Abstract

This master's thesis was commissioned at Song Networks AB, a Nordic network-provider.

Today data-carrying networks take a central role for many companies and high network availability is often demanded from the network-provider. Availability statistics may be used as an offering to attract customers, but perhaps more importantly, the provider may benefit by its use in measuring general network quality.

The purpose of the thesis was to make a background investigation on network availability and then to develop a method for measuring the network availability that can be applied by Song Networks.

This thesis will give the reader an introduction on network availability in telecommunications systems and discusses important issues when planning a measurement on availability. The ITU-T standard G.826 for defining availability in SDH networks is studied to identify availability parameters and points of measure.

A method for measuring availability in the company's SDH network is developed and a database is implemented to store the measured values. Through a web interface users can create detailed availability reports based on the values stored in the database.

The conclusion is that the reports produced by the implemented process can be used to study trends in the network availability. These trends will give an indication of the condition of the network elements and help in planning the maintenance of the network.

Foreword

This Master's thesis report is the final part of the Master of Science degree at the Royal Institute of Technology (KTH) in Stockholm. The project was performed at Song Networks AB during the period May 2004 to September 2004.

I would like to thank my supervisors Maria Sandgren at Song Networks AB and Björn Pehrson at IMIT, KTH for their support during the project and to Matts Amundsen at Song Networks AB for giving me this opportunity. In addition I would like to thank everyone who has inspired me with ideas and encouragement.

Stockholm September 2004,

Mattias Thulin

Contents

1 Introduction

Today data-carrying networks are of crucial importance to most companies and even short interruptions can cause considerable economic losses. As networks grow bigger and more complex, the factors influencing the network availability will also increase. As a result many of these companies have invested in securing their networks with redundancy and quality of service as well as demanding high network availability from their network operator. For the network operator measuring and quantifying the network availability has become an important issue, not only to attract customers, but also as an indicator of the variation of quality in the network helping to organize maintenance and expansion of the network.

Song Networks AB is a Nordic network operator with an extensive network on both transmission and access layer. The principal products are VPN-networks, Internet connections and Telephone services. The customers are connected to the backbone by different means depending on their locations; normally via optic fiber, copper-pair or radio-link.

Today most network operators include availability guarantees to some extent in their service-level agreement (SLA). However, the definition of network availability and the methods of collecting data vary, as there is no standard or praxis commonly used by the network operators.

For Song Networks AB having a well-defined process for defining and measuring network availability serves various purposes:

- Maintaining customers service-level agreements
- Attracting new customers
- Providing statistics for the Network Operations division

With this background Song Networks AB want an investigation on Network Availability in order to see how it can be implemented into its network and how availability measurements can improve their network quality.

1.1 Purpose

During the thesis several questions were defined and answered:

- How is Network Availability defined?
- How can it be measured?
- Why should it be measured?
- What standards exist?
- Are there any recommended values for availability parameters?
- How can availability measurements be applied to Song Networks SDH transmission network?

Based on these questions the purpose can be summarized as:

Investigate existing methods for measuring network availability and develop a method that can be applied by Song Networks AB as a quality measure for network operation.

With this method implemented the network operation team will receive continuous information on what parts of the network generate most downtime. They can then focus their resources on improving those parts.

1.2 Delimitations

The first part of this thesis is a general study on Network Availability and is applicable on all transmission networks. The second part of the thesis was aimed at developing a method for availability measurement. As Song Networks AB has a transmission network using several protocols and equipment of various models it was decided to limit measurement to the part of the network using Nortel SDH equipment (product name Nortel DX). This includes the following SDH rings, which are all part of Song Networks backbone:

- Sweden ring
- Nordic ring
- European ring
- Baltic ring

These four rings consist of a total of 44 links resulting in 88 termination-points with possibility to measure performance parameters. Song

Networks uses the system Preside from Nortel for surveillance of these network elements. The surveillance mainly reacts on alarms from the network, but it is also possible to access historic data for both 15-min and 24-hour intervals in graphic and spreadsheet form.

It is also important to note that the method developed was to be oriented towards the network-management, with the purpose of improving network quality.

2 Method

This chapter will focus on the methods used, how information was gathered and analyzed.

In order to develop a method for measuring network availability a qualitative study was performed, aiming to identify and understand the factors involved. The studied literature consisted of books, articles, case studies, international standards and information from the internet. Few books have been published in the specific area on how to measure network availability. Most of the information was found in magazine articles and publications from telecommunication equipment manufacturers. Additionally, a lot of literature was found on measuring availability in a more general aspect, which could be applied to any type of equipment.

Network maps for the SDH network were provided by Song Networks, as well as documentation for the network monitoring system Preside. The structure of the Preside log files was studied in the Preside documentation.

Interviews were performed with employees at Song Networks to obtain understanding of the network structure and earlier projects within network availability. These interviews also gave ideas of possible points of measure for different parameters in the network. To obtain information on the current situation in the market, several Swedish network providers were interviewed about their availability measurements. Technicians from Nortel were consulted about the functionality of the Nortel DX system as well as the monitoring system Preside and the possibilities to retrieve statistics data into an availability database. Meetings were held with the network operations team in order to fully understand Preside and its possibilities. Existing standards were consulted to decide which parameters to include in an availability measurement, where to measure and how to sum up the total network availability.

The knowledge acquired from the background study and the interviews were applied to analyze the problem: to design a model for availability measurement that well suited the needs of Song Networks.

Once the parameters and points of measurement had been selected, a database structure was designed to store the daily availability information from the log files produced by Preside.

In order to parse the data in the log files into the database a java-program was written and tested. Error handling was added continuously.

The literature was studied to find a model for presenting the availability statistics. Also the interviews contributed to this model. A web-interface was developed to retrieve and analyze the data and present the result for any given time period. A script was added for creation of reports in PDF format directly from the web-interface. Crystal report was programmed to produce graphs from the availability statistics in the database and export them into PDF format.

3 Background study

This background information was compiled for the reader to obtain a general understanding on availability as well as the SDH network.

3.1 Definition

The network availability has been measured for a long time within the telecommunication sector. The term availability can be defined by:

The ability of a functional unit to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.[1]

Simplified: availability is a percentage value of the amount of time the network is delivering services divided by the amount of time it is expected to deliver services.

The time the network is not delivering services we define as downtime.

Applying this to the data-carrying network, we can interpret availability as a successful data transfer from point A to point B including the physical connectivity, link-layer protocol connectivity, and network-layer protocol connectivity[2].

3.2 The "five-nines"

Normally the availability is expressed as the percentage of the time the network is working. It was here the term "five-nines" came into use. Five-nines refer to the percentage 99.999%, which is a generalization that has for long been used for marketing and has been viewed as the desired goal for availability in many networks, at least at the core-level. Five nines correspond to 5 minutes of downtime a year. Table 1 explains the connection between percentage and minutes of downtime per year. It should be noted that taking the step from four to five nines would require going from 52 to only 5 minutes of downtime per year.

[1] ISO 2382-14, 1997
[2] Janet Kreiling, *High Availability Networking*, Packet Magazine p.54, Volume 15, No. 3, 2003

Availability	Downtime per year
99,9999%	32s
99,999%	5min 15s
99,99%	52min 36s
99,9%	8h 46min
99%	3 days 15h 40min

Table 1: Availability percentage in minutes

3.3 Theoretic availability

The literature often suggests a theoretic availability calculation as a pre-study when planning a network, or before having sufficient data to calculate the actual availability. To calculate a theoretic availability the network is divided into each depending unit, such as hardware, software, physical connections, power supplies etc. For most equipment the manufacturer will supply information on availability expectations, often described as Mean Time Between Failure (MTBF). For those parts of the network not having this data, such as power source, statistical data and estimations have to be used. The expected time to repair each part of the network has to be estimated. This is normally referred to as Mean Time To Repair (MTTR). The availability for each unit is calculated by:

$$Availability = \frac{MTBF}{MTBF + MTTR}$$

To calculate the total availability of the network the availability of all units has to be summed up. For example, a simple network consisting of four units, (see Figure 1: Point-to-point availability of four units) each having an expected availability 99,99% has a total availability of 99,96% or three and a half hours per year.

