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PART II

Recommendations E.500 to E.600

TRAFFIC ENGINEERING

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SECTION 1

MEASUREMENT AND RECORDING OF TRAFFIC

Recommendation E.500

TRAFFIC INTENSITY MEASUREMENT PRINCIPLES

1 Introduction

1.1 Traffic measurements provide the data base from which the planning, operation, management and, in some cases, accounting for transit considerations of the telephone network are carried out. Different applications may exist for the same traffic measurement.

1.2 This Recommendation gives the principles for measuring carried traffic and bids on circuit groups and exchanges. The number of bids and preferably also carried traffic intensity should also be determined by individual relations (destinations). Data so obtained are applied both for operation and planning. Recommendation E.501 gives methods for estimating

offered traffic from carried traffic measurements. Recommendation E.502 describes exchange requirements for traffic measurements both in national and international exchanges. Recommendation E.525 describes the traffic data analysis. Recommendation E.506 gives methods for forecasting future traffic requirements. The remainder of the E.500 Series of Recommendations describes how to utilize this data base in the operation and planning of telephone networks.

The measurements required for network management as described in the E.410 Series are generally similar to those described in this Recommendation. They will usually require a variable and shorter reporting interval.

2 Definitions

A **measurement of the amount of traffic carried** is the average Erlang value during a certain period of time (e.g. 15 min., 1 hour).

A **measurement of the number of bids** is a count of this entity during a certain period of time.

Measurements are taken continuously during the day or with exclusion of known low traffic periods. The set of days at which measurement has been taken is called the *measurement days* .

In the **yearly continuous measurement** the measurement days are post-selected from a base period with a length of the whole year. The post-selected days include the peak intensity values measured during the base period.

In the **yearly non-continuous measurement** the measurement days are scheduled (pre-selected) from a base period of a few months. The pre-selected days include the high load days of expectation or of earlier observations.

A traffic profile is defined to be *stable* when the individual daily traffic profiles differ only little in shape and traffic volume between each other.

A traffic profile is defined to be *unstable* | hen the individual daily traffic profiles differ in shape or traffic volume between each other.

3 Overview

Circuit group dimensioning is based on a congestion objective, on the traffic intensity values at high load time and on the forecast value of intensity until the next augmentation of circuits. Intensity is measured during a daily busy hour and averaged over a number of days, to avoid exceptional values.

If traffic measurements are taken every day of the year (yearly continuous measurements), the required averages can be calculated directly as described in § 4. If traffic measurements are taken only during a limited number of days in the year (yearly non-continuous measurements), the equivalent traffic loads may be estimated using the procedures given in § 5.

The busy hour concept is an important aspect of teletraffic engineering and may be applied in a number of ways. In the E.500 Series of Recommendations the busy hour traffic used is an average of several days with, in some cases, an allowance for day to day variations (Recommendation E.521).

Within the busy hour, traffic is considered to be stationary and thus the recorded intensity is the mean value during the busy hour.

The recommended standard method of calculating the daily average requires *continuously* | easuring all quarter hours for *all* days concerned and selecting the busiest hour in the average profile for all days. This method is called the Time-Consistent Busy Hour (TCBH) and is described in detail in § 6. This method is most valuable in situations of stable traffic profiles. The daily continuous measurements provide the data necessary for confirming profile stability.

Another method of arriving at the representative average busy hour also involves *continuously* | easuring all quarter hours, but only the busiest hour of *each day* is retained for averaging. This method is called the Average Daily Peak Hour (ADPH) and is described in detail in § 6 together with the relation of ADPH results to TCBH results.

The advantages of ADPH are that it requires less data storage and manipulation than TCBH and that it gives a more representative value in the situation of unstable traffic profiles.

In some situations Administrations do not measure traffic *continuously* | ver the day, but only for the hour or few hours expected to be busiest. This method is called the Fixed Daily Measurement Period (FDMP) or Fixed Daily Measurement Hour (FDMH) and is described in detail in § 7 together with the relation of FDMP results to TCBH results.

The advantage of FDMP is that it requires less measurement resources than TCBH or ADPH. The disadvantage is that in individual situations the difference between FDMP and TCBH results may vary widely.

In some network situations significant savings can be made by multihour dimensioning (e.g. cluster engineering, time zone differences). This requires daily continuous measurements.

4 Yearly continuous measurements

Traffic statistics should be measured for the significant period of each day of the whole year. The significant period may in principle be 24 hours of the day.

The measurements for computing normal traffic load should be the 30 highest days in a fixed 12-month period. Normally these will be working days, but in some cases separate weekend or tariff-related period measurements should be examined so that Administrations can agree bilaterally on appropriate measures to maintain a reasonable grade of service (GOS) for weekends and tariff-related periods. Recurring exceptional days (e.g. Christmas, Mother's Day, etc.) should be excluded for network dimensioning purposes although the data should be collected for network management purposes (Recommendation E.410). This method gives traffic information of relatively high accuracy and is suitable for circuits groups operated automatically or semiautomatically.

4.1 *Normal and high load levels*

Teletraffic performance objectives and dimensioning practices generally set objectives for two sets of traffic load conditions.

A normal traffic load can be considered the typical operating condition of a network for which subscribers service expectations should be met.

A high traffic load can be considered a less frequently encountered operating condition of a network for which normal subscriber expectations would not be met but for which a reduced level of performance should be achieved to prevent excessive repeat calling and spread of network congestion.

In order to estimate normal and high load levels, offered traffic intensity values should, where necessary, be estimated from daily carried traffic measurements. Estimation procedures are presented in Recommendation E.501.

Normal and high loads are defined in Table 1/E.500.

H.T. [T1.500]

TABLE 1/E.500

Circuit groups		
Parameter	Normal load	High load
Carried traffic intensity Mean of the 30 highest working days during a 12-month period. } Mean of the five highest days in the same period as normal load. }	{ {	
Number of bids Mean of the same 30 days on which the offered traffic intensities are highest. } Mean of same five days on which the offered traffic intensities are the highest. }	{ {	
Exchanges		
Parameter	Normal load	High load
Carried traffic intensity Mean of the ten highest days during a 12-month period. } Mean of the five highest days in the same period as normal load. }	{ {	
Number of bids Mean of the same ten highest days (not necessarily the same as the highest offered traffic days) during a 12-month period. } Mean of the five highest days (not necessarily the same as the highest offered traffic days) in the same period as normal load. }	{ {	

Table 1/E.500 [T1.500], p.

5 Yearly non-continuous measurements

5.1 *Introduction*

This method consists in taking measurements on a limited sample of days in each year. Limited sample measurements will normally be taken on working days, but Administrations may agree bilaterally to measure weekend or reduced tariff periods separately.

