EXTENSIVE TRAFFIC INVESTIGATIONS IN A LOCAL TELEPHONE EXCHANGE

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ABSTRACT

A system for data recording and analysis allowing extensive telephone traffic investigations is presented. The system consists of:

- a data collection and recording equipment controlled by a mini-computer in on-line operation
- software for subsequent traffic data analyses at a computer center.

The system is installed in a local telephone exchange. The first recordings are primarily concentrated about traffic investigations where the traffic sources are implied.

The paper describes:
- the philosophy behind the investigations
- the subject of investigation
- the test points in the exchange and the information related to them
- the data recorded for each call
- the recording equipment and the recording performance
- the procedure of the subsequent analysis
- the possibilities of statistical traffic data analyses.

1. INTRODUCTION

To improve the economy and grade of service in a telephone network of increasing complexity and traffic, it is necessary to collect adequate information about the traffic offered and the way it is handled. This information is vital for planning, dimensioning and maintenance purposes. In connection with theoretical studies and simulations, data from live traffic are essential in order to verify theories and models.

The conventional methods and equipment in use for traffic measurements give some of the information needed. Examples are "peg counts" and traffic usage sampling. However, the analysis of the collected data very often demands considerable manual participation. Only recently the adoption of modern data collection and processing methods has begun. The need for traffic information is increasing, and it is essential to make data collection and handling as effective as possible. For a better understanding of the traffic sources, the service system and the interaction between sources and system, more detailed traffic information is required. It is therefore necessary to perform investigations for better methods and equipment for traffic data recording and analysis. The aim is to establish a traffic recording strategy which includes design and operation of measuring equipment, analysis methods and the application of results.

In Norway, the Norwegian Telecommunications Administration, the Norwegian Institute of Technology and the Electronics Research Laboratory (ELAB) are engaged in a joint project, the general aim of which is to investigate:

- the information required in a specific exchange, with regard to:
  * traffic generated
  * load and service in the exchange and the network
- the data which can be readily collected to give this information
- the trends in recording equipment design and the advantages of modern technology for:
  * the number and types of connecting points
  * the reduction of costs per connecting point
  * the storage of large amounts of data
  * the analysis of recorded data on-line as well as off-line

Some of these problems have been examined earlier through the work performed with the METRO recording system [1].

2. INFORMATION REQUIRED

Experience with the METRO-recordings indicate that there is a need for traffic investigations near the traffic sources. It was therefore decided to perform the recordings in a local exchange, and to connect the measuring equipment to the subscribers' individual circuits as well as common equipment. This offers the opportunity of studying parameters of general importance for the traffic process. Also, it enables us to see the telephone network from the subscriber's point of view, and to follow his actions from when the call is initiated, through the different phases of call establishment until the call is rejected or answered. Furthermore we can watch the conversation phase to observe its duration and cost.

Emphasis is placed on the collection of data giving information for the study of:
a. the call generation process
b. subscriber behaviour, especially call repetitions
c. the influence of different subscriber categories (private, office, PABX) on the character of traffic generated
d. traffic destination
e. waiting times, establishing times and holding times
f. congestion problems in the exchange and network.

3. SUBJECT OF INVESTIGATION

The recordings are performed in a subscriber exchange of conventional electromechanical type (AGF system manufactured by L. M. Ericsson). Currently there are 13 000 extension lines installed.

The subscribers are grouped in units of 500, and the initial recordings are limited to the individual and common equipment of such a group. Of the extension lines 120 are PABX trunk lines while the rest are shared between business offices and private residences.

The recordings comprise outgoing traffic from these subscribers only and not the incoming traffic.

4. DATA

In figure 1 the test points of the individual and common equipment are shown. The main information obtained for each call referred to the test points is:

AB: Calling subscriber identity (A-number), call initiation time, time until line finder detects calling subscriber or time till handset replacement if the call is abandoned before the dial tone is received.

REG: Register seizure, dialled number (B-number), predialling delay, pulsing and interdigital times, post dialling delay.

SB: Junctor seizure, end of call/end of conversation.

GS: Group selector finds free outlet, selector release.

R: Accounting pulses. The first accounting pulse also indicates answering time.

ID/AB: Identification of subscriber connected to junctor. (The calling subscriber is identified twice: When initiating the call, he is identified on the subscriber line side (AB), and when he is connected to a junctor, he is identified from the junctor side).

