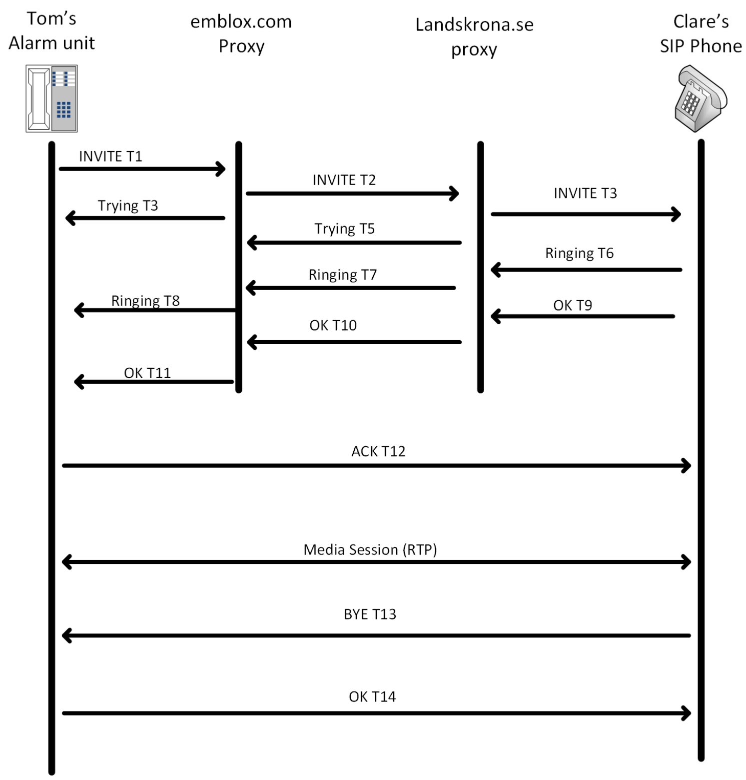

Figure 3.1: SIP session setup

Figure 3.1 also shows two SIP proxy servers namely emblox.com and landskrona.se, that facilitate the sessions on behalf of Tom and Clare respectively. In this example, Tom calls Clare using her SIP identity. A SIP identity is an example of a Uniform Resource Identifier (URI) that is alike to an email address, essentially containing a username and a host name for example sip:clare@landskrona.se. Similarly, Tom also has a SIP URI of sip:tom@emblox.com. However, sometimes SIP also provides a more secure URI, called a SIPS URI. Clare 's URI address could have been already configured in Tom's address book.

SIP essentially relies on a request/response mechanism where any communication between the server and, either Tom or Clare, consists of a request with at-least one response [10]. In this example, communication starts when Tom's Alarm unit sends an INVITE request whose address is Clare's SIP URI. In [10], an INVITE request is a SIP method that specifies what actions the Tom wants the server to act upon. It contains a number of header fields, which provide additional information about the message. The information present in the INVITE message includes a unique identifier for the call, the destination address, Tom's address, and information about the type of session that Tom wants to establish with Clare.

As illustrated in Figure 3.1, initiating a communication session between Tom and Clare starts when the Tom's Alarm unit sends an INVITE (T1) to the SIP server (emblox.com domain). Tom cannot contact Clare directly because he does not know the location of Clare or the SIP server with the landskrona.se domain that serves Clare's domain. Hence, Tom first has to connect to the SIP server (emblox.com domain). The address of the emblox.com SIP server can be configured in Tom's Alarm unit. Sometimes, it can be discovered by Dynamic Host Control Protocol (DHCP) server.

The proxy server receives the INVITE (T1) request from Tom and sends response (Trying T3) back to Tom's Alarm unit, which shows that INVITE (T1) has been received and that the proxy is working on his behalf to send the INVITE to the destination. The emblox.com proxy server finds the proxy server at landskrona.se by performing a Domain Name Service (DNS) lookup, to find the SIP server that serves the landskrona.se domain [10]. When it finds the proxy server, it obtains the IP address of the landskrona.se proxy server and forwards the INVITE (T2) request messsage. However, before the proxy server forwards the request, the emblox.com proxy server adds an additional Via header field value that contains its own address.

The landskrona.se proxy server receives the INVITE (T2) and sends a response back (Trying T5) to the emblox.com proxy server to indicate that it has received the INVITE (T2), and is processing the request. The proxy server then proceeds to search through a location service database, which contains the current IP address of Clare [10]. Hence, the landskrona.se proxy server also adds another Via header field value with its own address to the INVITE and sends it to Clare's SIP phone.

Clare's SIP phone receives the INVITE (T3) message and alerts Clare to the incoming call from Tom. Clare decides whether to pick up or not to pick up the call when the phone rings. The ringing response is sent back through the proxy servers back to Tom. When Clare picks up the call, the SIP phone responds, to indicate that the call has been answered with an OK message, which also shows the Session Description Protocol (SDP) media description. When the call is answered, media session is started by the Real-time Transport Protocol (RTP). In case Clare is too busy to answer the call, then an Error message would be sent instead of the OK message and thus no media session is started.

3.2.2 H.323

H.323 is a protocol that provides multi-media communication sessions on an IP network. H.323 protocol essentially defines components, procedures, and protocols that are used over a multi-media communication session.

Overview of H.323 Functionality

In reference to Figure 2.2 and Figure 2.4, H.323 protocol is used between the VOIP gateway and the Alarm receiver. H.323 protocol was chosen ahead of SIP because it is interoperable with the hardware at the Alarm receiver. Figure 3.2 illustrates the call set up procedure between two H.323 terminals, where by Terminal 1 wants to establish communication with Terminal 2.

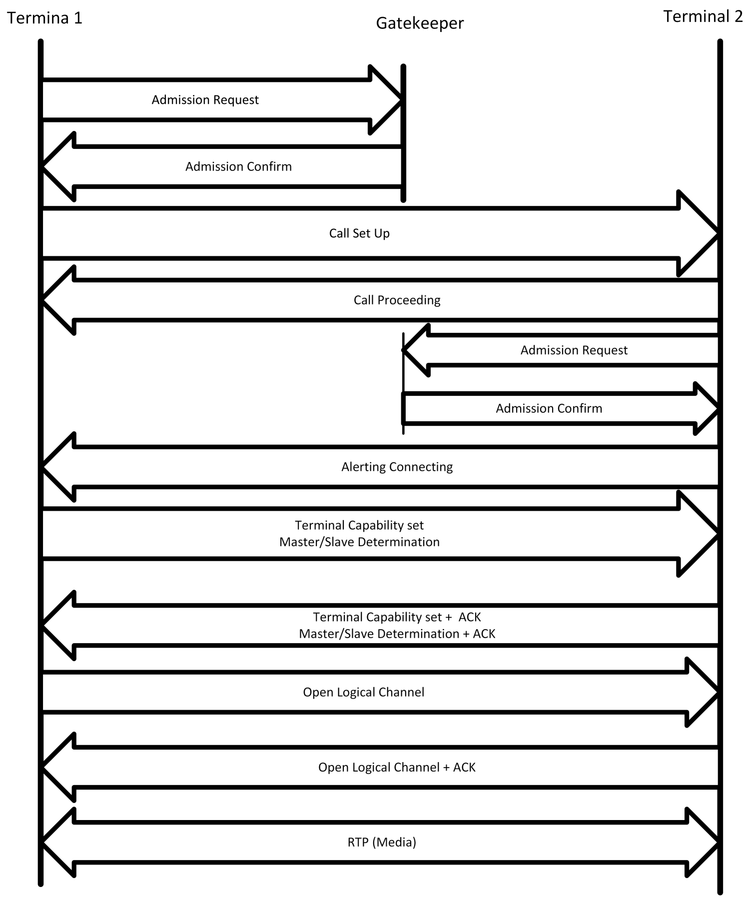

Figure 3.2: H.323 session setup

Terminal 1 exchanges Admission Request (ARQ) and Admission Confirmation (ACF) messages with the Gatekeeper. According to [11], the Gatekeeper is an H.323 entity on the network that provides services such as address translation and network access control to H.323 terminals. The call signalling address of the Terminal 2 is returned to the Terminal 1 at the same time when the admission confirmation is sent by the Gatekeeper. The Gatekeeper also sends a Q.931 message to Terminal 2, which contains information about the H.245 protocol, for example the H.245 negotiation port.

Terminal 1 then sends call-set up messages to Terminal 2. The call is established and call proceeding takes place. Hence, Terminal 2 exchanges an ARQ/ACF message with the Gatekeeper if it wants to accept the call. When this is complete, Terminal 1 receives an alert message that Terminal 2 phone is ringing.