Any Administration proposing to use a yearly non-continuous measurement procedure is advised to confer with other end Administrations to ensure that the maximum information is available to assist in the choice of measurement days. For example, if the other end Administration has continuous measurement capability it may be possible to identify busy seasons or consistent low-traffic days.

Table 2/E.500 shows the results of a study carried out on circuit groups within a large metropolitan network [1]. The errors shown are the under-estimates resulting if average busy hour carried traffic intensity is measured over a pre-defined two-week period of the year, rather than the actual busiest two-week period. (The pre-defined period was, in fact, the peak period of the preceding year.)

The error averages 7.6% more or less, depending on circuit group size. Had an Administration wished to estimate the true peak two-week intensity with 90% confidence, starting with the pre-defined two-week measurements, the latter would have had to be increased by amounts ranging from about 14% for large circuit groups, up to about 31% for small ones. (The magnitude of these corrections indicates how inadequate a two-week sample can be as a basis for network planning.)

H.T. [T2.500]
TABLE 2/E.500
Weighted mean error and the upper limit of the intensity error class

for a cumulative proportion of circuit groups, categorized according to traffic intensity

	Total	Low < 10 Erl	Medium 10-100 Erl	High > 100 Erl
Circuit groups	2728	1056	1564	110
{ Weighted mean error of the intensity value }	7.6%	13.7%	7.8%	5.2%
{ Cumulative proportion of circuit groups }				
50%	7.9%	12.9%	6.9%	3.9%
80%	16.9%	22.9%	17.9%	7.9%
90%	23.9%	30.9%	23.9%	13.9%
95%	31.9%	37.9%	34.9%	17.9%
98%	41.9%	47.9%	40.9%	26.9%

Table 2 [T2.500], p.

5.2 *Estimation method*

An approximate statistical method for estimating normal and high load levels from limited sample measurements is provided below.

5.2.1 *Principle of estimation method*

Measurements are taken on a limited sample of days, and the mean (M) and standard deviation (S) of the daily busy hour traffic loads are calculated. Normal and high load level estimates (L) are given by:

$$L = M + k \times S$$

different values of the factor k | eing used for normal and high load levels.

[Unable to convert formula]

where

X_i | is the time-consistent busy hour traffic measured on the i th day,

M = [Unable to convert formula] X_i is the sample mean, and

n | s the number of measurement days.

If the measurement period is less than 30 days then the estimate will not be very reliable. In this case Administrations should, if possible, carry out special measurement studies to determine typical values of the standard deviation (e.g. as a function of the sample mean).

5.2.2 *Base period for measurements*

It is important to determine the ‘‘base period’’ since the length of this period influences the values assigned to the multiplication factors k.

The base period is the set of valid days in each year from which measurement days are preselected. This period should include all days which are potential candidates for being among the 30 highest days (but excluding recurring exceptional days — see § 4).

The base period may be restricted to a busy season (which need not necessarily comprise a set of consecutive weeks) provided that the traffic is known to be consistently higher during this period than during the remainder of the year.

The base period may be the whole year, but Administrations may also decide to exclude known low-traffic days.

5.2.3 *Selection of measurement days*

Measurement days should be distributed reasonably evenly throughout the base period. If the base period extends over the whole year then the measurement sample should include some days from the busiest part of the year, if these are known. The limited sample should comprise at least 30 days to

ensure reliable estimates. If this is not possible, then a minimum of 10 measurement days may be used. In this case the reliability of the estimate is poor.

5.2.4 *Multiplication factors*

Multiplication factors k | or 5-day, 10-day, and 30-day load levels are given by the curves in Figure 1/E.500, as a function of the number of days in the base period. These factors are derived from tables of order statistics from the normal distribution [2].

When the base period extends over the whole year these factors may not always be reliable because of the effects of differing seasonal patterns. Individual Administrations may then prefer to use different values for the factors, if they have obtained more precise information from special measurement studies.

Figure 1/E.500, p

5.2.5 *Example*

The following data illustrate the application of this procedure to the estimation of normal and high load levels from non-continuous measurements on a circuit group over a 1-year period.

After excluding holidays and other known low traffic periods the base period which is available for measurement purposes is determined to be 220 days. The k -factors to be used are therefore (from Figure 1/E.500):

Normal (30-day) load level: $k = 1.6$

High (5-day) load level: $k = 2.3$

Measurements are taken on 50 days within the base period. The daily measured busy-hour traffic values, in Erlangs, are as follows:

H.T. [T3.500]

21.5	20.5	18.7	15.0	18.4	21.6	18.1	24.2	26.7	22.1
21.8	17.8	17.2	19.8	15.2	20.4	16.7	20.6	23.1	23.5
19.6	18.1	21.3	15.9	15.9	17.8	17.4	20.9	25.9	20.6
20.9	19.2	17.6	12.9	14.2	18.1	16.9	24.2	22.2	26.8
22.5	22.8	19.3	19.1	18.7	19.8	18.0	26.0	22.5	27.5

Table [T3.500], p.

The sample mean and standard deviation are:

$M = 20.11$

$S = 3.37$

The normal and high load level estimates are then calculated from $L = M + k$ | (mu | fIS to give:

Normal load = 25.5 Erlangs

High load = 27.9 Erlangs

5.2.6 *High to normal traffic ratios*

In some circumstances, actual values of high day loads are not available. In such cases, various Administrations use standard ratios of high to normal load for forecasting for design or planning purposes.

For example, as a general order of magnitude, the following ratios of high to normal load may be used as a guide for a healthy network:

Parameter	*Circuit groups*	*Exchanges*
Offered traffic intensity	1.2	1.1
Number of call attempts	1.4	1.2

6 Daily continuous measurements

6.1 *Measurement*

It is recommended that Administrations take traffic measurements continuously over the day throughout the measurement period.

Depending on the application, a busy hour value for dimensioning should be calculated as the peak value of the mean day profile or the average of daily peak values.

6.2 *Time-consistent busy hour (TCBH)-intensity (post-selected)*

For a number of days, carried traffic values for each quarter hour for each day are recorded. The values for the same quarter hour each day are averaged.

The four consecutive quarter-hours in this average day which together give the largest sum of observed values form the TCBH with its TCBH-intensity. This is sometimes referred to as post-selected TCBH.

In the case where a stable traffic profile exists, the TCBH-intensity is used as a base method for dimensioning; if measurement methods yielding systematically lower or higher intensity values than the TCBH-method are used, adjustments to the calculations are needed.

6.3 *Average of the daily peak hours traffic , defined on quarter hour or on full hour basis*

To find the average of daily peak quarterly defined hour (ADPQH) intensity, the traffic intensity is measured continuously over a day in quarter-hour periods. The intensity values are processed daily to find out

the four consecutive quarter hours with the highest intensity value sum. Only this daily peak hour traffic intensity value is registered. The average is taken over a number of working days peak intensities. The timing of peak intensity normally varies from day to day.