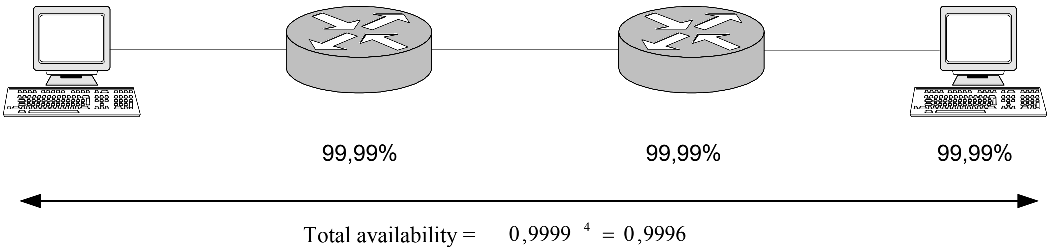


Figure 1: Point-to-point availability of four units

Logically, a chain can never be stronger than its weakest link. Adding redundancy will result in increased availability. Figure x describes how to sum the availability of the units in the network, depending on if they are connected in serial or parallel (redundant) form. For the serial case the total availability is worse than the worst unit availability, while for the parallel case it is better than the best unit availability. However, adding redundancy does not always increase the availability linearly. A switchover from one route to another takes time, and during this period the connection will be down.

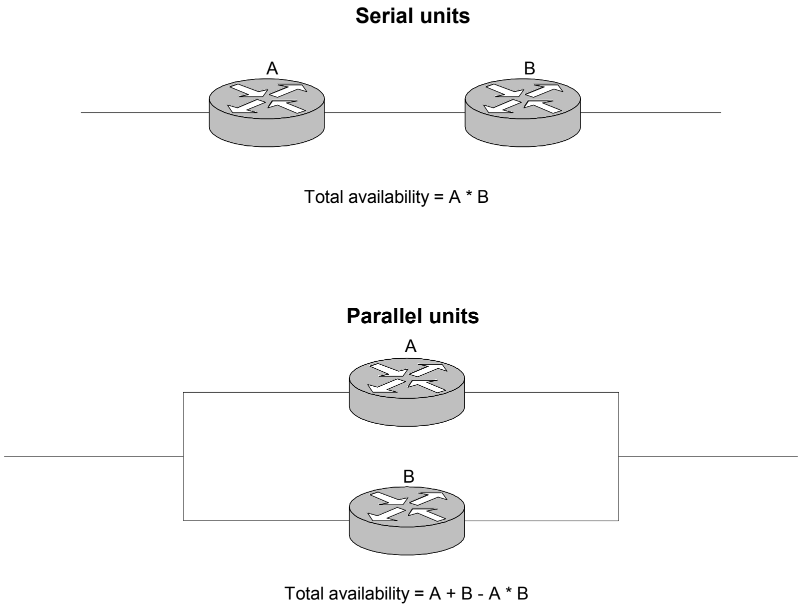


Figure 2: Serial and parallel availability[3]

According to Jim Thompson at Cisco Systems[4], a theoretic calculation of the availability will provide a good figure of what is theoretically possible to attain in practice and set expectations. For this type of calculation he

[3] Van Valkenburg, Mac. Middleton, Wendy. *Reference Data for Engineers: Radio, Electronics, Computers and Communication.* Elsevier, 2001.
[4] *High Availability Networking*, Packet Magazine, Volume 15, No. 3, 2003

recommends dividing the network into its three main segments: access, distribution and core. A theoretical calculation on Song Networks core network in 2004 gave an average availability of 99,95%.

3.4 Reactive Availability

As opposed to an active measurement of the availability, a reactive measurement calculates the downtime using the data from e.g. a trouble-ticket system. Apart from giving a good figure of the customer-experienced availability, it contains information about what equipment failed and what solved the error. However, a reactive measurement is likely to lack information of very short interruptions and failures outside of office hours. In a customer-perspective the reactive measurement will show fair values, since it is based on customer-initiated data. In a network-operations perspective an active measurement would prove more favorable.

3.5 Time intervals

An important issue is what time interval to use when presenting the availability statistics. Trends in the availability statistics should be observed in the long run. Today, most companies generate reports covering a week or a month, but it is recommended to trend for a time interval of six month up to a year[5].

3.6 Adjusted availability

Measuring the raw availability will include also the downtime produced by planned work on the network. These planned outages, or service windows, are normally regulated with the customer in the Service Level Agreement (SLA). They normally take place during nighttime and/or weekends to produce minimum disturbance on the users' activity. In addition they are always pre-announced by the network operator so that the customer can make adequate preparations for the downtime. All downtime that affects customers must be measured, but planned outages should be measured differently to report the true service level provided to the customers[6]. Therefore, in addition to measuring raw availability, the

[5] Kreiling, Janet. *High Availability Networking*, Packet Magazine, Volume 15, No. 3, 2003, pp 56.
[6] *How Cisco IT-LAN-SJ Achieved High Availability*, Cisco Whitepaper, www.cisco.com

raw availability should be adjusted so that the downtime that occurs during planned works is excluded from the statistics.

3.7 Customer or Network-management oriented?

Availability can be measured for different purposes. Either it can be measured in a customer-oriented way, trying to give an accurate figure of the actual point-to-point availability experienced in a customer perspective. This type of measurement must include all layers and parts of the network connecting two points. If a link is down and the traffic is rerouted via another link, from a customer perspective the connection is available and no downtime is calculated.

The other way of measuring availability is from a network-management perspective. The purpose is to ensure good network quality by administrating resources and maintenance in the network in an efficient manner. If a link is down and the traffic is rerouted via another link, it is still important for the network management to know what links and units show lower availability. In this way they can redirect their resources to find problems with units that show lower availability and hence could be a future threat to the total network quality.

Before defining a method of measuring network availability one should first answer the question: for whom, or for what purpose am I measuring? The method will greatly depend on the answer of the question above. In order to get useful availability statistics it is extremely important that the method in use is adapted to the purpose of the measurement.

3.8 SDH network description

SDH stands for Synchronous Digital Hierarchy and is an international standard for transmitting digital information over optical fiber. It is based on the American standard SONET (Synchronous optical network) and is regulated by the international standardization organization ITU.

The SDH standard specifies how payload data is framed and transported synchronously across optical fiber transmission links. The basic building block signal of SDH is called STM-1 (Synchronous Transport Module level 1) and operates at 155.52 Mbps. Faster SDH rates are defined as STS-*n*, where *n* is a multiple of 155.52 Mbps. STM-1 is equivalent to SONET's Optical Carrier (OC) level 3.

SDH defines a number of “containers”, each corresponding to an existing rate (1.5, 2, 6, 34, 45 and 140 Mbps). Each “container” has some control information known as *Path Overhead* (POH) added to it. The POH allows the network operator to achieve end-to-end path monitoring. Together the container and the path overhead form a *Virtual Container* (VC).

SDH backbone networks are usually built in a ring-structure. This way, if an error occurs on one of the links, the transmission can easily be switched over to a redundant path. Protective switching is normally initiated automatically after exceeding pre-configured threshold values for certain performance parameters.

Most of the protocols used for data and voice transmission can be transmitted over SDH. No error correction and retransmission are done at the SDH layer; this is done by the overlaying protocols (for instance TCP-IP).

3.8.1 Song Networks DX network

This thesis focuses on the part of the SDH network that operates with Nortel Networks DX equipment. Its core consists of four interconnected ring structures covering Scandinavia and the northern part of Europe (see Figure 3).

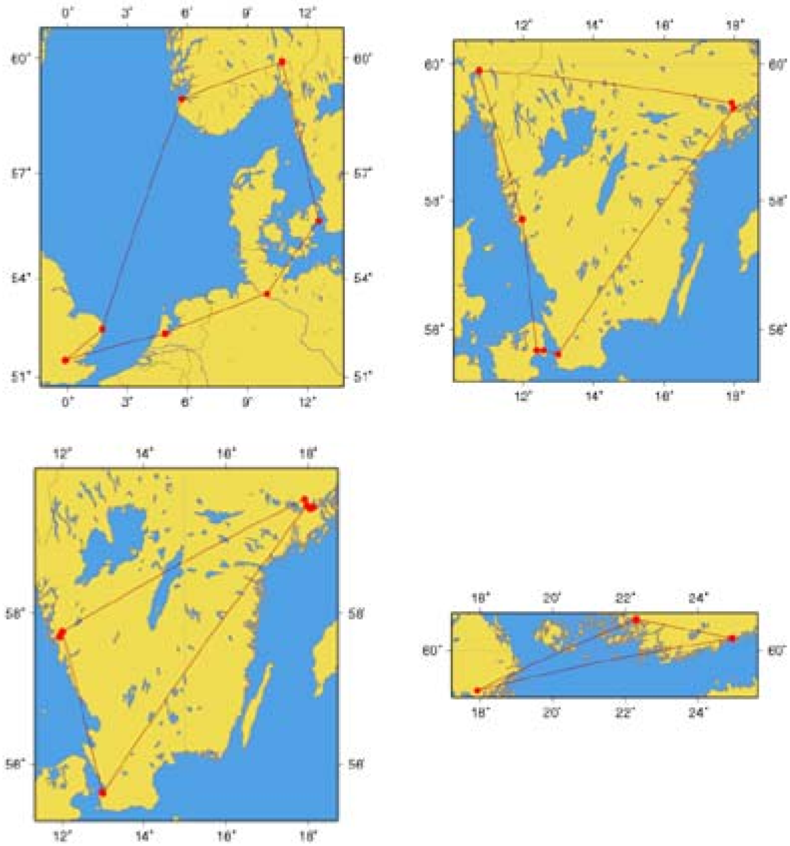


Figure 3: Europe ring, Nordic ring, Sweden ring, Baltic ring

The SDH network uses the standard DWDM for transmission over optical fibers. Each ring consists of a number of connection points named **Network Elements (NE)**. Totally there are 26 Network Elements in the four rings, distributed as follows:

- Sweden ring – 9 Network Elements
- Nordic ring – 7 Network Elements
- European ring – 7 Network Elements
- Baltic ring – 3 Network Elements

The Network Elements are named with a unique four-digit number and a detailed description including country and location. Each link connecting an NE to another NE is named *G + a two digit number* (for instance G11). These link names are only unique within its NE; they are repeated throughout the network in each NE. Figure 4 gives a schematic example of a small ring consisting of four NE.