With the use of a TCP connection for the H.245 protocol, Terminal 1 negotiates the terminal capability and also initiates a Master Slave determination request. Terminal 2 responds with a combined "terminal capability" and "master-slave" ACK. Hence, Terminal 1 becomes master and Terminal 2 becomes slave. Terminal 1 ends an open channel request to Terminal 2. Terminal 2 acknowledges the message. The voice is then packed and sent as RTP packets.

Chapter 4

Measurements

This chapter presents the procedure of how the measurements of delay and packet loss were performed on the fiber and GPRS networks. In addition, this chapter illustrates the methodology for evaluating the performance of the GPRS and fiber transmission networks. The data that was used in the derivation of the evaluation methodology is located in the Appendix for easy reference.

4.1 Methodology

Prior to the measurements, the project defined the quantity and the measurable parameter, which were used in the performance evaluation of the GPRS and fiber networks.

4.1.1 Quantity

The social care service consists of a series of events. In this project, the series of events mainly consisted of activating alarms and picking up of the alarm call at the premises of the operator. Time was defined as a quantity to compare the duration of events between activating alarms and picking up of the alarm call by the operators. In this project, a timestamp for each of the events was defined as follows:

Alarm Trigger Time (T_{Trigg})

Alarm Trigger Time referred to the time when each alarm was triggered by the Alarm unit.

Ringing Time (T_R)

Ringing Time referred to the time when the telephone at the Alarm receiver started to ring due to an alarm that was triggered by the Alarm unit.

Alarm PickUp Time (T_{PU})

Alarm PickUp Time referred to the time when the operators at the Alarm receiver picked up the telephone that was ringing due to an alarm, which was triggered by the Alarm unit.

4.1.2 Measurable

The project defined delay as the measurable parameter, which was used to evaluate the performance of the GPRS and fiber networks. The quantities of Alarm Trigger Time, Ringing Time, and Alarm PickUp Time were used to evaluate the different types of delay experienced by the users of the social care service. Figure 4.1 shows the two different types of delay experienced by the users of the social care service.

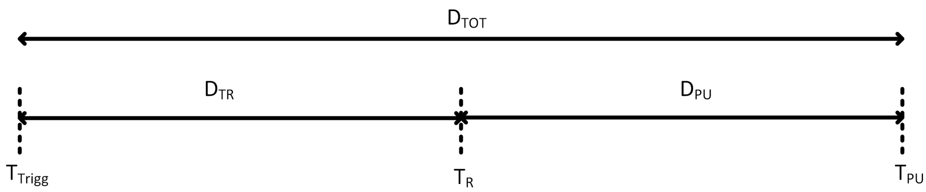

Figure 4.1: Types of Delays

Transmission Network Delay

In this project, Transmission Network Delay is also referred to as the Trigger to Ring Delay (D_{TR}). Trigger to Ring Delay refers to the time interval between manually pressing the alarm button (T_{Trigg}) at the Alarm unit and receiving the ringing response from the telephone at the Alarm receiver (T_{R}). This type of delay arises due to transmission network or connection challenges, as the Alarm unit attempts to set up a call with the Alarm center.

Trigger to Ring Delay, D_{TR} is defined as

$$D_{\mathrm{TR}} = T_{\mathrm{R}} - T_{\mathrm{Trigg}} \tag{4.1}$$

Human Delay

In this project, Human Delay is also referred to as PickUp Delay (D_{PU}). PickUp Delay is defined as the time interval between when the operators at the Alarm receiver answers the ringing telephone (T_{PU}) and the time when the telephone started to ring (T_{R}). This type of delay arises due to the operators delaying to respond to a ringing telephone.

PickUp Delay, D_{PU} is defined as

$$D_{\mathrm{PU}} = T_{\mathrm{PU}} - T_{\mathrm{R}} \tag{4.2}$$

The sum of the Trigger to Ring Delay and the PickUp Delay is what is known as the Total Delay (D_{TOT}), which is experienced by the users of the social care service.

4.2 Measurements SetUp

4.2.1 Hardware

This project developed a prototype of the social care system, which is based on fiber. A comparison was made to determine whether transmitting social alarms over fiber could be better than using the GPRS network. Hence, this section describes the hardware used for performing the experiments on the architectures illustrated in Figure 2.4 and Figure 2.2. The hardware did consist of two Alarm units and two measurement probes. The Alarm units were used to trigger the social alarms. During the experiments, one of the Alarm units was configured to transmit using IP/SIP communication over fiber, and the second Alarm unit was configured to transmit over GPRS. The Alarm units were programmed by the Social Alarms Provider before being put to use. Hence, already configured alarm units were used for the implementation of the project.

The Measurement Probes used in the project were developed by Netrounds on a certified x86 hardware (HW Probe) [12]. The probes measured traffic on the network and stored the measurements on a cloud. The measurement data was retrieved from the cloud as WireShark files.

4.2.2 Measurement Environment

Test Locations

Because of the need to establish whether a change in location could have an affect on the measurements of delay, experiments were performed in different locations in the municipality. At each of the Test Locations, the GPRS signal strength was measured.

The locations namely Test Location 1 and Test Location 2 were chosen by the operators at the Alarm receiver because, it was at these locations that the elderly population petitioned for help from the municipal authorities regarding the quality of the social care service. The average GPRS signal strength at Test Location 1 and Test Location 2 was -75 dBm and -73 dBm respectively. Test Location 3 was chosen by Landskrona Energi so as to act as a Reference location. The average GPRS signal strength at Test Location 3 was -63 dBm, which was superior than the threshold of -83 dBm required for the Alarm unit to operate effectively.

4.2.3 Measurement of Delay

At each of the locations, the measurement environment was prepared according to the archictectures in Figure 4.2 and Figure 4.3. The two Alarm units in Figure 4.2 and Figure 4.3 were triggered simultaneously. Alarms were triggered from 10:00 am to 4:00 pm in intervals of 20 minutes. Hence, during the experiments, a measurement period was defined as the interval between 10:00 am to 4:00 pm when the alarms were triggered, and transmitted from the Alarm unit to the Alarm receiver.

In Figure 4.2, two measurement probes are used. One of the measurement probes is connected at the Alarm unit. The second measurement probe is con-

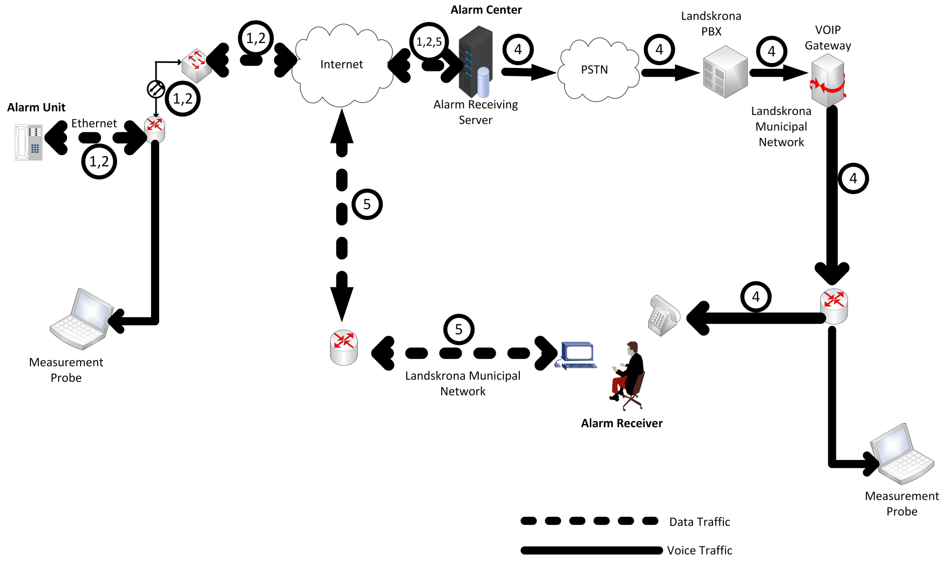

Figure 4.2: Measurement Set-Up on the Fiber Network

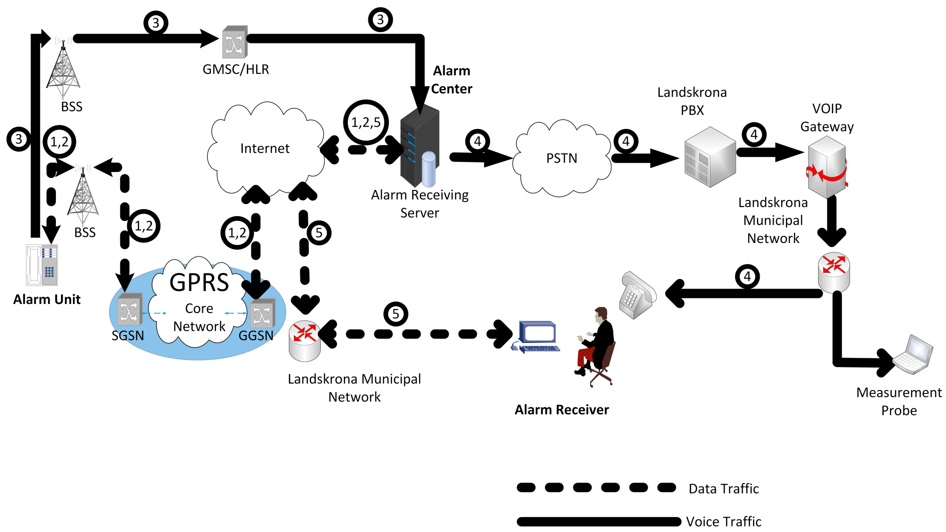

Figure 4.3: Measurement Set-Up on the GPRS Network

nected at the premises of the Alarm receiver. The two probes were synchronized using Network Time Protocol (NTP).