To find the average of daily peak full hour (ADPFH) intensity, the traffic intensity is measured continuously over a day in full-hour periods. Only the highest of these intensity values is registered. The average is taken over a number of days peak intensities.

The comparative measurements have shown that the traffic intensity values measured by the ADPFH-method, are very consistent with the values measured by the TCBH-method, whereas the ADPQH-method yields slightly (a few percent) higher values. (See Annex A.) ADPH has an advantage over TCBH when traffic profiles are unstable.

6.4 *Alternate routing networks*

When alternate routing is used, the dimensioning methods in Recommendation E.522 should be applied (multi-hour dimensioning technique). In general this requires the continuous measurement of a 24-hour profile for each traffic quantity in the alternative routing cluster.

In Annex A the differences in results between busy hours defined for individual circuit groups and for clusters indicate the advantage of continuous measurements and multi-hour dimensioning for alternative routing networks.

In circumstances where the traffic profiles are stable and similar in the whole cluster, the multi-hour dimensioning may be applied on a few selected hours of significance to the entire cluster. The stability of traffic profiles must be confirmed.

7 Daily non-continuous measurements

7.1 *Measurement*

Some Administrations may find it necessary or economically attractive to restrict measurements to a few hours or only one hour per day. Such measurements will always be less accurate than continuous measurements. The resulting busy hour values will always be less than or equal to TCBH.

The time of fixed daily measurements should be confirmed several times a year by measurement of the full daily traffic profile for every circuit group. The measurement can cover several periods daily, as well.

7.2 *Fixed daily measurement period (FDMP)*

With this method measurements are taken within a fixed period (e.g. of 3 hours) each day. This period should correspond to the highest part of the traffic profile, which is expected to include the TCBH. Measurement values are accumulated separately for each quarter-hour, and the busiest hour is determined at the end of the measurement period, as for the TCBH. This method will normally give results which are about 95% of the TCBH traffic level, when the time of fixed daily measurement is defined for every single circuit group, although major changes in the traffic profile could lead to larger errors.

In alternate routing networks with traffic profiles that are similar and stable in the whole cluster, FDMP may be used to produce measurements for multi-hour dimensioning applied on a few selected hours of significance. The stability of traffic profiles should be confirmed several times a year.

7.3 *Fixed daily measurement hour (FDMH)*

If the fixed daily measurement period is reduced to 1 hour, then it is only necessary to accumulate a single measured value from each day. This is the simplest measurement method, and it will normally give results which are about 90% of the TCBH traffic value, when the time of the fixed daily measurement is

defined for single circuit groups individually. However, the variations around the average are large.

8 Flow chart for the application of the different calculation methods

The decisions represented in Figure 2/E.500 compare measurement and analysis costs to variations in the results for a single circuit group or cluster. The costs are particular to each Administration.

The preceding sections of this Recommendation indicate the amount of measurement variance that can occur in typical situations which can result in overprovisioning or a risk of poor grade of service.

In cluster engineering for alternative routing networks, measurements outside the busy hour are normally needed if the traffic profile is unstable. In situations of stable traffic load the significant traffic hours can be predicted accurately, allowing use of a

FDMP method.

Figure 2/E.500, p.

ANNEX A
(to Recommendation E.500)

Example of
influence of different busy hour definitions on

measured traffic intensity

A.1 *Introduction*

The influence of different busy hour definitions on measured traffic intensity has been investigated by means of measurements on real traffic outgoing from an international exchange.

Three clusters with a total of 15 circuit groups have been studied. One of the clusters (Cluster 1) carries traffic between different time zones.

Traffic per quarter of an hour was measured during the whole day in 5 two-week periods (10 consecutive working days). The total elapsed time covered 9 months.

From the results of the first two-week period of daily continuous measurements the times of FDMH and FDMP have been determined:

— for each circuit group individually (ind),

— per cluster (clu), and

— for all three clusters commonly (com).

The time of FDMH is equal to the time of TCBH in the first two-week period. FDMP includes FDMH and the hour before and the hour after.

A.2 *Results of measurements*

The results of the measurements undertaken are summarized in Figures A-1/E.500 to A-5/E.500.

Figure A-1/E.500 shows how the starting time of TCBH varies between the five measurement periods:

— for each cluster, and

— for individual circuit groups in each cluster.

The following observations on the starting time of TCBH can be made:

— the starting time of TCBH is the same in not more than 2 periods. This refers to both circuit groups and clusters;

— 5 circuit groups and 1 cluster have different TCBH in all periods;

— 8 circuit groups and 2 clusters have TCBH within the same part of the day (morning or evening) in all periods;

— TCBH common to all clusters is in the evening in all periods. Only 2 periods have the same common TCBH.

In Figures A-2/E.500 to A-5/E.500 traffic intensities according to different busy hour definitions have been compared. Traffic intensity according to the TCBH definition has been used as reference value (corresponding to 100% in the figures).

Figure A-2/E.500 shows the results of comparisons on a cluster level, and Figures A-3/E.500 to A-5/E.500 on a circuit group level.

Means and variations of traffic intensities are given as:

— an average of all five periods (ADPQH and ADPFH), and

— an average of measurement periods 2, 3, 4 and 5 compared with period 1 (FDMH and FDMP).

A.3 *Results on cluster level (Figure A-2/E.500)*

ADPQH intensities over 100%, mean = 102%.

ADPFH intensities around 100%, mean = 100%.

FDMP$_{c\backslash \mathrm{d}l\backslash \mathrm{d}u}$ intensities from 95 to 100%, mean = 99%.

FDMH$_{c\backslash \mathrm{d}l\backslash \mathrm{d}u}$ intensities from 90 to 98%, mean = 94%.

FDMP$_{c\backslash \mathrm{d}o\backslash \mathrm{d}m}$ intensities from 42 to 100%, mean = 89%.

FDMH$_{c\backslash \mathrm{d}o\backslash \mathrm{d}m}$ intensities from 35 to 93%, mean = 83%.

A.4 *Results on circuit group level (Figures A-3/E.500 to A-5/E.500)*

ADPQH intensities over 100%, mean = 104%.

ADPFH intensities around 100%, mean = 100%.

FDMP$_{i\backslash \mathrm{d}n\backslash \mathrm{d}d}$ intensities from 88 to 100%, mean = 99%.

FDMH$_{i\backslash \mathrm{d}n\backslash \mathrm{d}d}$ intensities from 80 to 100%, mean = 93%.

FDMP$_{c\backslash \mathrm{d}l\backslash \mathrm{d}u}$ intensities from 51 to 100%, mean = 98%.

FDMH$_{c\backslash \mathrm{d}l\backslash \mathrm{d}u}$ intensities from 45 to 99%, mean = 91%.

FDMP$_{c\backslash \mathrm{d}o\backslash \mathrm{d}m}$ intensities from 24 to 100%, mean = 89%.