As an example, figure 2 illustrates the signalling sequences of the test points for a successful local call.

Except for the A-number, all data recording is based upon the detection of level changes at the testpoints. The B-number and accounting data are recorded by pulse counting. Most of the data collected are concerned with time measurements, which may be relative or absolute values.

With reference to figure 2 the times recorded are:

\[ T_0: \text{call initiation time. This is the base time for every call, and is referred to midnight.} \]
\[ T_1: \text{time interval from } T_0 \text{ until line finder detects calling subscriber} \]
\[ T_2: \text{" " " junctor seizure} \]
\[ T_3: \text{" " " release} \]
\[ T_4: \text{" " " register seizure} \]
\[ T_5: \text{" " " release} \]
\[ T_6: \text{" " " group selector finds free outlet} \]
\[ T_7: \text{" " " selector release} \]
\[ T_8: \text{" " " first accounting pulse} \]

Figure 1. Block diagram for exchange and recording equipment.

Figure 2. Signalling sequences for local call.
In relation to the subscriber's dialling the following times are measured:

- $\theta_0$: predialling delay
- $\theta_1$: interdigital time between first and second digit
- $\theta_2^1$: interdigital times between the following digits
- $\theta_4$: time interval from last digit till register release. For local calls this time is identical with post dialling delay.

The data for each call or conversation are organized in a master list where each element is unique to a junctor. Figure 3 shows this list for the conversation in figure 2. It consists of 18 items (words) each of 16 bits. The junctor numbers are in the range 0 - 59, and the A-numbers in the range 0 - 49.

<table>
<thead>
<tr>
<th>JUNCTOR NUMBER</th>
<th>A-NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DIGIT</td>
<td>0</td>
</tr>
<tr>
<td>2. DIGIT</td>
<td>1</td>
</tr>
<tr>
<td>3. DIGIT</td>
<td>2</td>
</tr>
<tr>
<td>4. DIGIT</td>
<td>3</td>
</tr>
<tr>
<td>5. DIGIT</td>
<td>4</td>
</tr>
<tr>
<td>6. END</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_0$</td>
</tr>
<tr>
<td>$\theta_1$</td>
</tr>
<tr>
<td>$\theta_2^1$</td>
</tr>
<tr>
<td>$\theta_4$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NUMBER OF ACCOUNTING PULSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DIGIT</td>
</tr>
<tr>
<td>2. DIGIT</td>
</tr>
<tr>
<td>3. DIGIT</td>
</tr>
<tr>
<td>4. DIGIT</td>
</tr>
<tr>
<td>5. DIGIT</td>
</tr>
<tr>
<td>6. END</td>
</tr>
</tbody>
</table>

Figure 3: Master list element for the conversation in figure 2.

A master list element similar to that in figure 3 is recorded for any call or conversation, but the number of items and their content depend, of course, upon the type of call and the signalling sequences.

Examples:

- a. For an international call, up to 15 digits and their interdigital times are recorded.
- b. If a call is abandoned before the dial tone is given, $\tau_1$ is recorded instead of $\tau_2^1$. The record then consists only of A-number, $\theta_0$ and $\tau_1$.
- c. For a local call with the called subscriber busy, the register and group selector are released at approximately the same time, i.e. $\tau_4 \approx \tau_1$. In this case - as for any call without an answer - the number of accounting pulses is zero.

5. RECORDING EQUIPMENT

Because of the large volume of data of different types, no suitable recording equipment was available commercially when the project was planned. Also, there was a requirement for a versatile measuring tool allowing options for the selection of:

- recordings from a specified group of the connected testpoints
- the types of recordings required
- the time for recording to start and stop

This led to the development of a special recording equipment based on a small computer, *) which could be programmed to offer the necessary flexibility.

The tasks of the computer are to:

- a. examine the test point states via the interface
- b. transform the state information into useful data
- c. build a master list element for each call
- d. transfer the content of the master list element to a buffer area when the call or conversation is completed
- e. write data blocks to magnetic tape.

The main components of the equipment are shown in figure 4. For installation simplicity the interface circuits are separated in two cabinets. ABTEST is for the test points of the subscribers' individual equipment, and SNRTTEST is for the test points of the common equipment and a control system, common for both cabinets.

The following system design features should be emphasized:

- a. Minimum interference in the exchange.
- b. Uniformity in interface design.
- c. Easy extension of test points.
- d. Storage of large amounts of data.