The probe at the Alarm unit generated a WireShark file, which provided the time when the alarm was triggered (T_{Trigg}), and the time when the telephone at the Alarm receiver started to Ring (T_R). The WireShark file generated from the probe at the premises of the Alarm receiver provided the time when the telephone was picked up by the operators (T_{PU}).

With the set-up in Figure 4.3, the delay that occurs over the GPRS network was estimated using measurements. In this set-up, a single probe located at the premises of the Alarm receiver was used to measure the time when the telephone is picked up by the operators (T_{PU}). The measurements of the Alarm Trigger Time (T_{Trigg}), and the Ringing Time (T_R) for alarms transmitted using GPRS required a specialized measurement probe. Because the Alarm units in Figure 4.2 and Figure 4.3 were triggered at the same time, the Alarm Trigger Time for the alarms transmitted over fiber was the same as the Alarm Trigger Time for alarms transmitted over GPRS.

For each alarm triggered, the probes were able to capture the Alarm Trigger Time, Ringing Time, and the Alarm PickUp Time. Figure 4.4 illustrates a WireShark file that was retrieved from the probe at the Alarm unit, for an alarm triggered at 15:00:00.778 Hrs.

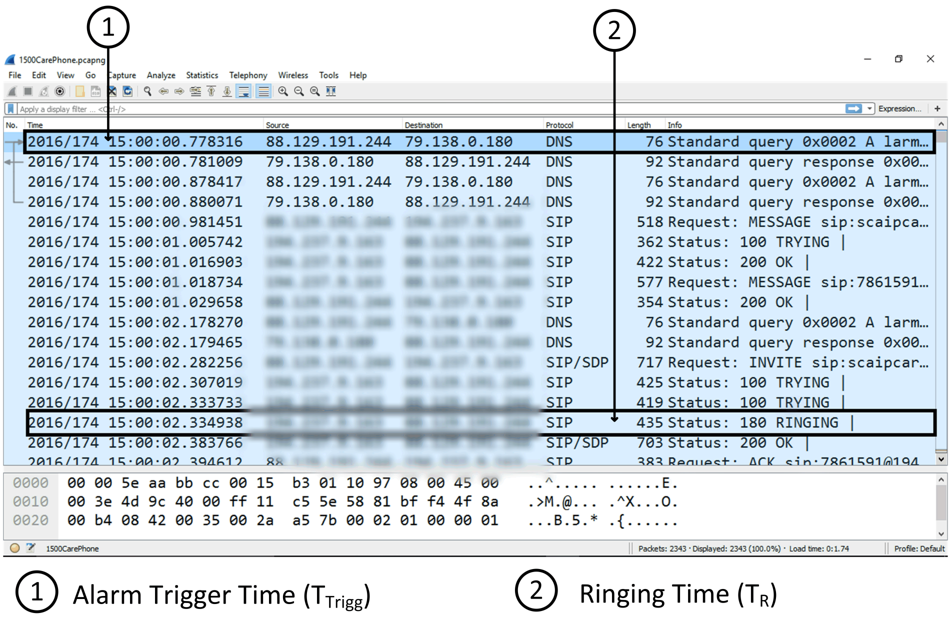

Figure 4.4: WireShark output from the probe at the Alarm unit, for an alarm transmitted using fiber.

In Figure 4.4, the window labelled 1 shows the time when the Alarm unit was triggered (T_{Trigg}). The Alarm unit performs a query of the Domain Name Service (DNS) server for the IP address of the Alarm receiving server, which returns with an IP address of the Alarm receiving server. The Alarm unit establishes a SIP session with the Alarm receiving server.

In the window labelled 2 of Figure 4.4, a Ringing response is returned to the Alarm unit that triggered the alarm. Hence, the window labelled 2 shows the Ringing Time (T_R) for the telephone at the Alarm receiver. Therefore, windows labelled 1 and 2, show the Alarm Trigger Time (T_{Trigg}) and Ringing Time (T_R) for an alarm that was triggered at 15:00:00.778 Hrs.

Figure 4.5 shows the Alarm PickUp Time (T_{PU}) for the alarm triggered at 15:00:00.778 Hrs, and transmitted using the fiber.

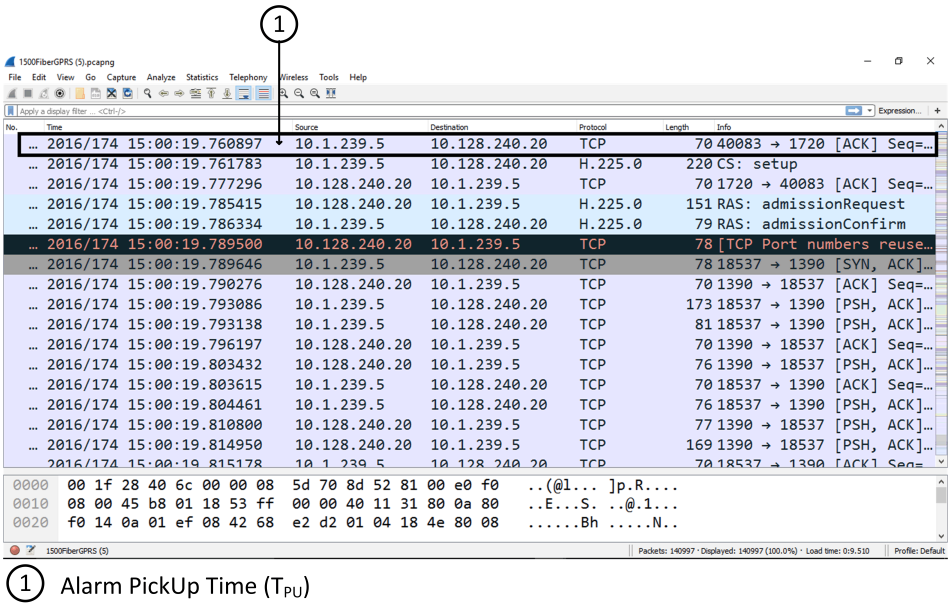

Figure 4.5: WireShark output from the probe at the Alarm receiver, for an alarm transmitted using fiber.

Although, the two alarms had the same Alarm Trigger Time (T_{Trigg}), the Alarm PickUp Time (T_{PU}) for each alarm was different. Figure 4.6 is of a WireShark file showing when the telephone was picked up for an alarm that was triggered at 15:00:00.778 Hrs, and transmitted using GPRS.

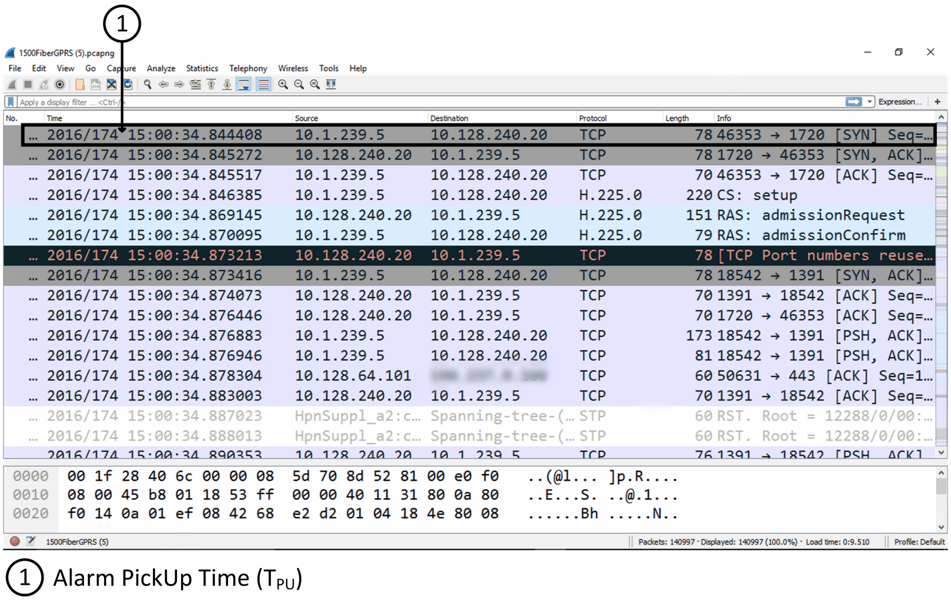

Figure 4.6: WireShark output from the probe at the Alarm receiver, for an alarm transmitted using GPRS.