FDMH$_{c\backslash \mathrm{d}o\backslash \mathrm{d}m}$ intensities from 14 to 99%, mean = 81%.

Figure A-1/E.500, p.

Figure A-2/E.500, p.

Figure A-3/E.500, p.

Figure A-4/E.500, p.

Figure A-5/E.500, p.

References

[1] PARVIALA (A.): The stability of telephone traffic intensity profiles and its influence on measurement schedules and dimensioning (with Appendix). 11th International Teletraffic Congress, Kyoto 1985.

[2] Biometrika Tables for Statisticians, Table 9, Vol. 2. *Cambridge University Press* , 1972.

Recommendation E.501

ESTIMATION OF TRAFFIC OFFERED IN THE INTERNATIONAL NETWORK

1 Introduction

For planning the growth of the international network the following quantities must be estimated from measurements:

— traffic offered to international circuit groups,

— traffic offered to destinations, on a point-to-point basis,

— traffic offered to international exchanges,

— call attempts offered to international exchanges,

— traffic offered to signalling links.

(The term ‘‘traffic offered’’ as used here is different from the ‘‘equivalent traffic offered’’ used in the pure lost call model, which is defined in Annex B.)

These quantities are normally estimated from measurements of busy-hour carried traffic and call attempts, but there are a number of factors which may need to be taken into account within the measurement and estimation procedures:

a) Measurements may need to be subdivided, e.g. on a destination basis, or by call type (for example, calls using different signalling systems).

b) It may not be possible to obtain a complete record of traffic carried. For example, in a network with high usage and final groups it may not be possible to measure the traffic overflowing from each high usage group.

c) Measurements may be affected by congestion. This will generally result in a decrease in traffic carried, but the decrease may be affected by customer repeat attempts and by the actions (for example, automatic repeat attempts) of other network components.

d) When high levels of congestion persist for a lengthy period (many days), some customers may avoid making calls during the congested period of each day. This apparent missing component of offered traffic is known as suppressed traffic. It should be taken into account in planning since the offered traffic will increase when the equipment is augmented. At present, suitable algorithms for estimating suppressed traffic have not been defined.

Three situations should be distinguished:

i) congestion upstream of the measurement point. This is not directly observable;

ii) congestion due to the measured equipment. Congestion measurements should be used to detect this;

iii) congestion downstream of the measurement point. This can often be detected from measurements of ineffective traffic or completion ratio. Note that where groups are bothway, congestion elsewhere in the network may be both upstream and downstream of the measurement point for different parcels of traffic.

When congestion is due to the measured equipment this must be properly accounted for in the estimation of traffic offered, which is used for planning the growth of the measured equipment.

When congestion arises elsewhere in the network the planner needs to consider whether the congestion will remain throughout the considered planning period. This may be difficult if he does not have control of the congested equipment.

This Recommendation presents estimation procedures for two of the situations described above. § 2 deals with the estimation of traffic offered to a fully-operative only-route circuit group which may be in significant congestion. § 3 deals with a high-usage and final group arrangement with no significant congestion. These estimation procedures should be applied to individual busy-hour measurements. The resulting estimates of traffic offered in each hour should then be accumulated according to the procedures described in Recommendation E.500.

2 Only-route circuit group

2.1 *No significant congestion*

Traffic offered will equal traffic carried measured according to Recommendation E.500. No estimation is required.

2.2 *Significant congestion*

Let A_c be the *traffic carried* in the circuit group. Then on the assumption that augmentation of the circuit group would have no effect on the mean holding time of calls carried, or on the completion ratio of calls carried, the *traffic offered* to the circuit group may be expressed as

$$A = A_c \frac{1 - WB}{1 - B}$$

where B is the present average loss probability for all call attempts to the considered circuit group, and W is a parameter representing the effect of call repetitions. Models for W are presented in Annex A.

To facilitate the quick determination of offered traffic according to the approximate procedure in Annex A, Table A-1/E.501 including numerical values of the factor $(1 - WB)/(1 - B)$ was prepared for a wide range of B, H and r' (for the definition of H and r', see Annex A). For the use of Table A-1/E.501, see Note 2 in Annex A.

Note 1 — Annex A gives a derivation of this relationship, and also describes a more complex model which may be of use when measurements of completion ratios are available.

Note 2 — When measurements of completion ratios are not available a W value may be selected from the range 0.6-0.9. It should be noted that a lower value of W corresponds to a higher estimate of traffic offered. Administrations are encouraged to exchange the values of W that they propose to use.

Note 3 — Administrations should maintain records of data collected before and after augmentations of circuit groups. This data will enable a check on the validity of the above formula, and on the validity of the value of W used.

Note 4 — In order to apply this formula it is normally assumed that the circuit group is in a fully operative condition, or that any faulty circuits have been taken out of service. If faulty circuits, or faulty transmission or signalling equipment associated with these circuits remain in service, then the formula may give incorrect results.

3 High-usage/final network arrangement

3.1 *High-usage group with no significant congestion on the final group*

3.1.1 Where a relation is served by a high-usage and final group arrangement, it is necessary to take simultaneous measurements on both circuit groups.

Let A_H be the traffic carried on the high-usage group, and A_F the traffic overflowing from this high-usage group and carried on the final group. With no significant congestion on the final group, the traffic offered to the high-usage group is:

$$A = A_H + A_F$$

3.1.2 Two distinct types of procedure are recommended, each with several possible approaches. The method given in § 3.1.2.1 a) is preferred because it is the most accurate, although it may be the most difficult to apply. The methods of § 3.1.2.2 may be used as additional estimates.

3.1.2.1 Simultaneous measurements are taken of A_H and the total traffic carried on the final group. Three methods are given for estimating A_F, in decreasing order of preference:

a) A_F is measured directly. In most circumstances this may be achieved by measuring traffic carried on the final group on a destination basis.

b) The total traffic carried on the final group is broken down by destination in proportion to the number of effective calls to each destination.

c) The traffic carried on the final group is broken down according to ratios between the bids from the high-usage groups and the total number of bids to the final group.

3.1.2.2 Two alternative methods are given for estimating the traffic offered to the high-usage group, which in this circumstance equals the equivalent traffic offered:

a) A | s estimated from the relationship

$$A_H = A\,[1 - E_N(A)]$$

Here $E_N(A)$ is the Erlang loss formula, N | s the number of working circuits on the high-usage group. The estimation may be made by an iterative computer program, or manually by the use of tables or graphs.

The accuracy of this method may be adversely affected by the non-randomness of the offered traffic, intensity variation during the measurement period, or use of an incorrect value for N.

b) A | s estimated from

$$A = A_H/(1 - B)$$

where B | s the measured overflow probability. The accuracy of this method may be adversely affected by the presence of repeat bids generated by the exchange if they are included in the circuit group bid register.