The test points used in the exchange are easily connected. The interface circuits are of high impedance and have no influence on the function of the exchange. The Test points are wired to two contact frames (see figure 4). Loose cables connect contact frames and interface circuits. Thus the installation costs in the exchange are reduced to a minimum.

*) The computer selected is a NORD 20 manufactured by Norsk Dataelektronikk, Oslo, Norway.
6. RECORDING PERFORMANCE

The electrical levels of the test points are examined at regular intervals. In ABTEST this is done by an autonomous scanner every 100 ms. When a new call is detected, an interrupt signal is given and the subscriber’s reference number (A-number) in the 500-group is transferred to the computer where it is temporarily stored together with $T_0$.

The autonomous scanner is not in syncronism with the system’s basic clock which has a time resolution of 10ms. To obtain the best resolution in the initiation time, $T_0$ is given in centiseconds from midnight, and the maximum inaccuracy in $T_0$ is then 100 ms.

The test points connected to SNRTEST are scanned under computer control. SB is scanned every 50 ms for the detection of junctor seizure or release. The same scanning interval is used at GS to detect the level changes when GS finds a free outlet and GS is released. R is scanned for accounting pulses every 20 ms. To ensure correct detection of the digits the scanning interval at REG is 10 ms.

When changes in test point levels are detected, the corresponding data are generated and inserted into correct positions in the master list elements.

The times $T_1$-$T_6$ are measured relatively to $T_0$, in units of 8 centiseconds. This is because the exchange itself cannot determine which subscriber is connected to a specific junctor.

The calling subscriber is identified twice, on the subscriber line side and from the junctor side. This is because the exchange itself cannot determine which subscriber is connected to a specific junctor. This information is, however, necessary when a call is to be followed from its initiation onwards.

To identify the subscriber connected to a specific junctor, an identification pulse is injected on the c-wire. This wire is through-connected to the subscriber line side. Here the pulse is conducted through a ring encoder and the response from this is the subscriber’s reference number in the 500-group. This A-number is compared with that transferred to the computer for temporary storage at call initiation. Thus $T_0$ for each call is found and inserted together with the A-number in the correct master list element. As the call progresses the required data are computed and inserted into the master list element.

When a call or conversation is terminated the content of the master list element is transferred to form a data block in a buffer area. When this is filled, the block is written to the magnetic tape unit controlled by an autonomous data channel using direct memory access.

The magnetic tape is the input medium to a large general purpose computer where data analysis is performed.

7. SYSTEM TEST

In order to install a system operating as reliably as possible it was important to perform a detailed test and calibration of the system in the laboratory. Because of the accurate time measurements and the need to test the system in operation under different load conditions, the system test could not be done by simply connecting the test points to handswitches. It was therefore decided to generate test patterns similar to the signalling sequences in figure 2 by another computer and to use these as inputs to the system test points.

The simulation system developed for this purpose can generate up to 16 simultaneous "calls", each "call" 

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**Figure 4. Main components of recording equipment.**
Data are treated in a three step process. The first step is the data collection and recording process described in the proceeding chapters. The second step is a data control and reformatting process at the computer center where the data analyses are performed. The statistical analyses of data is the third step, this is discussed in more detail in chapter 9. Figure 5 gives a schematic view of the data processing performed.

There are three reasons for the second step in the data processing:

1. To check for and if possible correct any errors which may be caused by magnetic tape recording incompatibility.
2. To reformat the data to make them FORTRAN compatible.
3. To perform validity checks on the data.

The analysis programs insist that the input tape format be correct. Because of the potential incompatibility between the magnetic tape unit at the recording computer and at the analysis computer (which may be caused by a variety of mechanical reasons) it is vital to rewrite the data while bypassing error records and blocks.

Using a reformatting process it is possible to put data from different recording systems into the format used in the analysis programs which are thus independent of the recording system source.

Basic range and consistency checks are performed to allow the analysis programs to view the data received as being perfect.

9. TRAFFIC ANALYSIS TO BE PERFORMED

The off-line analysis of the data recorded on magnetic tape are performed by different handling programs. The results are mainly presented in the form of distribution and time functions and are compared with statistical models and previously obtained observations.

As the identities of the calling as well as the called subscriber are known for every call, the most important keys to the study of the subscriber behaviour and their influence on the traffic process are available.