4.3 Packet loss

Measurements of packet loss were performed on the GPRS network, in order to establish why alarms transmitted using GPRS experienced extremely long delays. In addition, measurements of packet loss were also performed were on the fiber network.

Two host computers were separately used to ping the Swedish University Computer Network (SUNET) as the destination computer. Hence, one of the computers was connected to the GPRS network, and second computer was connected to the fiber network. The host computers did send request messages to SUNET at periodic intervals. Hence, the Command Prompt reported a statistical summary of the packet loss, and the time it took for a response message to return to the host computers.

The measurements of packet loss were performed at each Test location (Test Location 1, Test Location 2, and Test Location 3) for a period of 7 hours from 10:00 am to 4:00 pm. Figure 4.7 shows a summary of the statistics generated from the packet loss measurements performed at Test Location 1.

```
C:\Users\Administrator>ping -t ping.sunet.se

Pinging ping.sunet.se [192.36.125.18] with 32 bytes of data:

Reply from 192.36.125.18: bytes=32 time=183ms TTL=53
Reply from 192.36.125.18: bytes=32 time=263ms TTL=53
Reply from 192.36.125.18: bytes=32 time=191ms TTL=53
Reply from 192.36.125.18: bytes=32 time=194ms TTL=53
Reply from 192.36.125.18: bytes=32 time=234ms TTL=53
Reply from 192.36.125.18: bytes=32 time=182ms TTL=53
Reply from 192.36.125.18: bytes=32 time=184ms TTL=53

Ping statistics for 192.36.125.18:
Packets: Sent = 19157, Received = 18766, Lost = 391 (2 %)
Approximate round trip times in milli-seconds:
Minimum = 119 ms, Maximum = 4058 ms, Average = 305 ms

Control-C
^C
C:\Users\Administrator>
```

Figure 4.7: Command-line output of the Packet loss measurements of the GPRS network at Test Location 1

4.4 Evaluation Methodology

In this section, a measurements-based evaluation methodology was developed to determine the Trigger to Ring Delay and PickUp Delay for all alarms triggered in the project. Hence, an alarm triggered at 15:00:00.778 Hrs is used as an example to show how the data retrieved from the WireShark files was evaluated, to determine the Trigger to Ring Delay (D_{TR}) and PickUp Delay (D_{PU}) over fiber and GPRS networks.

However, it is important to note that all alarms in the project were grouped according to the measurement period when the alarms were triggered. For example, the Table A.1 and Table A.2 in the Appendix shows how the alarm triggered at 15:00:00.778 Hrs was grouped with others, triggered during the same measurement period.

4.4.1 Analysis of Alarms transmitted over Fiber

This subsection describes how the Trigger to Ring Delay (D_{TR}) and the PickUp Delay (D_{PU}) were determined for the alarms transmitted over fiber.

Trigger to Ring Delay over Fiber

Figure 4.4 shows the time when the alarm was triggered, (T_{Trigg}). Figure 4.4 also shows the time when the telephone at the Alarm receiver starts to ring, (T_R). Hence, the Alarm Trigger Time and the Ringing Time for this particular alarm, triggered at 15:00:00.778 Hrs is given by

$$T_{\text{Trigg}}(fiber) = 15 : 00 : 00.778 \text{ Hrs} \quad (4.3)$$

$$T_{\text{R}}(fiber) = 15 : 00 : 02.334 \text{ Hrs} \quad (4.4)$$

Using T_R(fiber), T_{Trigg}(fiber), and (4.1), the Trigger to Ring Delay (D_{TR}) for this alarm is given by

$$D_{\text{TR}}(fiber) = 1.556 \text{ s} \quad (4.5)$$

PickUp Delay over Fiber

Figure 4.5 provides the time for which the operators at the Alarm receiver picked up the telephone, which was ringing due to the alarm triggered at 15:00:00.778 Hrs. Hence, the Alarm PickUp Time is given by

$$T_{\text{PU}}(fiber) = 15 : 00 : 19.7608 \text{ Hrs} \quad (4.6)$$

Using T_{PU}(fiber), T_R(fiber), and (4.2), the

$$D_{\text{PU}}(fiber) = 17.4268 \text{ s} \quad (4.7)$$

Table A.1 shows the data that was processed out of the WireShark traces obtained during one of measurements performed at Test Location 1. Hence, using the Table A.1, (4.1) and (4.2), the Trigger to Ring Delay (D_{TR}(fiber)) and PickUp Delay (D_{PU}(fiber)) was calculated for all alarms showed in the Table A.1.

4.4.2 Analysis of Alarms transmitted over GPRS

This subsection describes how the Trigger to Ring Delay and the PickUp Delay was determined for alarms that were transmitted using GPRS. Due to the challenge of not finding a specialized measurement probe that would measure alarm traffic over a GPRS link, the following assumptions were made

- Because the Alarm units that transmitted alarms using GPRS and fiber networks were triggered simultaneously, the Alarm Trigger Time for alarms transmitted using GPRS was assumed to be the same as Alarm Trigger Time for alarms transmitted using fiber.

  Hence,

  T_{Trigg}(GPRS) =T_{Trigg}(fiber)
- The average PickUp Delay for fiber transmissions, during a measurement period was assumed to be the same as the average PickUp Delay for GPRS transmissions during the same measurement period. Hence,

  mean(D_{PU}(GPRS)) = mean(D_{PU}(fiber))

These assumptions were made in order to get an estimation of Alarm Trigger Time and Ringing Time for GPRS transmissions. However, the Alarm PickUp Time for the alarms transmitted using GPRS was known because the measurement probe at the Alarm receiver captured all the traffic that was received, in-respective of whether it was transmitted using GPRS or fiber.

PickUp Delay over GPRS

Using the assumption where the average PickUp Delay for fiber transmissions is the same as the average PickUp Delay over GPRS transmissions for the same measurement period. Hence, the PickUp Delay over GPRS ($\mathrm{D_{PU}}$(GPRS)) is defined as

$$mean(D_{\mathrm{PU}}(GPRS)) = mean(D_{\mathrm{PU}}(fiber)) \tag{4.8}$$

The mean PickUp Delay calculated from all alarms grouped in Table A.1 is 17 s. Hence, using (4.8) the

$$mean(D_{\mathrm{PU}}(GPRS)) = mean(D_{\mathrm{PU}}(fiber)) = 17 \text{ s} \tag{4.9}$$

Re-arranging (4.2), the Ringing Time for each of the alarms transmitted over GPRS can be approximated from the following equation

$$T_{\mathrm{R}}(GPRS) = T_{\mathrm{PU}}(GPRS) - D_{\mathrm{PU}}(GPRS) \tag{4.10}$$

From Figure 4.6, the Alarm PickUp Time for the alarm triggered at 15:00:00.778 Hrs is

$$T_{\mathrm{PU}}(GPRS) = 15:00:34.844 \text{ Hrs} \tag{4.11}$$

Using (4.11) and (4.9), the Ringing Time for this alarm transmitted over GPRS as defined by equation (4.10) was approximated as

$$T_{\mathrm{R}}(GPRS) = 15:00:17.844 \text{ Hrs} \tag{4.12}$$

Trigger to Ring Delay over GPRS

Using the assumption where the Alarm Trigger Time for alarms transmitted over GPRS is the same as the Alarm Trigger Time for alarms transmitted over Fiber. The Alarm Trigger Time for this alarm that was transmitted using GPRS is approximated as

$$T_{\mathrm{Trigg}}(GPRS) = 15:00:00.778 \text{ Hrs} \tag{4.13}$$

Using the Ringing Time for GPRS in (4.12), and Alarm Trigger Time in (4.13), the Trigger to Ring Delay for this alarm transmitted using GPRS is approximated as

$$D_{\mathrm{TR}}(GPRS) = 17 \text{ s} \tag{4.14}$$

The methodology derived here shows how the Trigger to Ring Delay and the PickUp Delay were determined, for an alarm that was triggered at 15:00:00.778 Hrs, and transmitted from the Alarm unit to the Alarm receiver. However, the same methodology was used to determine the Trigger to Ring Delay and the PickUp Delay for all alarms that were triggered in this project.

Error sources

Truncation and rounding off of the values used in the determination of the Trigger to Ring Delay and PickUp Delay is a possible source of errors.