It is recommended to apply both methods a) and b); any significant discrepancy would then require further investigation. It should be noted however that both of these methods may become unreliable for high-usage groups with high overflow probability: in this situation a longer measurement period may be required for reliable results.

3.2 *High-usage group with significant congestion on the final group*

In this case, estimation of the traffic offered requires a combination of the methods of §§ 2.2 and 3.1. A proper understanding of the different parameters, through further study, is required before a detailed procedure can be recommended.

ANNEX A

(to Recommendation E.501)

A simplified model for the formula presented in § 2.2

The call attempts arriving at the considered circuit group may be classified as shown in Figure A-1/E.501.

The total call attempt rate at the circuit group is

$$N = N_0 + N_{N\backslash dR} + N_{L\backslash dR}.$$

We must consider $N_0 + N_{N\backslash dR}$ which would be the call attempt rate if there were no congestion on the circuit group.

Let

$B = \frac{N - N_c}{N}$ = measured blocking probability on the circuit group.

$W = \frac{N_{LR}}{N - N_c}$ = proportion of blocked call attempts that re-attempt.

We have

$$N_0 + N_R = N - N_{LR} = (N - N_{LR})\frac{N_c}{N_c} = N_c \frac{N - N_{LR}}{N - (N - N_c)} = N_c \frac{(1 - BW)}{(1 - B)} .$$

FIGURE A-1/E.501, p.

Multiplying by the mean holding time of calls carried on the circuit group, h , | ives

$$A_c = A \frac{1 - BW)}{1 - B)} ,$$

where

A_c | the traffic carried on the circuit group.

The above model is actually a simplification since the rate $N_{N\backslash\mathrm{d}R}$ would be changed by augmentation of the circuit group.

An alternative procedure is to estimate an equivalent persistence *W* from the following formulae:

$$W = \frac{\text{f Ir ‘ | f IH}}{— H(1 — r\text{ ‘})}$$

$$H = \frac{(\text{*b} — 1}{(\text{*}b(1 — r)}$$

$$\beta = \frac{ll\ call\ attempts}{irst\ call\ attempts}$$

where *r* ‘ is the completion ratio for seizures on the considered circuit group and *r* | s the completion ratio for call attempts to the considered circuit group.

These relationships may be derived by considering the situation after augmentation (see Figure A-2/E.501).

FIGURE A-2/E.501, p.

It is required to estimate N'_c, the calls to be carried when there is no congestion on the circuit group. This may be done by establishing relationships between N_c and N_0 (before augmentation) and between N'_c and N_0 (after augmentation), since the first attempt rate N_0 is assumed to be unchanged. We introduce the following parameters:

H = overall subscriber persistence,

r ‘ = completion ratio for seizures on the circuit group.

Before augmentation:

$$H = \frac{fIN_{NR}\ fR + N_{LR}\ fR}{fIN_N fR + N_L fR}$$

$$r\text{ ‘} = \frac{fIN_c fR — N_N fR}{fIN_c fR}$$

After augmentation:

$$H =$$

$$\frac{f_{IN}\,' \; f_R \; N \; R \; f_R}{f_{IN}\,' \; f_R \; N \; f_R}$$

$$r\,' = \frac{f_{IN}\,' \quad f_R \; c \quad f_R - N\,' \quad f_R \; N \quad f_R}{f_{IN}\,' \quad f_R \; c \quad f_R}$$

It is assumed for simplicity that H and r' are unchanged by the augmentation. The following two relationships may be readily derived:

$$N_0 = \frac{N_c [1 - H(1 - r') - r' BH]}{1 - B}$$

$$N'_0 = N'_c [1 - H(1 - r')].$$

Hence

$$N'_c = \frac{N_c}{1 - B}\left[1 - \left(\frac{r' H}{1 - H(1 - r')}\right) B\right]$$

On multiplying by the mean call holding time, h, this provides our estimate of traffic offered in terms of traffic carried.

The relationship $H = \frac{W - 1}{W(1 - r)}$

is valid both before and after augmentation, as may easily be derived from the above diagrams.

Note 1 — Other Administrations may be able to provide information on the call completion ratio to the considered destination country.

Note 2 — The procedure of estimating the factor W above is based on the assumptions that H, r' and h remain unchanged after augmentation. The elimination of congestion in the group considered leads to a change in H and in practical cases this causes an underestimation of the factor W and consequently an overestimation of offered traffic in the formula of § 2.2. A relevant study in the period 1985-88 has shown that the overestimation is practically negligible if B 0.2 and $r' \geq 0.6$. For larger B and smaller r' values, the overestimation may be significant unless other factors, not having been taken into account by the study, do not counteract. Therefore caution is required in using Table A-1/E.501 in the indicated range. In the case of dynamically developing networks the overestimation of offered traffic and relevant overprovisioning may be tolerated, but this may not be the case for stable networks.

Blanc

H.T. [T1.501]

TABLE A-1/E.501

{ Values of $\frac{— WB}{— B}$ } center box ; cw(30p) | cw(30p) | cw(30p) | cw(30p) | cw(30p) | cw(30p) | cw(30p) . *H* =

B = 0.1						
r‘ = 0.3	1.0653	1.0584	1.0505	1.0411	1.0300	1.0165
r‘ = 0.4	1.0574	1.0505	1.0427	1.0340	1.0241	1.0129
r‘ = 0.5	1.0512	1.0444	1.0370	1.0289	1.0202	1.0105
r‘ = 0.6	1.0462	1.0396	1.0326	1.0252	1.0173	1.0089
r‘ = 0.7	1.0421	1.0358	1.0292	1.0223	1.0152	1.0077
r‘ = 0.8	1.0387	1.0326	1.0264	1.0200	1.0135	1.0068
B = 0.2						
r‘ = 0.3	1.1470	1.1315	1.1136	1.0925	1.0675	1.0373
r‘ = 0.4	1.1293	1.1136	1.0961	1.0765	1.0543	1.0290
r‘ = 0.5	1.1153	1.1	1.0833	1.0652	1.0454	1.0238
r‘ = 0.6	1.1041	1.0892	1.0735	1.0568	1.0390	1.0201
r‘ = 0.7	1.0949	1.0806	1.0657	1.0503	1.0342	1.0174
r‘ = 0.8	1.0872	1.0735	1.0595	1.0451	1.0304	1.0154
B = 0.3						
r‘ = 0.3	1.2521	1.2255	1.1948	1.1587	1.1158	1.0639
r‘ = 0.4	1.2216	1.1948	1.1648	1.1311	1.0931	1.0498
r‘ = 0.5	1.1978	1.1714	1.1428	1.1118	1.0779	1.0408
r‘ = 0.6	1.1785	1.1530	1.1260	1.0974	1.0669	1.0345
r‘ = 0.7	1.1627	1.1382	1.1127	1.0862	1.0587	1.0299
r‘ = 0.8	1.1495	1.1260	1.1020	1.0774	1.0522	1.0264
B = 0.4						
r‘ = 0.3	1.3921	1.3508	1.3030	1.2469	1.1801	1.0995
r‘ = 0.4	1.3448	1.3030	1.2564	1.2040	1.1449	1.0775
r‘ = 0.5	1.3076	1.2666	1.2222	1.1739	1.1212	1.0634
r‘ = 0.6	1.2777	1.2380	1.1960	1.1515	1.1041	1.0537
r‘ = 0.7	1.2531	1.2150	1.1754	1.1342	1.0913	1.0466
r‘ = 0.8	1.2325	1.1960	1.1587	1.1204	1.0813	1.0411
B = 0.5						
r‘ = 0.3	1.5882	1.5263	1.4545	1.3703	1.2702	1.1492
r‘ = 0.4	1.5172	1.4545	1.3846	1.3061	1.2173	1.1162
r‘ = 0.5	1.4615	1.4	1.3333	1.2608	1.1818	1.0952
r‘ = 0.6	1.4166	1.3571	1.2941	1.2272	1.1562	1.0806
r‘ = 0.7	1.3797	1.3225	1.2631	1.2013	1.1369	1.0699
r‘ = 0.8	1.3488	1.2941	1.2380	1.1807	1.1219	1.0617