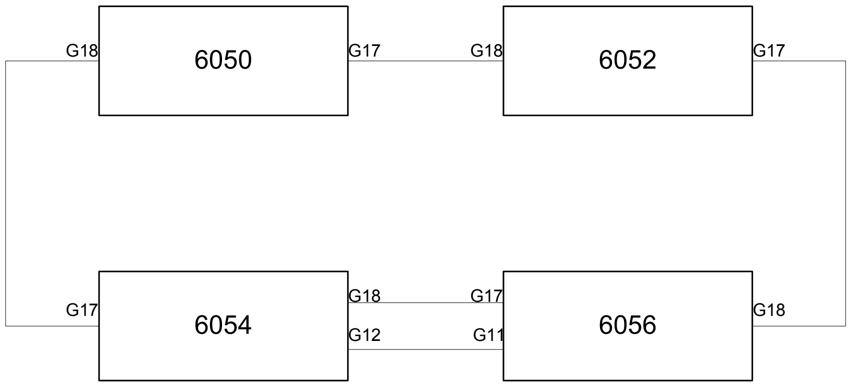


Figure 4: Schematic example of ring structured network of four NE's and the links interconnecting them.

3.8.2 Surveillance and statistics

Every Network Element in the SDH network collects performance, equipment and protection statistics. The Network Elements constantly communicate with an Operational Controller (OPC) for network surveillance. They also provide statistics for a number of SDH defined parameters that are stored in the OPC database for the following periods:

- 15 min averages are stored for 24 hours
- 24 hour averages are stored for seven days

An OPC normally handles around 30 Network Elements. In case of a failure, each OPC has a backup OPC that will take over until the failure is restored. The OPCs operate with Nortel-specific software on a HP-UNIX platform. They can be accessed via a terminal window connection, but normally surveillance is done with Preside.

Preside is a system developed by Nortel Networks for global performance monitoring of an SDH network. It communicates with all OPCs in the network to provide a centralized facility in order to monitor and retrieve performance statistics for the network. Its graphic user interface provides an overview of the network elements and the links connecting them. Figure x shows an example screen from Preside. Preside can also display a global alarm list and query performance statistics for each network element.

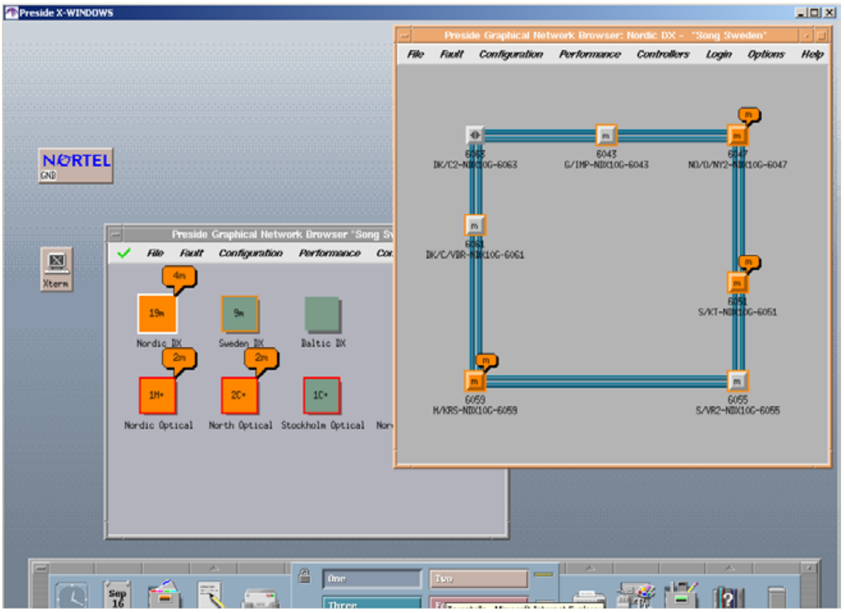


Figure 5: Screenshot from the graphical network monitoring system Preside

3.8.3 Preside log files

By performing a query for a specific network element, Preside can produce a log file including chosen performance parameters for all links connected to the NE. The log file will contain values for each 15-minute period during the past 24 hours and for each 24-hour period during the past week. There are 8 values for the 24-hour counts, since the first and last days are broken (together they sum 24 hours).

The files are in CSV ASCII text file format, i.e. the fields are comma-delimited. Table 2 describes the content of each field in a row. A new-line character separates each link in the NE.

Field number	Field name	Field description
1	NE number	Network element ID number
2	NE name	Network element name (up to 20 characters)
3	Product	E.g. TN-1X
4	NE type	One of: LTE, Regen, ADM, FCOT, RFT, DXC
5	Facility	Valid facility on the network element
6	Unit	Includes CPG, as well as Port and Channel if applicable (for example G11)
8	Parameter layer	One of: Path, Line, Section, VC4, STS1 Path, LP, HP, PPI CV, PPI TX, AU PJE, TU, PJE, TX, MS, OOF, Framed
9	Parameter direction	One of: Rx (receive) or Tx (transmit)

10	Parameter location	One of: Ne (near end) or Fe (far end)
11	Parameter name	One of: CV, ES, SES, SEFS, UAS etc.
12	Daily counts date	Date of the most recent of the daily counts in the format: DD/MM/YY
13	15 minute end date	Date of the last of the 15-min counts in the format: DD/MM/YY
14	15 minute end time	Time of the last of the 15-min counts in the format: HH:MM
15-22	Daily counts	The 8 daily counts – from the oldest to the most recent. Each count field is an integer or real value and can be negative or positive.
23-54	15 minute counts	The 32 15-min counts – from the oldest to the most recent. Each count field is an integer or real value and can be negative or positive.

Table 2: Format of the Preside log file content[7]

```
1200,Ottawa,OC48,Term,DS3,G7,2,Line,Rx,Ne,SES,03/07/99,03/07/99,16:00,
0,0,0,2,3,8,12,6,
0,0,1,0,0,0,0,1,0,0,0,2,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0
```

Table 3: Example row from a Preside performance log file . The example is split over several lines to make the record easier to read.

3.9 ITU-T Standard G.826

The International Telecommunication Union (ITU) is an organization within the United Nations with headquarters in Geneva, Switzerland. The ITU consist of representatives from the legislate organs in member states as well as representatives from the private sectors in member states working within ITU's sphere of activities. The main objective of ITU is to develop standards and procedures and work for an improved radio- and telecommunication infrastructure in its member states.[8]

ITU-T has defined a set of standards providing procedures, objectives and limits for links in international SDH Networks. The standard covering performance evaluation and availability measurements is G.826: *End-to-end error performance parameters and objectives for international, constant bit rate digital paths and connections*.

[7] Nortel Networks. *Preside: Performance Monitoring for Synchronous Devices 9.2 User Guide.* October 2002.

[8] www.itu.org

3.9.1 Availability parameters in G.826

The G.826 standard defines a number of SDH parameters that are used in availability measurements. Together they form a subset of the parameter Unavailable Seconds (UAS), which is the parameter indicating downtime (also called unavailable time) for a SDH link at a given time interval. These parameters are:

- **Block:** A block is defined as a set of consecutive bits associated with the path; each bit belongs to one and only one block. Consecutive bits may not be contiguous in time.

- **Errored Block (EB)**: A block in which one or more bits are in error.

- **Errored Second (ES)**: A one-second period with one or more errored blocks or at least one defect.

- **Severely Errored Second (SES)**: A one-second period which contains ≥30% errored blocks or at least one defect. SES is a subset of ES.