Chapter 5

Results and Discussion

5.1 Transmission Network Delay

In this section, results from Test Location 1 are presented. Using the data in Table A.1 and Table A.2, the Trigger to Ring Delay for alarms transmitted using fiber and GPRS were separately estimated. Figure 5.1 shows the comparison of the Trigger to Ring Delay experienced by alarms transmitted by fiber and GPRS networks. The standard error plot of the mean Trigger to Ring Delay for alarms transmitted using fiber and GPRS networks is presented in Figure 5.2.

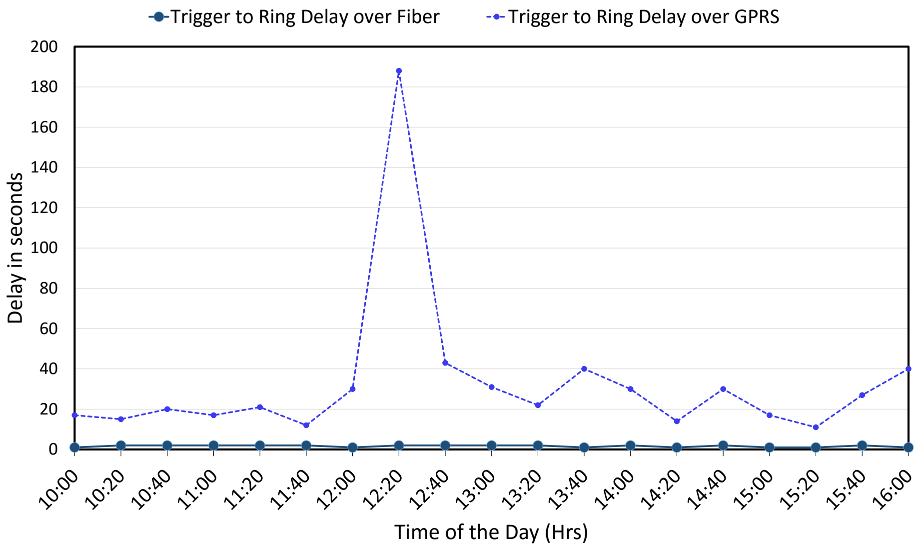

Figure 5.1: Comparison of the Trigger to Ring Delay for alarms transmitted using GPRS and fiber.

In Figure 5.1, the maximum and minimum Trigger to Ring Delay for alarms transmitted by GPRS are 188 s and 11 s, respectively. The maximum and minimum Trigger to Ring Delay for alarms transmitted using fiber are 2 s and 1 s, respectively.

Figure 5.2 shows that there is significant difference between the Trigger to Ring Delay over fiber and GPRS transmission technologies. Hence, the mean Trigger to Ring Delay over GPRS for the entire measurement period is 33 s while the mean Trigger to Ring Delay over fiber is approximately 2 s. The difference of the mean Trigger to Ring Delay between the two transmission technologies is approximately 31 s.

Figure 5.2 also shows that the standard error of the mean Trigger to Ring Delay for alarms transmitted using fiber and GPRS as 0 s and 8 s, respectively. Hence, the values of the Trigger to Ring Delay for alarms transmitted by fiber are very close to the mean Trigger to Ring Delay. However, the values of the Trigger to Ring Delay for alarms transmitted by GPRS are spread out over a wider range of values. This shows that the Trigger to Ring Delay over GPRS is highly unstable when compared to the Trigger to Ring Delay over fiber, which is relatively stable.

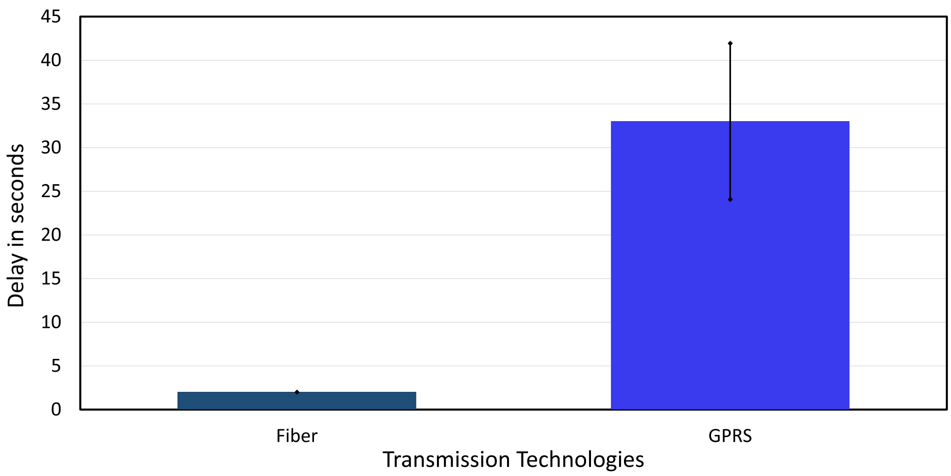

Figure 5.2: Standard Error Plot of the Mean Trigger to Ring Delay for alarms transmitted using fiber and GPRS.

5.2 Human Delay

The comparison between the Trigger to Ring Delay and PickUp Delay for alarms transmitted using the fiber network is presented in Figure 5.3. This comparison is made to find out whether the Trigger to Ring Delay or PickUp Delay contributes more, towards the total delay experienced by the users of the social care service.

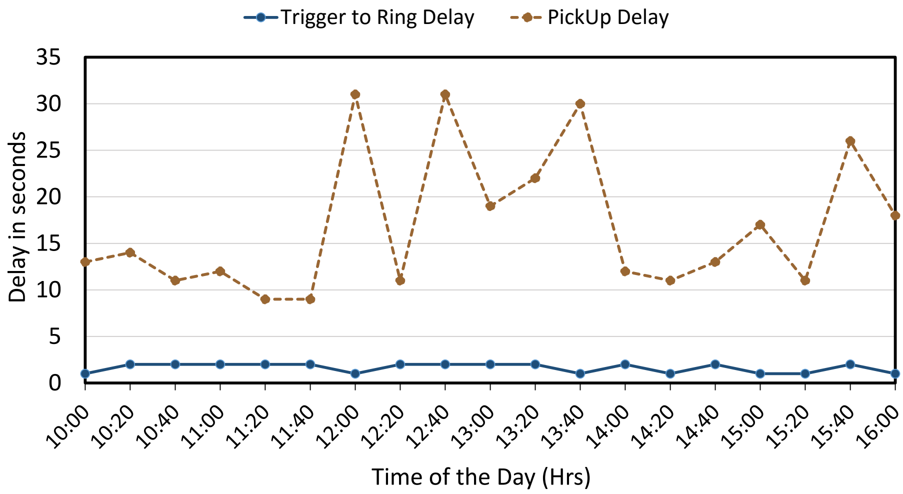

Figure 5.3: Comparison between the Trigger to Ring Delay and the PickUp Delay for alarms transmitted using fiber.

Figure 5.3 shows that the PickUp Delay contributes more towards the total delay experienced by the users of the social care service than the Trigger to Ring Delay. In Figure 5.3, the maximum and minimum delay contributed by the operators at the Alarm receiver are 30 s and 9 s, respectively. However, the delay contributed by the fiber network has a maximum of 2 s and a minimum of 1 s. Figure 5.4 shows that the standard error of the mean Trigger to Ring Delay for alarms transmitted using fiber is 0 s.

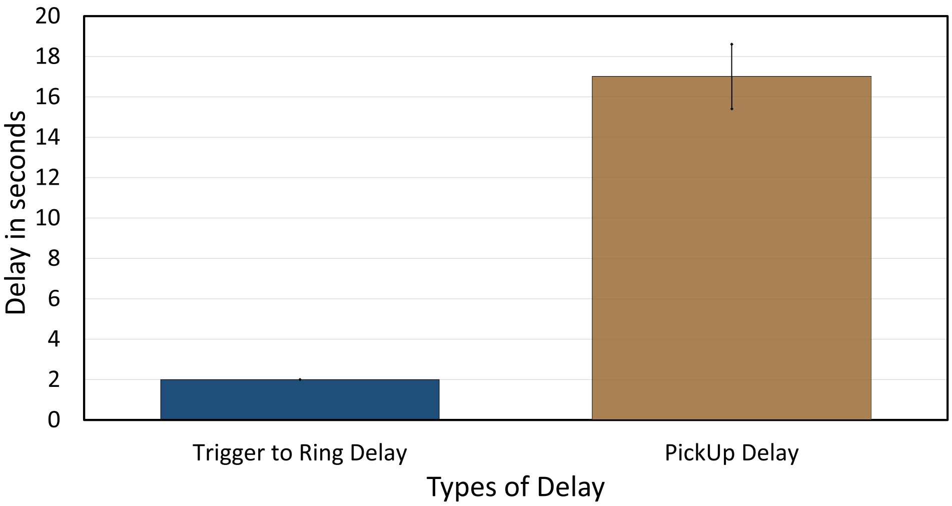

Figure 5.4: Standard Error Plot of the Mean Trigger to Ring Delay and the Mean PickUp Delay for alarms transmitted using fiber.