Tableau A-1/E.501 [T1.501], p.13

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ANNEX B

(to Recommendation E.501)

Equivalent traffic offered

In the lost call model the equivalent traffic offered corresponds to the traffic which produces the observed carried traffic in accordance with the relation

$$y = A (1 — B)$$

where

y | is the carried traffic,

A | is the equivalent traffic offered,

B | is the call congestion through the part of the network considered.

Note 1 — This is a purely mathematical concept. Physically it is only possible to detect bids whose effect on occupancies tells whether these attempts give rise to very brief seizures or to calls.

Note 2 — The equivalent traffic offered, which is greater than the traffic carried and therefore greater than the effective traffic, is greater than the traffic offered when the subscriber is very persistent.

Note 3 — B | s evaluated on a purely mathematical basis so that it is possible to establish a direct relationship between the traffic carried and call congestion B and to dispense with the role of the equivalent traffic offered A.

Recommendation E.502

TRAFFIC MEASUREMENT REQUIREMENTS FOR SPC (ESPECIALLY DIGITAL)

TELECOMMUNICATION EXCHANGES

1 Introduction

This Recommendation applies to all SPC (especially digital) telecommunications exchanges operating in a switched telephone network and providing basic telephony service. This Recommendation will be the basis for measurements in an Integrated Services Digital Network (ISDN).

Traffic measurements on exchanges and surrounding telephone network provide the data base from which the dimensioning, planning, operation and management of the telephone network are carried out.

Information gathered from these measurements can be used for:

— identifying traffic patterns and distributions on a route and destination basis;

— determining the amount of traffic in the exchange and the network;

— monitoring the continuity of service and the grade of service.

The above data and information are gathered with the purpose of supporting the following fundamental activities:

a) dimensioning, planning and administration of the exchange and surrounding network;

b) performance monitoring of the exchange and surrounding network;

c) network management;

d) operation and maintenance of the exchange and surrounding network;

e) tariff and marketing studies;

f) forecasting;

g) dimensioning, planning and administration of the common channel signalling network;

h) performance monitoring of the common channel signalling network.

The information generated by the exchange (see Recommendation Q.544) can be provided to the end user in either real-time or non real-time (post processed). The activities being performed by the end user will dictate the speed of this response: for example, operation and maintenance will require real-time information while the forecasting and planning information can be provided after the event in non real-time.

For these activities, the following major processing steps can be identified:

— generation, collection and storage of data;

— analysis and processing of data;

— presentation and use of the analysis results.

The generation, collection and output of raw data is achieved by continuous as well as periodic and non-periodic measurements carried out in the exchange.

The data analysis may be performed by the SPC exchange or by another system depending on the following:

— total amount of data;

— need for analysis of data from multiple exchange;

— processor load constraints.

For further information see Recommendation E.503.

2 Traffic measurement

2.1 *Traffic measurement model*

This section establishes the basic structure for a traffic measurement model that can be applied to measurements of traffic generated by the basic telephony service.

Measurements of traffic generated by ISDN services and common channel signalling systems is for further study.

A measurement is identified by three basic elements: time, entities, objects. Time includes all the necessary information to define the start, the duration and periodicity of a certain measurement. Entities describe the quantities for which data collection must be performed with a certain measurement. Objects are individual items on which the measurements are performed. Some examples of entities and objects are given below:

Entities:

— traffic volume;

— number of call attempts;

— number of seizures;

— number of successful call attempts;

— number of call attempts for which a delay exceeds a predetermined threshold value.

Objects:

— subscriber line groups;

— circuit groups;

— common control units;

— auxiliary devices;

— destinations;

— common channel signalling links;

— signal transfer points (STP).

The measurements are classified into different measurement types on the basis of a measurement matrix in which each row represents an entity and each column represents an object (Figure 1/E.502).

A measurement type is a particular combination of entities and objects corresponding to certain entries in the measurement matrix. Part of these measurement types may be standardized while the rest of them seem to be system- and/or Administration-dependent. It should be noted that all the entries in the measurement matrix cannot be used because some of them will be impossible and some others may be meaningless. In all measurement types,

the entities are fixed although some entities may not be measured for some applications. Selected objects form an object list. In some measurement types, the object list is fixed. In other types one can choose for the actual measurement some or all of the allowed objects. A measurement set is a collection of measurement types.

Figure 1/E.502, p.

2.2 *Traffic measurement structure*

A traffic measurement consists of:

- measurement set information;
- time information;
- output routing and scheduling information (output parameters).

Measurement set information, time information and output routing and scheduling information may be predefined as well as object lists. It should be noted that predefinition characteristic are system-dependent. Time data routing and the schedule may be fixed.

2.2.1 *Measurement set information*

Measurement set information consists of one or several selected measurement types with defined object (object lists) and measurement-type-dependent parameters (e.g. sampling interval, number of events in a certain category, destination codes, etc.).

2.2.2 *Time information*

Measurements may have an undetermined duration (stop date is not prespecified), or a predetermined duration, or be taken all the time. In addition, measurements may be performed continuously or on a non-continuous basis.

For measurements of undetermined duration and performed non-continuously, the recording days must be determined on a periodic basis (periodicity pattern within a calendar week). For measurements of predetermined duration, the recording days may be determined on a periodic basis or by defining the dates of the recording days (see Figure 2/E.502).

Figure 2/E.502, p.

As shown in Figure 3/E.502, time data are measurement level, recording day level and recording period level.

Measurement level: | ontains information about dates of recording days for non-periodic measurements or periodicity pattern for periodic measurements.