The Unavailable Second start with the occurrence of 10 consecutive Severly Errored Seconds. These ten seconds are considered to be part of unavailable time. It ends with the occurrence of 10 consecutive non-SES. Figure x illustrates the definition of Unavailable Second.

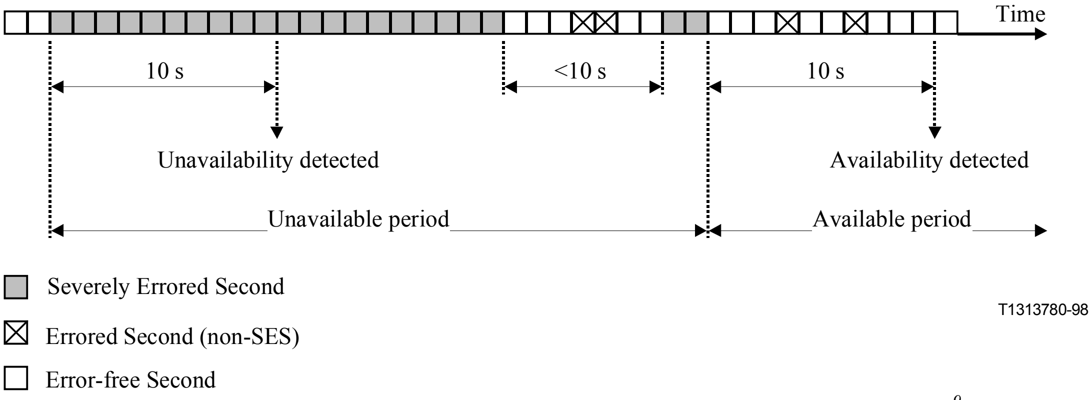


Figure 6: Illustration of the UAS definition[9]

3.9.2 Random error distribution

The standard also recommends measuring on the highest bit rate of each link, and using this figure as the availability for the link: *Under the assumption of random error distribution, meeting the allocated objectives in Table 1/G.826 for the highest bit rate should be sufficient to ensure that all paths or connections through the system are achieving their objectives.*

[9] International Telecommunication Union (ITU-T). *Standard G.826: End-to-end error performance parameters and objectives for international, constant bit rate digital paths and connections.* 2002.

4 Methodology

Before implementing a system for availability measurement in the existing SDH network there are certain areas that have to be analyzed. First of all, availability should be defined. An existing standard or guideline would be the preferable choice here. A model of calculating the average availability has to be developed. It is also important to define what parts of the network that should be included in an availability report.

Secondly, the log files have to be analyzed to see what information can be utilized, and what is not covered. The time period covered by the log file has to be found to decide with what frequency the new log files have to be generated, in order to avoid gaps in the database. A database structure has to be developed, ensuring a stable and scalable application. Finally, an application for generating availability reports has to be specified in order to meet the requirements of Song Networks AB.

4.1 Defining availability for SDH networks

Song Networks want to implement a method of measuring availability in their SDH network based on a standard or praxis that is used in the market today. Interviews with representatives from some of Sweden's leading network operators (Telia International Carrier, Telenor, IP-Only) were performed to answer the following questions:

- Are you measuring availability for your SDH network today?
- What are the points of measurement?
- What parameters are included in the measurement?
- What tools are used to collect the parameters?
- What algorithm is used to calculate the availability?
- Over what period of time is the availability presented?

Not all network operators were measuring availability at SDH level at the time of the interviews. The network operators that were measuring followed the regulations of standard ITU-T G.826, using the parameters defined in the standard. As stated by the standard, network availability is measured per link, but averages are calculated as well for different sections of the network. The measurements are used for internal purposes and are presented per month and quarter.

After studying the methods used in the market, it was decided that the availability measurements that were to be implemented should follow the standard ITU-T G.826. This standard is widely applied in the market. The standard is described more thoroughly in section 3.9. According to the standard, the availability will be measured and calculated per link. Unavailable Seconds (UAS) is the definition of downtime, and the availability expressed as percentage is therefore calculated by:

$$Availability = \frac{MeasuredTime - UAS}{MeasuredTime} * 100$$

This should be applied to all active links in the SDH network. Assuming random error distribution among the different bit-rates transmitted on the link (see section 3.9.2), the UAS is measured on the STM-64 level, this being the highest bit-rate for all links in the network.

Apart from studying the availability per link, it is also of interest in studying the trends in total availability per ring and of the network as a whole. An average is calculated adding all the unavailable seconds (UAS) in a group of links and then dividing by the number of links.

When calculating the average availability it is advisable using UAS values and converting them to percentage availability in the last step of the calculation. This will avoid rounding error. Based on example implementations in the literature[10] it was decided to present the first five significant figures of the percentage availability.

4.2 Analyzing the log files

Information about the structure of the log files can be found in Section 3.8.3. The log files have to be produced manually in Preside, unfortunately there is no way of creating a macro polling all the NE at a given interval. This is because the statistics databases in the OPCs are only accessible through Preside. The parameter of interest is UAS, so each NE will be polled for UAS statistics using the Performance statistics function in Preside. This will produce one log file for each NE in the network.

[10] Cisco White Paper. *How Cisco IT-LAN-SJ Achieved High Availability.* www.cisco.com.

The log files produced both contain 15-minute statistics from the past 24 hours and 24-hour statistics for the past week. Using the 15-minute statistics would require that the log files had to be produced at least every 24 hours in order to not contain any gaps. Given that the availability statistics will be presented on weekly basis there is no need for the high detail of the 15-minute statistics.

Deciding to work only with the 24-hour statistics, the log files have to be produced from Preside every six days. These files will be stored into a new directory. There are eight 24-hour posts in the log files, but the first and last days are broken dates and do not contain information for the full day (together they sum 24 hours). Using the broken days and updating their entries in the database would be difficult. Instead they are discarded and only the six days containing complete statistics will be used. This means that log files have to be analyzed every 6th day in order to not loose any statistics.

The information of interest that has to be parsed from each log file is:

- NE number
- Unit (Link name)
- Daily counts date (last of the 8 days stored)
- UAS values for day 2 to 7

This information then has to be inserted into the database. Each log file will yield six daily entries of UAS for each link that is connected to the NE.

4.3 Specification of a parser program

A parser program will have to be constructed that can read the information from the log files and parse the required fields into a database. It will have to open all files in a given directory and read in line by line, parsing the information of interest into the database. The position of the different parameters in the comma separated log files are specified in Table 2. Each UAS value has to be associated with its NE, port and date. The program will then set up a connection with the database and insert all the posts. If the post already exists, it will insert the new value.

4.3.1 Error handling

If the files are empty or do not contain UAS information, the program has to give an error message about where the error occurred. An error message would also be generated if the connection to the database fails.

4.4 Database structure

With a total of 88 points of measure in the network, the database will store 88 daily posts. The size of the database will grow linearly and over a year the database will increase with approximately 32.000 posts. A good table structure with good choice of variable data-type will save storage space and make queries quicker. Each post will contain the following fields:

- NE
- Port
- Day
- Unavailable Seconds count

4.5 The presentation program

The presentation program should show the availability, expressed in percentage, for any time period entered. In the literature the percentage availability is most often expressed with five significant figures. The same rounding to five significant figures will be used in the presentation program.

The availability should be presented per link (measure point), per SDH ring, and for the entire SDH network. For this type of presentation a table structure is preferable. The program has to include error handling to deal with dates entered in a wrong format and dates that do not exist in the database. To ensure accessibility the program has to be platform independent and be accessible from any computer at Song Networks.

5 Implementation

The implemented availability-statistics system consist of a parser program that reads information from the log files and parses in availability information into a database. This will be done weekly, as the log files are created from the network surveillance system Preside. Another program is used to retrieve, analyze and present the data in the database and generate reports.

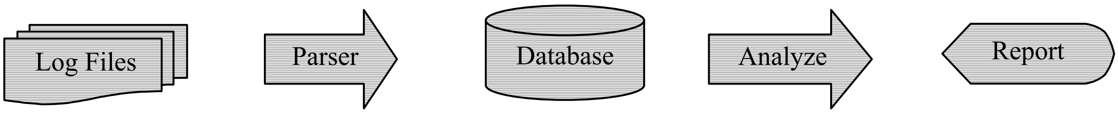


Figure 7: Availability data flow chart

5.1 The database

The choice of database was MySQL[11], being a well-documented software with a public license. It has support for many programming languages and understands SQL standard expressions. Making queries from other programs and exporting data from MySQL is an easy procedure. Crystal Report, the program used by Song Networks to generate graphs and reports, can easily import data from MySQL tables.

Based on knowledge of the content of each field, the table was set up with data-types as shown in Table 4.