Hence, the values of Trigger to Ring Delay are very close to the mean Trigger to Ring Delay. However, Figure 5.4 also shows that the standard error of the mean PickUp Delay to be approximately 1 s. This means that the values of the PickUp Delay are are spread out over a wider range of values. Hence, the PickUp Delay across the entire measurement period was relatively unstable.

5.3 Reference Location

Because Test Location 1 and Test Location 2 are the locations where the majority of the complaints about delays originated, the measurements of the Trigger to Ring Delay obtained at these two locations were grouped together. Hence, Figure 5.5 shows the comparison of the mean Trigger to Ring Delay obtained from the Trigger to Ring Delay measurements at Test Location 3, and from the combined measurements of the Trigger to Ring Delay obtained at Test Location 1 and Test Location 2.

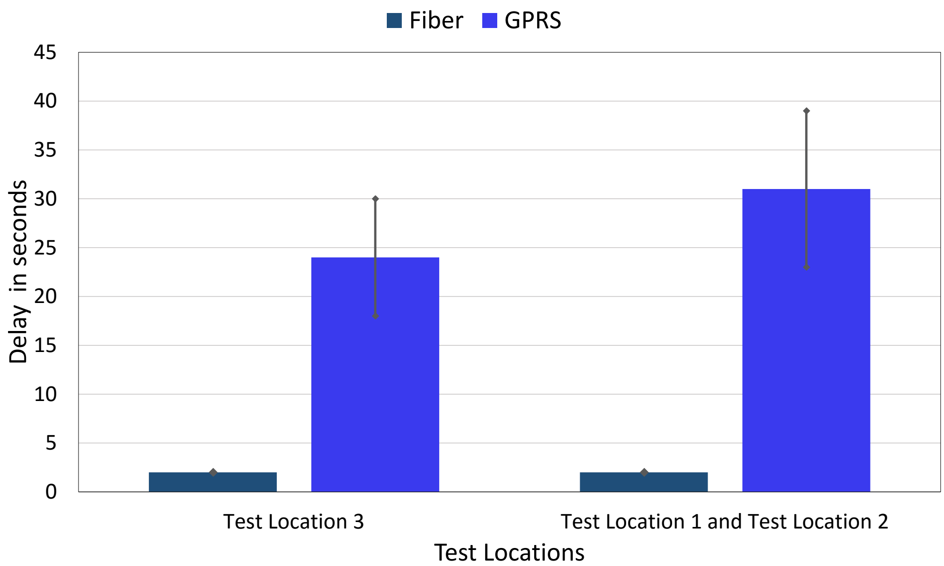

Figure 5.5: Standard Error Plot of the Mean Trigger to Ring Delay at different Test Locations in the Municipality.

Figure 5.5 shows that the mean Trigger to Ring Delay for alarms transmitted using GPRS is different, depending on the Test location where the alarms were triggered. The mean Trigger to Ring Delay for alarms transmitted using GPRS was 31 s at Test location 1 and Test location 2. However, the mean Trigger to Ring Delay was 24 s at the Test Location 3.

The mean Trigger to Ring Delay for alarms transmitted using fiber was the same in-respective of the Test location where the measurements were performed. Hence, the mean Trigger to Ring Delay was 2 s at all the Test Locations.

5.4 Impact of Packet loss

Figure 5.6 shows that the packet loss measurements of the GPRS network at Test Location 3 was 1 %. Test Location 1 and Test Location 2 generated an average packet loss of 2 %. However, Figure 5.6 also shows that a statistic of 0 % packet losses was obtained on the fiber network at all the Test Locations.

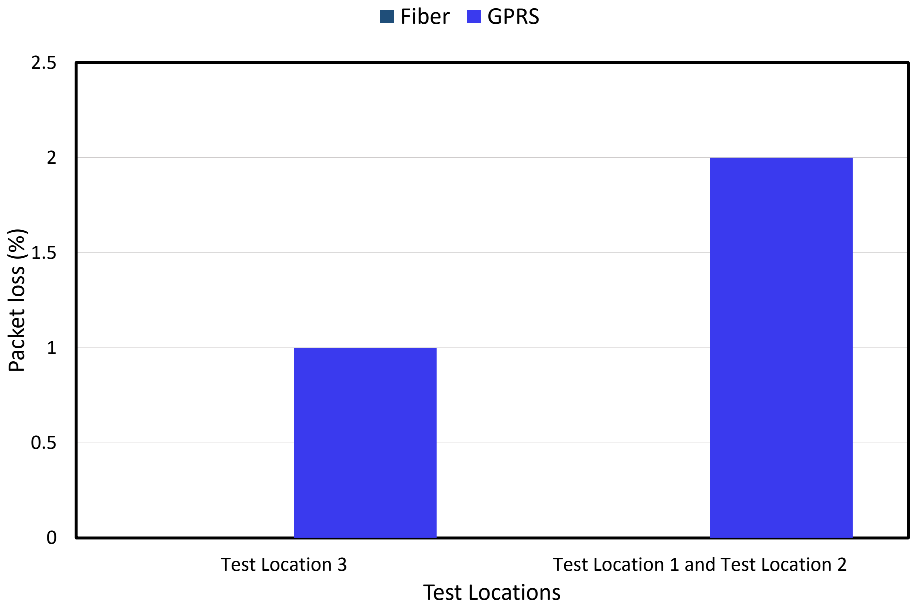

Figure 5.6: Plot of Packet Loss measurements for GPRS and Fiber transmission networks.

5.5 Discussion

The higher the loss rates, the higher will be the number of connection failures experienced by a given network. Hence, having packet losses on a network equal or even greater than 1 %, will definitely have an impact on the overall performance of such a network. With a packet loss range between 1 % to 10 %, the duration of the transmission network delay on any wireless network will remain between 1 to 100 seconds [13]. Given that GPRS generated packet losses of more than 1%, demonstrated that, part of the delays experienced by the social care system is due to the usage of GPRS as a transmission medium. During one of the measurements that lasted 20 minutes, packets losses of up to 26 % were obtained at Test Location 1. This explains why sometimes the transmission network delay exceeded 100 seconds.

During the experiments, the GPRS signal strength was measured at Test Location 1, Test Location 2, and Test Location 3. The signal strength measurements at all the Test Locations was found to be greater than the threshold of -83 dBm. Hence, in real life situations, the Social Alarm Provider could have installed alarm units at each of these locations. Furthermore, alarms were only triggered at a time when the operators were not engaged by other users of the social care system. Hence, the holding time due to the operators being engaged by other users of the service was eliminated. Consequently, this study depicts what happens in real life situations.

With reference to Figure 5.5, it can be noted that GPRS always generates a high transmission network delay irrespective of the signal strength. Hence, a higher signal strength of a GPRS link provides a noticeable impact on the delay. But, it is significantly higher than the transmission network delay experienced over the fiber network. Figure 5.2 also showed that the transmission network delay for alarms transmitted by GPRS are spread out over a wider range of values. The large spread experienced by the GPRS network is due to the influence of the wireless channel as having a noisy environment [13]. However, the transmission network delay for alarms transmitted by fiber are very close to the average measurement.

The transmission network delay over GPRS cannot be described by a single value because it is dependent on the wireless channel characteristics (environment). Hence, it can be a range of values depending on the percentage of the packets lost. In this project, it has been shown that, the transmission network delay experienced by alarms transmitted by fiber could be between 1 and 2 seconds. Finally, it is also worth to mention that results obtained in this project cannot be generalized to other environments. The environment in which the experiments is performed will always have an effect on the results obtained.

Chapter 6

Conclusion

To the best of my knowledge, not so much work has been done in investigating the performance of transmitting social alarms over fiber and GPRS networks. In this project, the performance evaluation of transmitting social alarms through the GPRS and fiber networks has been performed. In addition, this project analyzed the effect of various parameters (like GPRS signal strength, packet loss rates) on the performance of the social care system that is deployed on the GPRS and fiber networks. This project has showed successful results in our goal of reducing the transmission network delays experienced by the users of this service. In the project, it was shown that GPRS is the major contributor to the delays experienced by the users of the current social care system in Landskrona municipality. The passive analysis of the data set collected during the measurements showed that GPRS is characterised by high transmission network delays, whereby the majority of the delays were as a result of necessary packet retransmissions. However, in the project, it was also shown that the fiber network experienced close to 0 % packet loss. Hence, the low transmission network delays experienced when alarms are transmitted using the fiber network.