Recording day level: | ontains information about the start and stop time for recording periods within a recording day.

Recording period level: | ontains information about the periodicity of the data collection, controlled by the result accumulation period. The result accumulation period can be shorter than the recording period; in that case, more than one set of data is collected for each of the recording periods, to be routed toward the output media according to the results output schedule.

Figure 3/E.502, p.

2.2.3 *Output routing and scheduling information*

Output routing information defines to what destination the produced measurement results should be routed for the recording; the output routing may be toward either a physical medium (e.g. printer) or a logical medium (e.g. file).

Output scheduling information defines when (days and time) the output of the results is to be made. The output of results may be related to the end of the result accumulation period.

3 Traffic flows

Each type of traffic flow occurring in/through the exchange can be distinguished by association with an inlet or outlet of the exchange, or both. The different types of traffic flow for a generalized exchange, viz. one that combines both local and transit functions and that provides operator (telephonist) service, are illustrated as shown in Figure 4/E.502:

From Figure 4/E.502 the following relations apply:

$$A = E + F + G + H + Z_1$$

$$B = I + J + K + L + Z_{\mathbf{O}}\text{lFEOC } 2$$

$$C = O + P$$

$$D = M + N + Z_3$$

where Z_1, $Z_{\mathbf{O}}$lFEOC 2 and Z_3 account for traffic flows corresponding to calls with incomplete or invalid dialling information, and

$$Q = M + F + K + O — d_1$$

$$R = N + G + L + P — d_2$$

$$S = H + J — d_3$$

$$T = E + I — d_4$$

where d_1, d_2, d_3 and d_4 account for traffic flows corresponding to calls that fail within the exchange owing to any of the following reasons:

a) all suitable outlets are busy or unavailable;

b) internal congestion ;

c) incomplete dialling ;

d) invalid destination code ;

e) service barring/blocking (as a result of network management controls, for instance, or the operation of some supplementary service (e.g. absentee service), or because the calling/called party is disallowed such service).

The types of calls, viz. *system-originating* | all and *system-terminating* | alls, result from the operation of some of the supplementary or value-added services that SPC exchanges offer in addition to conventional telephone service. In the traffic flow diagram of

Inlet is the point on or within the boundary of the exchange system where a call attempt arrives or arises.
Outlet is the point on or within the boundary of the exchange system to which a call attempt bearing adequate and valid dialling information would tend to be routed.

Figure 4/E.502, system-originating and system-terminating calls are identified by the aggregate traffic flows *C* and *S* respectively.

4 Basic measurement types

4.1 *General*

4.1.1 Depending on the activities listed in § 1, a different degree of detail may be needed.

In order to provide bulk data for each of the above-mentioned traffic categories, overall measurements can be performed on the totality of subscriber lines and/or circuits.

Figure 4/E.502, p.

Such overall measurements have been taken into account in this Recommendation only for the traffic items from *A* to *P* in Figure 4/E.502, while they have not been considered for items *Q* , *R* , *S* and *T* since, with the assumptions made above, it is possible to achieve the relevant information by taking into account the relationship between these items and the measured ones. It is recognized that the overall measurement results might be partitioned to cover various Administrations' needs. As an example, in an international transit exchange, the traffic data measured on the totality of incoming circuits should be split into data measured on national incoming circuits and international incoming circuits, and these in turn could be differentiated according to the relevant country.

More detailed information on traffic data relevant to the exchange and surrounding network performance can be provided by means of measurements on selected sets of circuit groups, subscriber line groups, common channel signalling links, STPs, auxiliary and control units.

Very detailed traffic data can be obtained by the analysis of call records.

These call records should be produced by the exchange, containing all data (e.g. time of occurrence of signalling event, dialled digits, etc.) characterizing each individual call attempt.

The basic measurement types are given in § 4.2 below.

Their applicability will depend on the function of the exchange (local, transit, international, etc.)

Manufacturers and Administrations are to note that the list of basic measurement types is derived from the traffic model given in Figure 4/E.502. It is not intended that every exchange system should contain all the different measurement types. The measurement types are exchange- and system-dependent, and are intended as a guide to the type of measurements required to fulfil various functions. Measurement types may be combined into a few sets to enable requirements to be met for specific exchange types, e.g. local. In particular Administrations may consider that by the use of a few measurement types it is possible to satisfy the majority of their requirements.

No single measurement type can be assumed to be exclusive to a single user or to satisfy a single requirement. More than one user may require the same information presented in different ways at the same time. As an example, measurement type 22 is required for both network management and traffic engineering purposes.

4.1.2 *Network management considerations*

4.1.2.1 Information on network management is contained in the E.410 Series of Recommendations. Network management requires ‘‘real-time’’ monitoring and measurement of network status and performance and the ability to take prompt action to control the flow of traffic when necessary.

4.1.2.2 *Performance reports*

Performance reports can be provided by the exchange and/or its network management operations system (OS) in the following ways, as required by the Administration:

i) automatic data — this data is provided automatically as specified in the exchange or OS program;

ii) scheduled data — this data is provided according to a schedule established by the network manager;

iii) demand data — this data is provided only in response to a specific request by the network manager. In addition to performance data, demand data includes reference data, such as the number of circuits provided or available for service, routing information, assigned threshold values, numbers of installed switching system components, etc.;

iv) exception data — this data is provided when a data count for calculation exceeds a threshold established by the network manager.

Data reports can be provided for example on a 5-minute, 15-minute or 30-minute basis. The specific interval for any data report will be determined by the network manager. Historic data relating to the previous two or three periods (5, 15 or 30-minute) must also be available.

4.1.2.3 In order to obtain information and apply controls which may be instrumental in reducing exchange congestion, Administration should ensure that network management terminals and functions should have the highest possible priority, so that network management operations can continue uninterrupted.

4.1.2.4 Information as to which network management controls, detailed in Recommendation E.412, are currently activated and whether the controls were activated by manual or automatic means should be available to all necessary points (for example, the network management centre, exchange staff).

4.1.3 *Traffic engineering*

Information on measurements for planning purposes is given in Recommendation E.500. For further details about requirements on measurement lengths over the year and the day, data reporting intervals, etc., reference should be made to that Recommendation.

4.2 *Measurements*

4.2.1 *Overall measurements*

Type 1: | verall measurements on originating traffic (*A*).

Object: | otality of subscriber lines.

Entities:

a) Number of originating seizures;

b) Number of call attempts not routed due to:

i) no dialling (including permanent signal),

Not enough digits to discriminate if internal or outgoing call.

ii) incomplete dialling ,

iii) invalid address;

When possible, broken down by reason of congestion, e.g. c-1 blocking through the switching network, c-2 unavailability of common resources, c-3 system faults.

c) Number of call attempts lost due to internal congestion

Entities may be broken down according to relevant traffic flows.