Field	**Type**	**Description**
NE	SMALLINT	The network element number (four-digits).
Port	CHAR(3)	The port (three characters).
Day	DATE	The date of measurement.
UAS	INT	Unavailable Seconds during the day. (Number between 0 and 86400)

Table 4: Fields in the availability database table

[11] www.mysql.com

The database was put on a central server for easy accessibility. Its size will be approximately 600kb per year.

To keep track of the links in the network, a separate database table was created. It contains information about the termination points of each link and the location name, city and country of the two network elements that are connected by the link. This is used in the report program, so that the user can relate to the links without remembering their numbers.

5.2 The parser program

Java[12] was used to develop the parser program *logReader*. Java's main advantage is that it is platform independent and the program can therefore work from any operating system.

5.2.1 Algorithm of the parser program

The directory where the log files are stored is the input argument for the program. The program will loop through all the files in the directory. The comma-delimited values will be tokenized and an array of the consecutive 6 days before the end date will be calculated. For each entry an object of type *logEntry* will be stored into a stack. The object logEntry contain the NE number, Port name, the seven dates in the log and the corresponding UAS values. When all files have been read and tokenized a connection is set up to the MySQL database. The *logEntry* objects are then taken from the stack and its values inserted into the database table. The method *replace* is used instead of *insert,* this way a duplicate entry will replace the old post instead of inserting a duplicate post into the database.

[12] www.java.sun.com

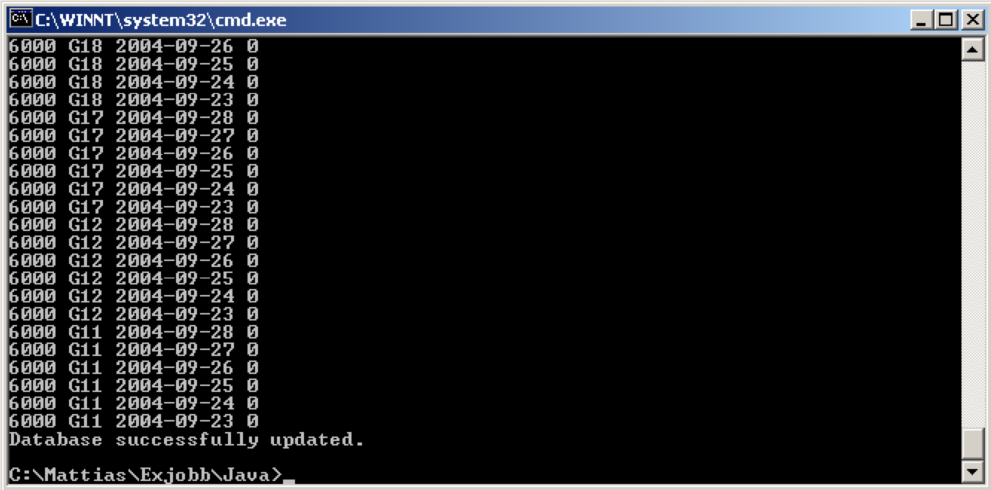


Figure 8: Screenshot from the parser program

5.2.2 Error handling

The program verifies that the log files contain availability statistics, if not it skips to the next file in the directory. If a connection to the database cannot be set up, the program will terminate with an error message.

5.3 The report-generating program

Apart from generating graphic reports in Crystal Report, Song Networks wanted a tool to easily generate availability-reports for anyone in the operations department. To make the tool easily accessible from all platforms and sites, the tool was implemented as a php-script that runs on a web-server. This way the users can generate reports from their web-browser without the need of installing any additional software.

After making a first version of the script, the format and contents of the report was discussed with the network operations department. Their suggestions concerning content and improvements were then implemented in the final script.

Using the web-browser to navigate to the php-page, the user enters the start-date and end-date for which to generate a report. The php-script makes a query to the MySQL database for the average daily UAS in each of the links in the network for the specified period. It then calculates the availability percentage for the period using the formula:

$$Availability = \frac{86400 - AverageUAS}{86400} * 100$$

86,400 in the equation is the number of seconds in a day. The average for each ring and the entire network are also calculated as described in section 3.3. The resulting values per link, per ring and for the entire network are then presented in tables as shown in Figure 9. A click at the link provides more information, such as location of start- and endpoint as well as a geographic map.

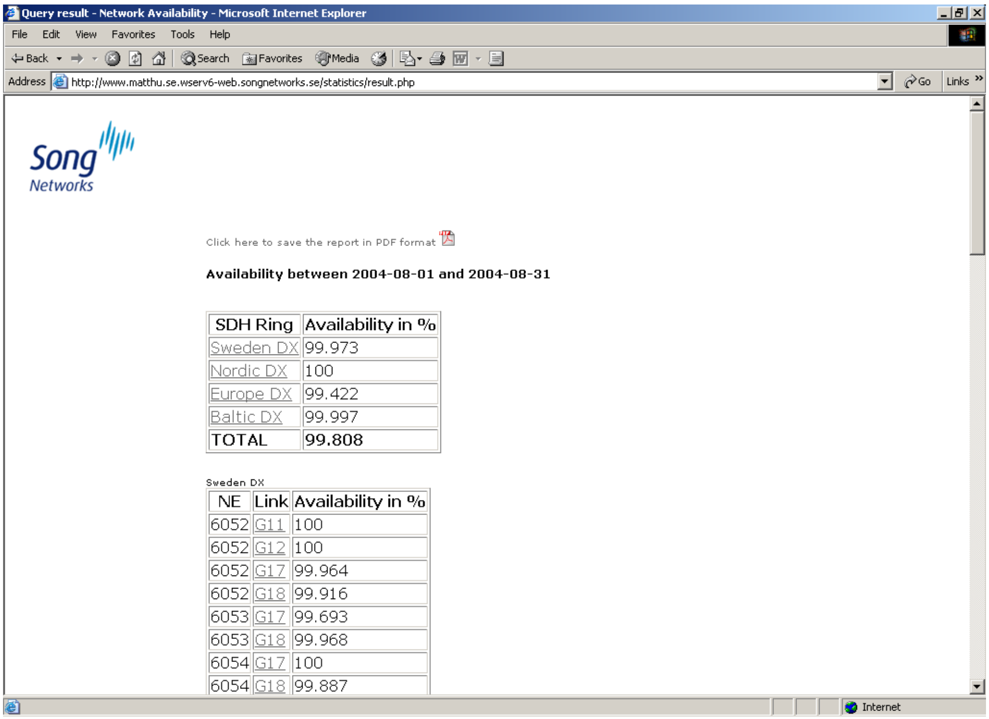


Figure 9: Screenshot of an availability report produced in the web-interface.

The user also has the option of saving the report in PDF format. This may be useful for archiving the report and also to easily send it by e-mail. The script incorporates a pre-defined, public license php-function[13] to generate the PDF file. By sending the tables that were generated in the report to the function, a PDF-file is created on the server. The user will then have the option to save the file on the local hard drive.

5.3.1 Error handling

[13] http://sourceforge.net/projects/pdf-php

A date entered in the wrong format will show a warning and prompt the user for a new date. If there are no data for the specified period, the user is advised to enter another time period. If some dates are missing in the database for an entered time period, the report will be generated without including the missing dates included in the average calculation.

5.4 Adjusted Availability

The time period when the network-provider performs planned maintenance work on the network is normally regulated with the users in the SLA. This downtime should be excluded from the network availability calculation. Song Networks has a ticket-system for planned works and affected units. Only after a planned work is it possible to know exactly for how long the outage lasted. Since the UAS statistics in the database are values per day, there is no possibility of knowing in what part of the day the downtime occurred. Therefore, it is not possible to automatically discard all downtime during a certain time-period each week. Instead, the database will have to be manually updated after each planned work that affects the SDH network.

A php-script was written in order for the technicians to manually update the availability database after a planned work (see section 3.6). Like the presentation program, this script is accessed through the user’s web-browser and run on the web-server. The affected unit and link is entered into the form, as well as the date when the service window occurred. The availability database is queried for the UAS value for that link and day and the user is presented with the result. The user now has the option to subtract the downtime used in the service window and enter a new downtime value into the form. The availability database is then updated with the new value.