Therefore, there is a big potential in reducing the transmission network delays experienced by social care systems should the underlying transmission infrastructure be replaced with fiber. However, in order to create a highly reliable social care system, GPRS could be used as a back up transmission medium in case of service disruption to the fiber network. It is worth mentioning that operators at the Alarm receiver contribute to the total delay experienced by the users of the service. Hence, this problem still exists.

6.1 Future Work

Regarding the future work that would build upon this project, a lot of work is needed to reduce the waiting time before the user can speak to an operator at the Alarm receiver. This waiting time is created by the operators who are reluctant to pick up a ringing telephone. Finally, there is need to study the feasibility of adopting the alarm units to the latest wireless transmission technologies for example LTE.

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Appendix A

Appendix

A.1 Results from Test Location 1 (Västra Fäladen)

Table A.1 shows the Alarm Trigger Time, Ringing Time, and Alarm PickUp Time for alarms transmitted using the Fiber network.

Table A.1: Results of Alarm Trigger Time, Ringing Time, and Alarm PickUp Time for alarms transmitted using Fiber

Alarm Trigger Time	Ringing Time	Alarm PickUp Time
10:00:00.727	10:00:02.456	10:00:15.243
10:20:00.064	10:20:02.116	10:20:16.494
10:39:58.496	10:40:00.716	10:40:11.984
11:00:00.041	11:00:02.715	11:00:14.736
11:20:00.144	11:20:02.512	11:20:11.461
11:42:00.768	11:42:02.808	11:42:12.300
12:00:01.033	12:00:02.676	12:00:33.967
12:20:02.082	12:20:04.544	12:20:16.008
12:46:00.986	12:46:03.335	12:46:34.817
13:00:00.981	13:00:03.222	13:00:22.243
13:20:01.030	13:20:03.091	13:20:25.354
13:41:01.172	13:41:02.920	13:41:32.916
14:01:01.422	14:01:03.770	14:01:16.167
14:20:00.679	14:20:02.638	14:20:13.354
14:42:00.913	14:42:03.467	14:42:16.467
15:00:00.778	15:00:02.334	15:00:19.760
15:20:00.627	15:20:02.184	15:20:12.881
15:40:00.577	15:40:03.033	15:40:28.671
16:00:00.926	16:00:02.887	16:00:19.971

Table A.2 is shows the Alarm Trigger Time, Estimated Ringing Time, and Alarm PickUp Time for alarms transmitted using GPRS network.

Table A.2: Results of Alarm Trigger Time, Estimated Ringing Time, and Alarm PickUp Time for alarms transmitted using GPRS

Alarm Trigger Time	Estimated Ringing Time	Alarm PickUp Time
10:00:00.727	10:00:18.123	10:00:35.123
10:20:00.064	10:20:15.667	10:20:32.667
10:39:58.496	10:40:18.674	10:40:35.674
11:00:00.041	11:00:17.111	11:00:34.111
11:20:00.144	11:20:21.778	11:20:38.778
11:42:00.768	11:42:13.579	11:42:30.579
12:00:01.033	12:00:31.704	12:00:48.704
12:20:02.082	12:23:10.561	12:23:27.561
12:46:00.986	12:46:44.464	12:47:01.464
13:00:00.981	13:00:31.987	13:00:48.987
13:20:01.030	13:20:23.506	13:20:40.506
13:41:01.172	13:41:41.441	13:41:58.441
14:01:01.422	14:01:31.464	14:01:48.464
14:20:00.679	14:20:15.650	14:20:32.650
14:42:00.913	14:42:31.112	14:42:48.112
15:00:00.778	15:00:17.844	15:00:34.844
15:20:00.627	15:20:12.443	15:20:29.443
15:40:00.577	15:40:28.086	15:40:45.086
16:00:00.926	16:00:41.143	16:00:58.143

Table A.3: Results of the Alarm Trigger Time, Ringing Time, and Alarm PickUp Time for alarms transmitted using Fiber

Alarm Trigger Time	Ringing Time	Alarm PickUp Time
10:03:00.024	10:03:02.761	10:03:58.232
10:23:00.065	10:23:02.150	10:23:13.067
10:42:59.469	10:43:02.128	10:43:18.471
11:03:00.094	11:03:02.895	11:03:42.102
11:23:00.890	11:23:02.743	11:23:21.374
11:43:00.056	11:43:01.187	11:43:17.111
12:03:00.787	12:03:02.440	12:03:18.461
12:23:00.092	12:23:02.125	12:23:44.943
12:46:00.862	12:46:03.121	12:46:32.022
13:05:59.121	13:06:01.698	13:06:40.246
13:26:00.759	13:26:02.814	13:26:24.581
13:45:58.345	13:46:01.781	13:46:24.581
14:07:00.056	14:07:02.431	14:07:14.660
14:27:00.127	14:27:02.341	14:27:19.376
14:37:00.721	14:37:02.284	14:37:16.468
15:07:00.067	15:07:01.892	15:07:10.689
15:27:00.086	15:27:02.136	15:27:23.117
15:37:00.767	15:37:02.829	15:37:13.244
16:07:00.812	16:07:02.145	16:07:29.035
16:27:00.431	16:27:02.126	16:27:19.196
16:37:00.074	16:37:01.876	16:37:23.674

Table A.4: Results of Alarm Trigger Time, Estimated Ringing Time, and Alarm PickUp Time for alarms transmitted using GPRS

Alarm Trigger Time	Estimated Ringing Time	Alarm PickUp Time
10:03:00.024	10:05:10.016	10:05:33.016
10:23:00.065	10:23:34.000	10:23:57.000
10:42:59.469	10:43:32.412	10:43:55.412
11:03:00.094	11:03:53.771	11:04:16.771
11:23:00.890	11:23:09.036	11:23:32.036
11:43:00.056	11:43:29.418	11:43:52.418
12:03:00.787	12:03:19.341	12:03:42.341
12:23:00.092	12:23:52.461	12:24:15.461
12:46:00.862	12:46:33.114	12:46:56.114
13:05:59.121	13:06:43.417	13:07:06.417
13:26:00.759	13:27:05.755	13:27:28.755
13:45:58.345	13:46:29.151	13:46:52.151
14:07:00.056	14:07:12.112	14:07:35.112
14:27:00.127	14:27:35.241	14:27:58.241
14:37:00.721	14:37:25.594	14:37:48.594
15:07:00.067	15:07:18.316	15:07:41.316
15:27:00.086	15:27:32.126	15:27:55.126
15:37:00.767	15:37:18.316	15:37:41.316
16:07:00.812	16:07:18.980	16:07:41.980
16:27:00.431	16:27:26.445	16:27:49.445
16:37:00.074	16:37:36.345	16:37:59.345

Table A.5: Results of Alarm Trigger Time, Ringing Time, and Alarm PickUp Time for alarms transmitted using Fiber

Alarm Trigger Time	Ringing Time	Alarm PickUp Time
10:00:00.727	10:00:03.168	10:00:17.387
10:23:59.745	10:24:01.990	10:24:18.590
10:40:00.723	10:40:02.877	10:40:37.855
11:04:00.742	11:04:02.687	11:04:42.145
11:25:00.483	11:25:02.536	11:25:35.982
11:45:00.331	11:45:02.383	11:45:22.130
12:07:00.665	12:07:02.213	12:07:18.461
12:25:00.429	12:25:02.081	12:25:35.214
12:45:00.477	12:45:02.933	12:45:40.157
13:07:00.611	13:07:02.758	13:07:49.011
13:25:00.775	13:25:02.625	13:25:19.118
13:45:00.724	13:45:02.474	13:45:35.613
14:10:00.435	14:10:02.284	14:10:20.014
14:25:00.521	14:25:02.170	14:25:17.174
14:44:59.970	14:45:02.022	14:45:10.361
15:05:00.918	15:05:02.867	15:05:42.262
15:27:00.652	15:27:02.717	15:27:45.333
15:45:00.716	15:45:02.564	15:45:49.462
16:06:00.956	16:06:03.412	16:06:21.538
16:20:00.231	16:20:02.434	16:20:23.547

Table A.6: Results of Alarm Trigger Time, Estimated Ringing Time, and Alarm PickUp Time for alarms transmitted using GPRS