Interesting subjects of analysis are:

a. Repeated calls.
   When a subscriber does not get an answer at the first attempt, he very often makes renewed attempts. Before he gets an answer or abandons the call he may have performed many unsuccessful calls. The reasons for no answer may be B-subscriber busy or absent, congestion or premature abandonment.

   Based upon data recorded in a PABX, analyses of repeated calls have been published earlier [2].

   Properties studied were:
   - the number of attempts in repetition series
   - probability of abandonment as a function of repetition series lengths
   - time intervals between calls in repetition series

   It will be of interest to extend these studies to include subscribers in a public exchange.

b. Individual calling rates, time consistency and concentration, called number repertoire, entropy and concentration factor.

   The study of the items above were started in [2] and will be carried on with data from this project.

c. The call generation process.

   When initiation time and identity for every call are known, the call generation process may be studied either for the subscriber group as a whole or for subgroups (PABX-lines, office lines, etc.). The influence from repeated calls will be subject to special attention.

d. Subscriber dialling.

   On the basis of B-number recording and time measurements during dialling, the subscriber behaviour when dialling special calls, local calls, national and international long distance calls will be studied.
Subjects are:
- predialling delay
- interdigital times
- number of calls with illegal dialling
- number of calls with interrupted dialling

e. Answering time.

Answering time is only recorded for local calls and equals the time interval between register release and the first accounting pulse.

f. B-subscriber busy/free.

Whether B-subscriber is busy or free can also be studied at local calls only. In this case register and group selector are released at almost the same time. Besides, no accounting pulses are recorded.

For a busy/free study, as well as the answering time study, it is generally of no importance whether a call is local or long distance. The B-subscriber's category (PABX, business office, private) will complicate the studies when taken into account.

g. Conversation times.

Conversation time is an important parameter in traffic calculations. It is therefore of interest to know conversation time distribution for local calls, national and international long distance calls.

It has been observed in other studies, [2], that conversation times depend on the time of day, and this will be further investigated.

h. Influence from changes in tariffs.

At intervals telephone tariffs are changed. Most frequently this is done to increase the income of the telephone company but also as attempts to change the traffic distribution over the day by means of differential tariffs.

It will be of interest to observe if call frequencies and conversation times are influenced by such tariff changes.

Data analysis may also give indications of traffic equipment malfunctions. Thus it is possible to examine which junctions have not been in operation for some time and therefore are likely to be in need of repair.

From B-number analysis and conversation time measurements the cost for each conversation, i.e. the number of accounting pulses may be calculated. For accounting control this calculated number of pulses are compared with those recorded.

The data also allow investigations of dimensioning and congestion. For these purposes relevant analysis will be:

a. Traffic interests.

Both for the dimensioning of the local exchange and the surrounding networks it is of great importance to know the destination of the traffic generated by group and thereby its contribution to the traffic matrices. This is easily done by arbitrarily detailed analysis of recorded B-numbers.

Besides, the recording equipment is connected to the registers in the exchange in such a way that there are possibilities for B-number recording from 2500 subscribers, even though the more complete recordings cover only 500 subscribers.

b. Traffic from different subscriber categories.

To obtain the best possible utilization of common equipment in the exchanges, it is of interest to investigate whether different subscriber categories (PABX, offices, private) have so significant differences in their utilization of lines that it may be of interest to take advantage of these differences for the composition of subscriber groups.

Investigations for this purpose will include a study of traffic intensities of different categories and how these are related to time of day and destination.

γ. Bottlenecks.

Analysis of the B-answering time combined with B-number analysis may indicate long establishing times or many unsuccessful calls in certain directions and may thus be of help in localizing bottlenecks.

For local calls the post dialling delay is recorded. This provides valuable information about the establishing time in the local network.

The dimensioning of the first group selector stage may be investigated specially well as it is known how many digits the group selector stage starts searching for a free outlet and it is recorded when an outlet is found.

δ. Dial tone delay and register holding times.

For every call, dial tone delay and register holding time are recorded. When the subscriber fails in getting the dial tone, this event and the time he waits before call abandonment are recorded. The number of such messages, dial tone delay and register holding time are supposed to be functions of call intensity and time of day.

In general, investigations under γ and δ are combined in studying congestion problems.

10. DATA PRESENTATION

Data presentation will be given by colleagues at the congress in connection with a companion read paper, titled "A Statistical Study of Telephone Traffic Data, with Emphasis on Subscriber Behaviour" by Arne Myskja and Odd Olav Walmann.

11. ACKNOWLEDGEMENTS

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