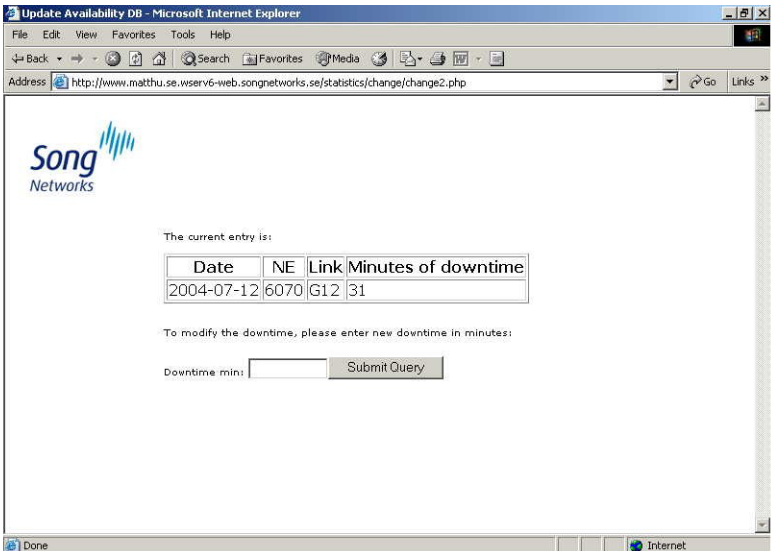


Figure 10: Screenshot from the database-update window.

This procedure should be repeated after each service window where downtime for any link in the SDH network has occurred.

6 Results

The database containing availability data collected from the log files was initiated in the third month of the thesis. This provided time to test the method of calculating and presenting the availability data. Also, at the end of the thesis there were some two months of availability data to study.

After having reports generated weekly during this period, the feedback from the network operations department is positive. Problems in the SDH network can easily be spotted in the availability reports. The network operations can then initiate improvements on the most frequent faults. With more data availability data in the database, the reports will hopefully show trends that could be used to estimate the condition of the network elements and help in planning maintenance and investments of the network. Future reports will include graphs showing the trend for the past year in order to be certain of the statistical accuracy of the trends.

6.1 Availability between 2004-07-12 and 2004-09-19

The following report was created using the full time period existing in the database at the end of the thesis. It consists of the availability statistics for ten weeks of measurements, from 2004-07-12 up to 2004-09-19. The graphs show the weekly average availability for each ring in the network, as well as the total average. The dotted line in the graphs indicates the desired availability level of 99,99%.

SDH Ring	Availability in %
Sweden DX	99.983
Nordic DX	99.997
Europe DX	99.462
Baltic DX	99.814
TOTAL	**99.81**

Sweden DX

NE	Link	Availability in %
6052	G11	99.989
6052	G12	99.989
6052	G17	99.944
6052	G18	99.958
6053	G17	99.856
6053	G18	99.959
6054	G17	100
6054	G18	99.95
6056	G11	99.989
6056	G12	100
6056	G17	99.951
6056	G18	100
6060	G11	100
6060	G12	100
6060	G17	100
6060	G18	99.993
6058	G17	99.993
6058	G18	100

6044	G11	100
6044	G12	99.989
6044	G17	100
6044	G18	100
6045	G17	100
6045	G18	100
6046	G17	100
6046	G18	100

Nordic DX

NE	Link	Availability in %
6051	G11	99.989
6051	G12	99.989
6051	G17	99.988
6051	G18	99.99
6055	G11	99.989
6055	G12	100
6055	G17	99.99
6055	G18	99.999
6059	G11	100
6059	G12	100
6059	G17	99.995
6059	G18	100
6061	G11	100
6061	G12	100
6061	G17	100
6061	G18	100
6063	G11	100
6063	G12	100
6063	G17	100
6063	G18	100
6043	G11	100
6043	G12	100

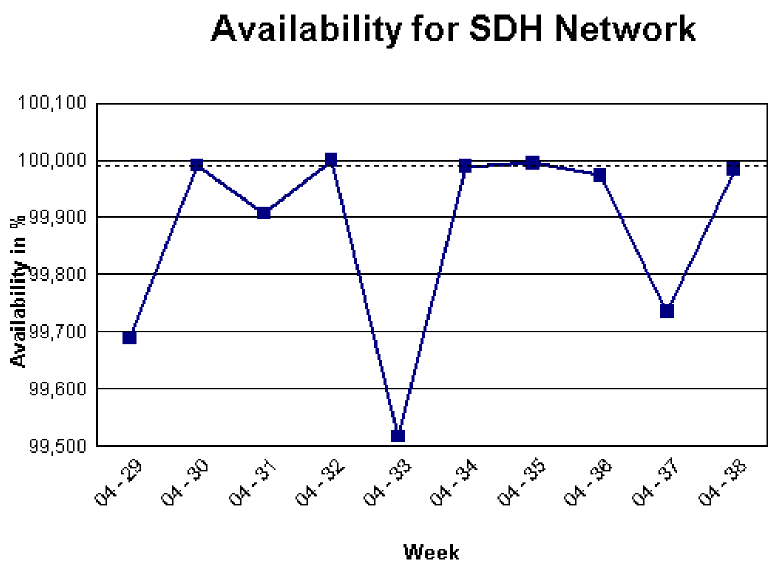
6043	G17	100
6043	G18	100
6047	G11	100
6047	G12	99.989
6047	G17	100
6047	G18	99.988

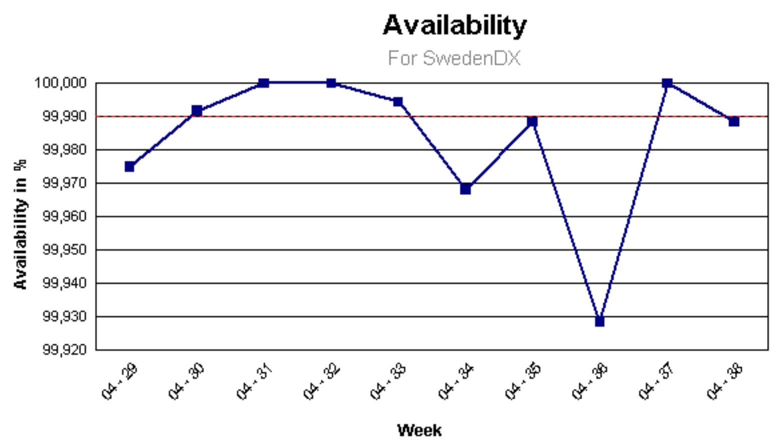
Europe DX

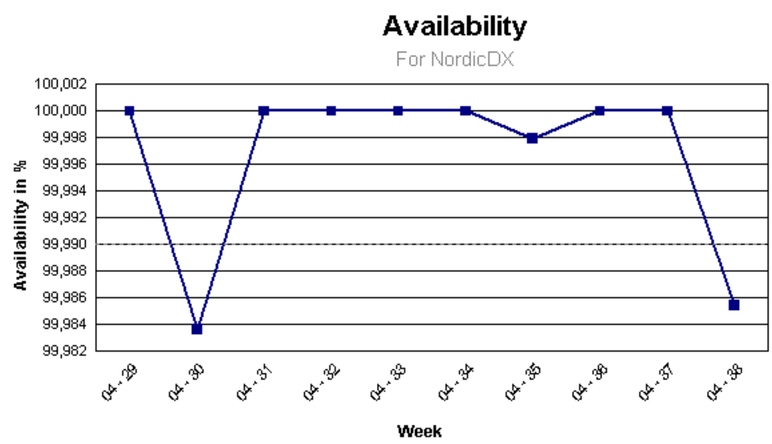
NE	Link	Availability in %
6000	G17	100
6000	G18	99.21
6003	G17	99.966
6003	G18	99.696
6005	G17	99.981
6005	G18	99.505
6006	G17	99.799
6006	G18	97.004
6007	G17	99.323
6007	G18	100
6008	G17	100
6008	G18	99.97
6009	G17	98.084
6009	G18	100

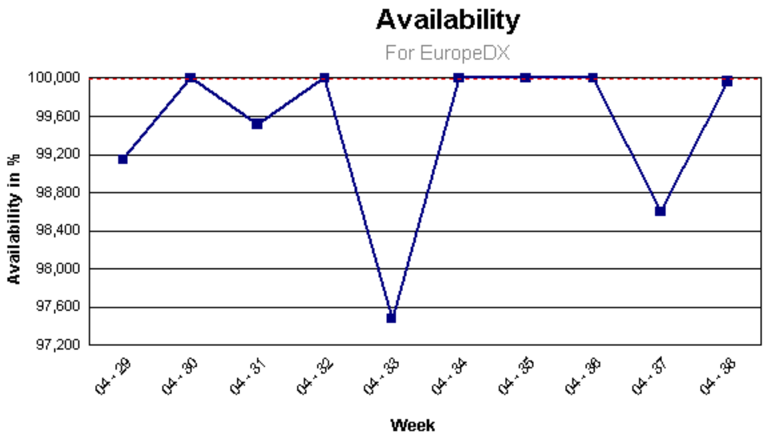
Baltic DX

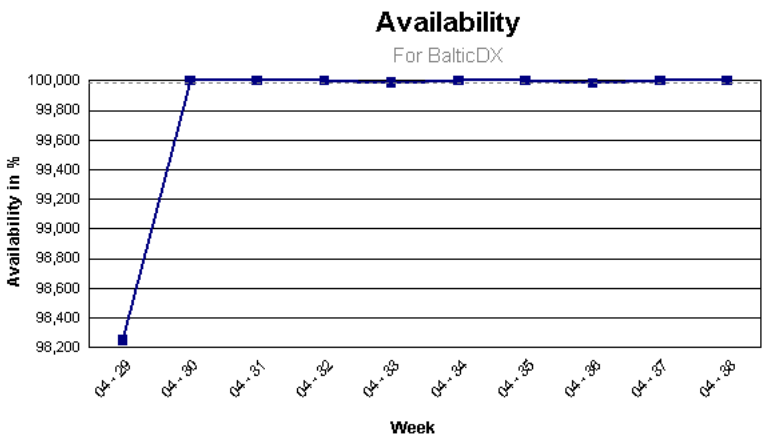
NE	Link	Availability in %
6050	G11	98.979
6050	G12	100
6070	G11	100
6070	G12	99.95
6071	G11	100
6071	G12	100