Alarm Trigger Time	Estimated Ringing Time	Alarm PickUp Time
10:00:00.727	10:00:29.259	10:00:56.259
10:23:59.745	10:24:27.417	10:24:54.417
10:40:00.723	10:41:25.159	10:41:52.159
11:04:00.742	11:04:46.195	11:05:13.195
11:25:00.483	11:25:23.596	11:25:50.596
11:45:00.331	11:45:20.828	11:45:47.828
12:07:00.665	12:07:21.368	12:07:48.368
12:25:00.429	12:25:27.210	12:25:54.210
12:45:00.477	12:45:32.606	12:45:59.606
13:07:00.611	13:08:00.450	13:08:27.450
13:25:00.775	13:25:12.433	13:25:39.433
13:45:00.724	13:45:26.133	13:45:53.133
14:10:00.435	14:10:14.426	14:10:41.426
14:25:00.521	14:25:33.543	14:26:00.543
14:44:59.970	14:45:03.518	14:45:30.518
15:05:00.918	15:05:44.691	15:06:11.691
15:27:00.652	15:27:35.271	15:28:02.271
15:45:00.716	15:45:42.684	15:46:09.684
16:06:00.956	16:06:16.408	16:06:43.408
16:20:00.231	16:20:29.112	16:20:56.112

A.2 Results from Test Location 2 (Saxtorpsskogen)

Table A.7: Results of Alarm Trigger Time, Ringing Time, and Alarm PickUp Time for alarms transmitted using Fiber

Alarm Trigger Time	Ringing Time	Alarm PickUp Time
10:52:00.134	10:52:02.210	10:52:11.651
11:00:00.121	11:00:02.234	11:00:24.234
11:20:00.004	11:20:01.751	11:20:13.413
11:40:00.052	11:40:01.599	11:40:19.000
12:00:00.500	12:00:02.447	12:00:20.780
12:20:02.148	12:20:02.230	12:20:19.928
12:40:00.496	12:40:02.000	12:41:13.000
13:00:00.445	13:00:02.000	13:00:13.310
13:20:00.293	13:20:01.841	13:21:24.369
13:40:00.541	13:40:02.689	13:40:18.548
13:59:59.890	14:00:01.537	14:00:38.000
14:20:00.538	14:20:02.385	14:20:43.459
14:40:00.587	14:40:02.223	14:40:25.444
15:00:00.211	15:00:02.000	15:00:20.235
15:20:00.383	15:20:01.929	15:20:31.000
15:40:00.231	15:40:01.770	15:40:23.275
16:00:00.267	16:00:01.345	16:00:14.121
16:20:00.129	16:20:02.494	16:20:50.769

Table A.8: Results of Alarm Trigger Time, Estimated Ringing Time, and Alarm PickUp Time for alarms transmitted using GPRS

Alarm Trigger Time	Estimated Ringing Time	Alarm PickUp Time
10:52:00.134	10:52:30.303	10:52:58.303
11:00:00.121	11:00:16.345	11:00:44.345
11:20:00.004	11:20:12.975	11:20:40.975
11:40:00.052	11:40:08.063	11:40:36.063
12:00:00.500	12:00:48.611	12:01:16.611
12:20:02.148	12:20:14.141	12:20:42.141
12:40:00.496	12:41:13.045	12:41:41.045
13:00:00.445	13:00:49.653	13:01:17.653
13:20:00.293	13:21:31.582	13:21:59.582
13:40:00.541	13:40:35.614	13:41:03.614
13:59:59.890	14:00:32.911	14:01:00.911
14:20:00.538	14:20:16.750	14:20:44.750
14:40:00.587	14:40:27.616	14:40:55.616
15:00:00.211	15:00:08.430	15:00:36.430
15:20:00.383	15:20:23.443	15:20:51.443
15:40:00.231	15:40:10.332	15:40:38.332
16:00:00.267	16:00:08.674	16:00:36.674
16:20:00.129	16:20:57.011	16:21:25.011

Table A.9: Results of Alarm Trigger Time, Ringing Time, and Alarm PickUp Time for Alarms transmitted using Fiber

Alarm Trigger Time	Ringing Time	Alarm PickUp Time
11:20:00.927	11:20:03.379	11:21:01.000
11:40:00.872	11:40:03.208	11:41:48.820
12:00:01.021	12:00:03.075	12:00:42.174
12:20:00.770	12:20:02.925	12:20:22.188
12:40:05.418	12:40:07.772	12:40:25.451
12:59:56.467	12:59:58.621	13:00:25.003
13:19:57.611	13:19:59.468	13:20:25.000
13:39:57.764	13:39:59.317	13:40:32.032
13:59:57.413	13:59:59.165	14:00:30.604
14:19:57.361	14:19:59.013	14:20:26.108
14:39:57.410	14:39:59.861	14:40:13.735
15:00:00.123	15:00:03.234	15:00:34.345
15:20:00.343	15:20:02.995	15:20:30.134
15:39:57.556	15:39:59.406	15:40:32.638
15:59:58.000	15:59:59.254	16:00:14.763
16:19:57.753	16:20:00.102	16:21:25.664
16:40:08.500	16:40:10.951	16:41:12.301
16:59:57.850	16:59:59.799	17:00:33.819

Table A.10: Results of Alarm Trigger Time, Estimated Ringing Time, and Alarm PickUp Time for alarms transmitted using GPRS

Alarm Trigger Time	Estimated Ringing Time	Alarm PickUp Time
11:20:00.927	11:21:07.000	11:21:45.000
11:40:00.872	11:42:19.889	11:42:57.889
12:00:01.021	12:00:44.654	12:01:22.654
12:20:00.770	12:21:55.600	12:22:33.600
12:40:05.418	12:40:15.787	12:40:53.787
12:59:56.467	13:00:41.052	13:01:19.052
13:19:57.611	13:20:33.000	13:21:11.000
13:39:57.764	13:40:19.519	13:40:57.519
13:59:57.413	14:00:47.590	14:01:25.590
14:19:57.361	14:20:22.731	14:21:00.731
14:39:57.410	14:39:56.429	14:40:34.429
15:00:00.123	15:00:25.341	15:01:03.341
15:20:00.343	15:20:20.346	15:20:58.346
15:39:57.556	15:40:13.423	15:40:51.423
15:59:58.000	16:00:11.610	16:00:49.610
16:19:57.753	16:21:26.603	16:22:04.603
16:40:08.500	16:41:08.830	16:41:46.830
16:59:57.850	17:00:21.330	17:00:59.330

A.3 Results from Test Location 3 (Gasverksgatan)

Table A.11: Results of Alarm Trigger Time, Ringing Time, and Alarm PickUp Time for alarms transmitted using Fiber

Alarm Trigger Time	Ringing Time	Alarm PickUp Time
10:02:00.623	10:02:02.580	10:02:11.329
10:22:00.973	10:22:03.428	10:22:24.924
10:40:01.037	10:40:03.296	10:40:12.529
11:00:01.441	11:00:03.121	11:00:14.114
11:20:01.330	11:20:02.870	11:20:34.347
11:40:01.385	11:40:03.841	11:40:15.909
12:00:00.734	12:00:02.689	12:00:31.565
12:22:00.568	12:22:02.519	12:22:38.839
12:42:00.619	12:42:02.368	12:42:24.167
13:03:01.060	13:03:03.198	13:03:22.418
13:21:00.824	13:21:03.065	13:21:20.689
13:42:01.066	13:42:02.913	13:42:37.862
14:00:01.030	14:00:02.781	14:00:15.311
14:21:00.872	14:21:02.478	14:21:18.309
14:41:00.721	14:41:02.307	14:41:21.075
15:01:00.670	15:01:02.307	15:01:13.668
15:30:00.552	15:30:02.099	15:30:19.059
15:45:00.839	15:45:02.985	15:45:09.383
16:06:00.681	16:06:02.835	16:06:30.276
16:26:00.731	16:26:02.684	16:26:11.838

Table A.12: Results of Alarm Trigger Time, Estimated Ringing Time, and Alarm PickUp Time for alarms transmitted using GPRS

Alarm Trigger Time	Estimated Ringing Time	Alarm PickUp Time
10:02:00.623	10:02:17.297	10:02:36.297
10:22:00.973	10:22:28.475	10:22:47.475
10:40:01.037	10:40:14.653	10:40:33.653
11:00:01.441	11:00:12.426	11:00:31.426
11:20:01.330	11:20:40.665	11:20:59.665
11:40:01.385	11:40:27.785	11:40:46.785
12:00:00.734	12:00:39.036	12:00:58.036
12:22:00.568	12:22:39.786	12:22:58.786
12:42:00.619	12:42:40.212	12:42:59.212
13:03:01.060	13:03:34.936	13:03:53.936
13:21:00.824	13:21:29.161	13:21:48.161
13:42:01.066	13:42:32.000	13:42:51.000
14:00:01.030	14:00:18.399	14:00:37.399
14:21:00.872	14:21:20.337	14:21:39.337
14:41:00.721	14:41:20.964	14:41:39.964
15:01:00.670	15:01:18.541	15:01:37.541
15:30:00.552	15:30:16.353	15:30:35.353
15:45:00.839	15:45:16.382	15:45:35.382
16:06:00.681	16:06:28.231	16:06:47.231
16:26:00.731	16:26:23.216	16:26:42.216