Availability for SDH Network
100,100
100,000
99,900
99,800
99,700
99,600
99,500
Availability in %
04 - 29
04 - 30
04 - 31
04 - 32
04 - 33
04 - 34
04 - 35
04 - 36
04 - 37
04 - 38
Week


Availability
For SwedenDX
100,000
99,990
99,980
99,970
99,960
99,950
99,940
99,930
99,920
Availability in %
04 - 29
04 - 30
04 - 31
04 - 32
04 - 33
04 - 34
04 - 35
04 - 36
04 - 37
04 - 38
Week


Availability
For NordicDX
100,002
100,000
99,998
99,996
99,994
99,992
99,990
99,988
99,986
99,984
99,982
Availability in %
04 - 29
04 - 30
04 - 31
04 - 32
04 - 33
04 - 34
04 - 35
04 - 36
04 - 37
04 - 38
Week





6.2 Result discussion

The statistics obtained for the two months presented in the results show satisfactory levels of availability. The only part of the network that was far below the desired level of 99,95% availability was the Europe ring. The explanation to those low levels of availability was some big errors on part of the ring. However, this did not have any big effect on the transmission, as it was rerouted on a redundant path.

It is still early to draw any conclusions on statistically secured trends using the two months of data presented. It is recommended to look back on at least a year of statistical availability data when analyzing trends in the network availability.

7 Conclusions

The purpose of the thesis was to make a background investigation on network availability and then to develop a method for measuring the network availability that can be applied by Song Networks.

The background study gave a lot of important input on what to take into account when planning an availability measurement. This information may come in use for implementing future measurements.

The system implemented for measuring availability in the SDH network has been running for some time, meanwhile weekly reports are presented to the network operations management. The feedback has been positive and both network operation and transmission team are able to study historical trends and differences in availability in between different network units.

Having only two months of statistics in the database it is still to early to observe any general trends. However, minor failures that have occurred in the network have been recognized in the statistics, which indicates that the statistics are working.

By studying the trends in availability, Song Networks can direct their resources to find problems with units that show lower availability and hence could be a future threat to the total network quality. By taking control of their investments in maintenance and new equipment the company will be able to decrease the budget for these expenses. Furthermore, in today's competitive market securing a high level of availability can be quite important for attracting and maintaining customers.

Recommended future work could be to develop a method for measuring network availability in the backbone from a customer point of view. This will have to include relational databases also taking into account the redundancy of the network. Additionally, it would be interesting to evaluate to what extent an error in the backbone affects the distribution layer, for instance the short interruption that occurs when switching over to a redundant path.

While networks grow bigger and more complex, many new applications used over the networks become more sensitive to disturbances. This development calls for higher consciousness for network availability among network-providers. More effort has to be put into studying the causes of interruptions and disturbances and quantifying them in order to fulfill customer contracts and expectations.

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http://dev.mysql.com/doc/mysql/en/index.html

PHP Manual. http://www.php.net/manual/en/

9 Glossary

Access layer Part of ISO-OSI layered protocol model. The Access layer is the lowest level of the TCP/IP protocol hierarchy.

Core layer Also referred to as the backbone of the network. Includes the high-end switches and high-speed cables such as fiber cables. Devices in this layer do not use packet manipulation.

Distribution layer This layer includes LAN-based routers and layer 3 switches. The Distribution layer is between the Core layer and the Access layer.

DWDM Dense Wave Division Multiplexing. A technology that increases the capacity of optic-fiber cables by using the colors within light waves to provide different wavelength.

ITU The International Telecommunication Union. An organization within the United Nations with headquarters in Geneva, Switzerland.

Latency Transmission delay, the time taken to deliver a packet from the source to the receiver.

Link An interconnecting circuit between two locations for the purpose of transmitting and receiving data

MTBF Mean Time Between Failure. A quality measure giving the average time between a failures or disturbances of a unit.

MTTR Mean Time To Repair.

NE Network Element. An addressable and manageable telecommunication hardware equipment. Typical attributes of an NE include: transmission ports, synchronization and timing capabilities, built-in intelligence, and a manageable interface.

Packet-loss The percentage of sent packets that was lost in the transmission. Packet loss can be an indication of congestion on a network

Port A hardware location for passing data in and out of a network element.

Redundancy The existence of more than one piece of equipment, any of which could perform a given function and serve as a backup. Intended to increase the availability.

Ring A topology in which the physical medium is distributed to form a closed loop in order to assure high availability.

SDH Synchronous Digital Hierarchy. An international standard for transmitting digital information over optical fiber. It is based on the American standard SONET and is regulated by the international standardization organization ITU.

Service window Time period when the network-provider performs planned maintenance work on the network. Normally regulated with the customer in the Service Level Agreement (SLA). The service window time is excluded from the network availability calculation.

STM-1 Synchronous Transport Module level 1. The basic building block signal of SDH, with a capacity of 155 mbps.

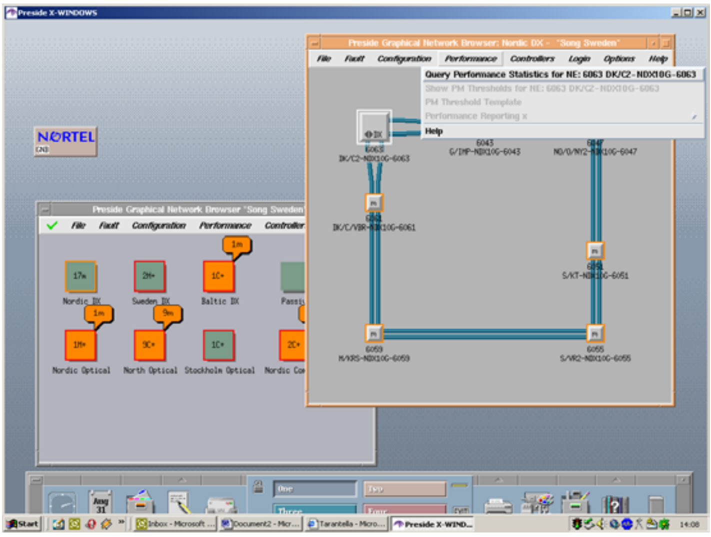
SLA Service Level Agreement. The service contract between the network provider and user.

Appendix A: Manual for the parser program

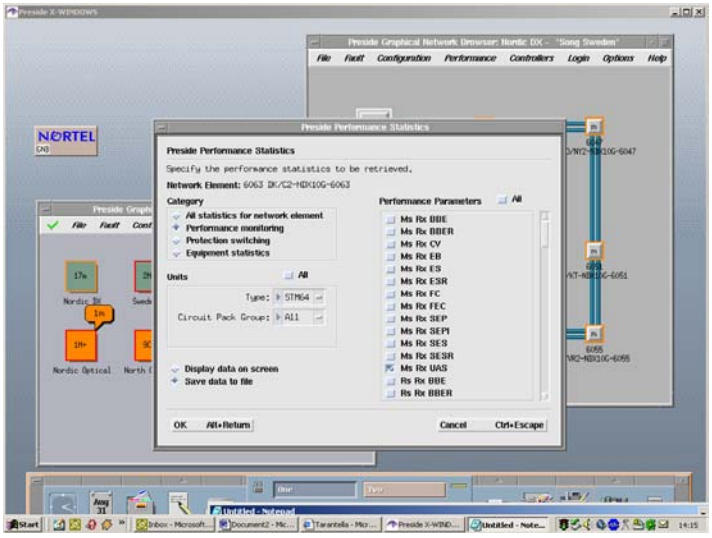
This procedure has to be repeated AT LEAST every 6 days, since information is stored in the OPCs only for the past 6 days.

1) Connect to Preside. Open a Xterm window and create a temporary directory in `/tmp/statistics/[date]`, for example: `mkdir /tmp/statistics/040831`

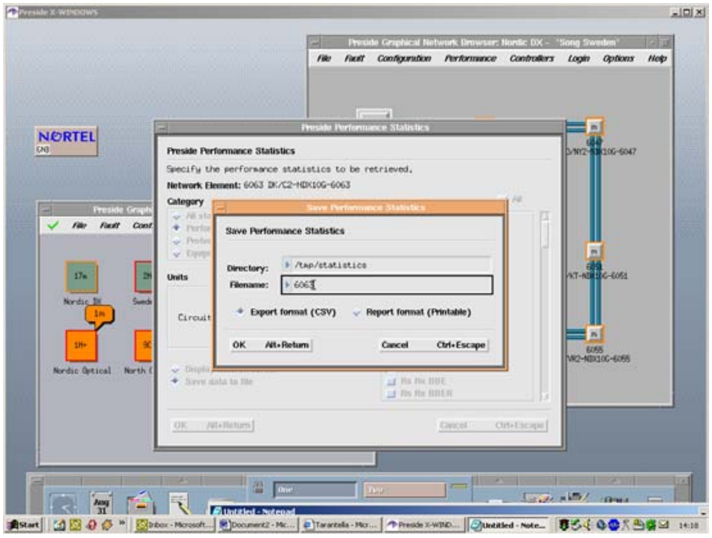
2) Open the graphical window for one of the SDH rings; choose one of the network elements and click on ***Performance -> Query Performance Statistics for NE: [xxxx]***



3) In the *Performance Statistics* dialog window, select ***Performance monitoring***, ***Type: STM-64*** (right-click), uncheck all Performance Parameters by clicking ***all*** then choose only ***Ms Rx UAS***. Choose ***Save data to file*** and click ***OK***.



4) In the *Save Performance Statistic*s dialog window, choose to save in the directory you created in step 1 and name the file, for example by its NE number (eg. 6063), select ***Export format (CSV)*** and click ***OK*** to save.



5) Repeat step 2-4 for all Network Elements in all rings.

6) Open an Xterm window in Preside and go to the directory you created in step 1. Use the ftp program to transfer all the files to a computer where you can execute a Java program. Use the command `ftp [destination_computer]` to connect and `mput` to transfer all files in the directory to eg. `~/statistics/040831/` on the remote computer.

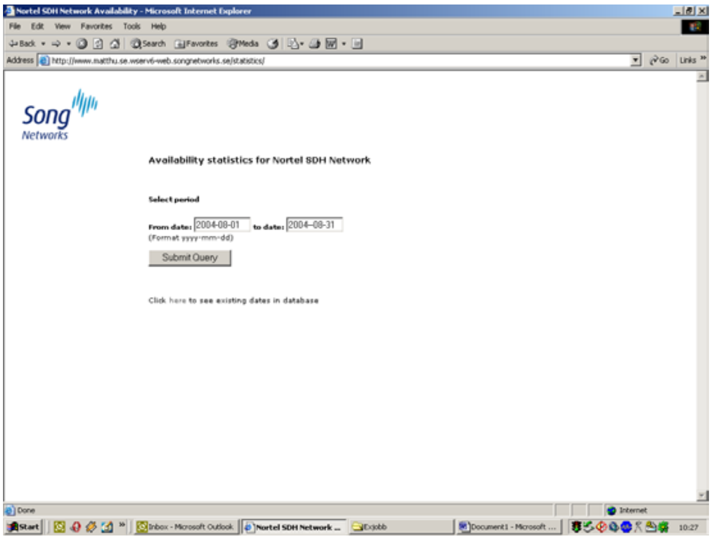
7) Close Preside and open a terminal window on the computer where you stored the files and go to the directory `~/statistics`. Run the script `driver.bat` to initiate MySQL driver and then initiate the

parse program with the command :>`java logReader [directory_name]` (eg. `java logReader 040831`). You will see that the program reads in all files in the directory and parses them into the MySQL database.

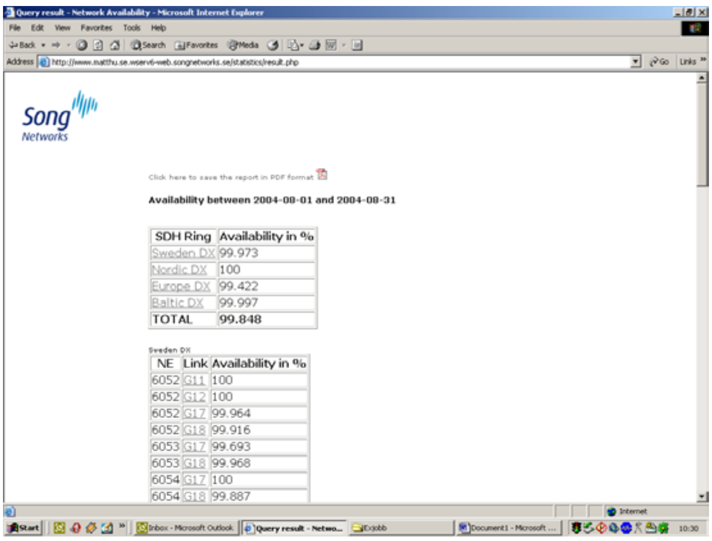
Appendix B: Manual for producing an availability report

1) Open the availability statistics page in your web-browser and log in with the name and password provided to you.

2) Enter the date period for which you want to create the report.



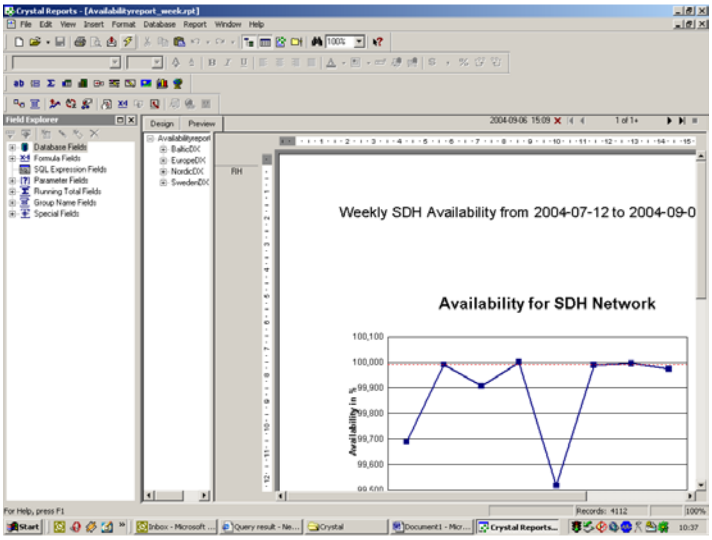
3) The report will be shown in your browser, first listing the average availability of each ring, then for each Network Element. To save the report in PDF format, click the link. To see more information about each connection, click the corresponding link in the table.



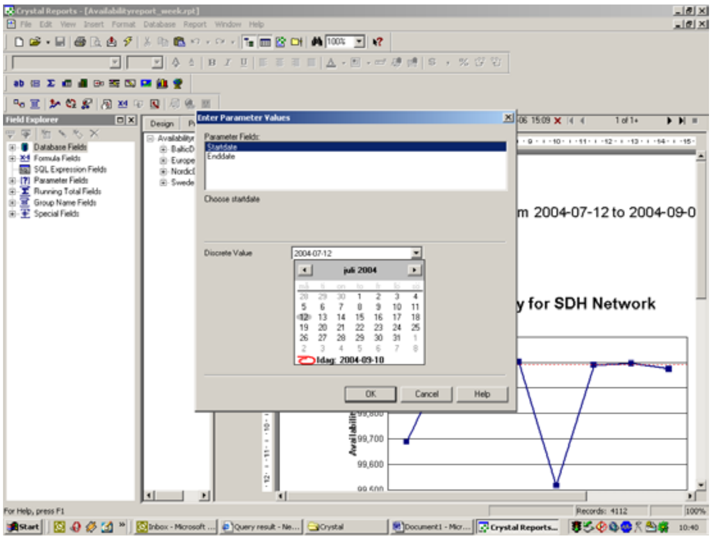
Graphic availability report

1) To produce a graphic availability report, Crystal Report needs to be installed on the user computer.

2) Open the file `Availabiltyreport_week.rpt`. Click F5 to refresh the data from the database. Choose ***Prompt for new parameter values*** in the dialog.



3) Choose a start date and an end date for the report. The report will show average data per week. It is recommended to choose a period up to a year. (The availability database contain records from 2004-07-12).



4) Go to menu **File –> Export** and choose ***Acrobat format (PDF) -> all pages*** and indicate where to store the PDF file.