Type 2: | verall measurements on internal traffic (*E* + *F* + *H*)

Object: | otality of subscriber lines.

Entities:

a) Number of internal seizures;

b) Number of call attempts lost due to internal congestion;

c) Number of call attempts:

i) with called-party busy,

ii) with called-party free/no answer ,

iii) answered;

iv) line out of order,

v) vacant national number,

vi) transferred subscriber;

d) Number of unsuccessful call attempts due to incomplete dialling

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Expiring of time-outs calling-party's abandon.

Type 3: | Overall measurements on originating outgoing traffic (*G*).

Object: | otality of subscriber lines.

Entities:

a) Number of outgoing seizures;

b) Number of call attempts lost due to internal congestion;

c) Number of call attempts in overflow on the last choice route;

d) Number of successful call attempts getting:

i) no answer ,

ii) answer or metering pulse(s);

e) Number of unsuccessful call attempts due to incomplete dialling

Due to time-out expiring or calling-party’s abandon or called-party busy.

Type 4: | Overall measurements on incoming traffic (*B*).

Object: | otality of incoming circuits and both-way circuits.

Entities:

a) Number of incoming seizures;

b) Number of call attempts not routed due to:

i) incomplete dialling ,

ii) invalid address;

c) Number of call attempts lost due to internal congestion.

Type 5: | Overall measurements on incoming terminating traffic ($I + J + K$)

Object: | otality of incoming circuits and both-way circuits.

Entities:

a) Number of incoming terminating seizures;

b) Number of call attempts lost due to internal congestion;

c) Number of successful call attempts:

i) with called-party busy,

ii) with called-party free/not answered,

iii) answered or metering pulse(s);

d) Number of unsuccessful call attempts due to incomplete dialling.

Type 6: | Overall measurements on transit traffic (*L*).

Object: | otality of incoming circuits and both-way circuits.

Entities:

a) Number of incoming transit seizures;

b) Number of call attempts lost due to internal congestion;

c) Number of call attempts in overflow on the last-choice route;

d) Number of successful call attempts obtaining:

Expiring of time-out or receiving a release forward.

i) no answer

ii) no answer or metering pulse(s);

e) Number of unsuccessful call attempts due to incomplete dialling

Type 7: | Overall measurements on system originating traffic ($O + P$)

Object: | xchange system.

Entities:

a) Number of system originating seizures;

b) Number of call attempts lost due to internal congestion;

c) Number of successful call attempts:

i) with called party busy or no free outlet,

ii) with called party free/not answered (for *O*),

iii) answered.

Type 8: | verall measurements on operator-originating traffic ($M + N$)

Object: | otality of operator board trunks.

Entities:

a) Number of operator originating seizures;

b) Number of unsuccessful call attempts due to:

i) incomplete dialling,

ii) invalid address,

iii) internal congestion;

c) Number of successful call attempts:

i) with called party busy or no free outlet,

ii) with called party free/not answered (for M),

iii) answered.

4.2.2 *Measurement on selectable objects*

Type 9: | Incoming traffic measurements

Object: | ach incoming circuit group and both-way circuit group.

Entities:

a) Number of incoming seizures;

b) Traffic volume;

c) Number of call attempts lost due to internal congestion ;

d) Number of circuits in service;

e) Number of circuits out of service.

Type 10: | Outgoing traffic measurements

Object: | ach outgoing circuit group and both-way circuit group.

Entities:

a) Number of outgoing seizures;

b) Traffic volume;

c) Number of call attempts in overflow;

d) Number of seizures obtaining answer;

e) Number of circuits in service;

f) Number of circuits out of service;

g) Number of dual seizures (both-way circuits only).

Type 11: | oute destination traffic measurements.

Object: | or destinations on each outgoing circuit group and both-way circuit group.

Entities:

a) Number of outgoing seizures;

b) Number of effective call attempts;

c) Traffic volume;

d) Number of call attempts, lost due to congestion on the circuit group;

e) Source (identity of incoming circuit group) — if available.

Type 12: | Measurements on subscriber line groups

Object: | et of lines composing a functional unit.

Entities:

a) Originating traffic volume;

b) Terminating traffic volume;

c) Number of originating seizures;

d) Number of terminating seizures;

e) Number of terminating call attempts.

Type 13: | easurements on auxiliary units

Object: | elected groups of auxiliary units.

Entities:

a) Number of seizures;

b) Traffic volume;

c) Numbers of non-serviced call attempts;

d) Number of units in service;

e) Number of units out of service.

4.2.3 *Measurements on control unit(s)*

Type 14: | easurements on control unit(s).

Object: | ontrol unit(s).

These measurements are highly system-dependent and therefore no specific recommendations on relevant entities can be made. However, it is essential that systems have provisions for determining the utilization of control units as required for dimensioning, planning, and grade of service monitoring of the exchange.

4.2.4 *Measurements on call records*

Type 15: | raffic dispersion and duration.

Object: | riginating (by subscriber, exchange system, operator) and/or incoming seizures ($A + B + C + D$).

Entities:

a) Source of inlet (local subscriber, exchange system or incoming/both-way circuit group);

b) Time of seizure of inlet;

By auxiliary units it is meant multifrequency code (MFC) receivers, tone circuits, etc.
The collection of the totality of call attempts could cause an excessive load for the SPC system resources, therefore such measurements might be performed on a sampling basis.

c) Dialled digits;

d) Service characteristic of call attempt for successful call attempt;

e) Identity of exchange outlet;

f) Time of seizure of outlet;

g) Time of occurrence of call attempt at exchange outlet;

h) Time of address-complete signal (if available);

i) Time of answer signal;

j) Time of release of outlet;

k) Time of release of inlet.

Whether the call attempt uses or seeks to use any of the supplementary facilities of the exchange; if so, the supplementary facility concerned shall be specifically indicated.

Type 16: | Quality-of-service assessment

Object: | riginating (by subscriber, exchange system, operator) and/or incoming seizures ($A + B + C + D$).

Entities:

a) Source or inlet (local subscriber, exchange system or incoming/both-way inter-office circuit group);

b) Time of seizures of inlet;

c) Dialled digits.

For unsuccessful call attempt, specify causes of failure:

d) No dialling;

e) Incomplete dialling;

f) Invalid address;

g) No free outlet;

h) Internal congestion;

i) Due to network management action.

For successful call attempt:

j) Order of routing choice (first, second, . | | , last) (when considering the automatic repeated attempts and/or rerouting);

k) Time of address-complete signal (undifferentiated subscriber free, subscriber busy, backward congestion) (if available);

l) Result of call attempt (answer, release due to abandon, release due to congestion).

4.2.5 *Delay grade-of-service (GOS) monitoring*

Measuring delays on a per call basis could produce severe cost penalties to the exchange. Since the accuracy requirements from the statistical viewpoint are not very high, call sampling procedures or test calls are normally sufficient for GOS monitoring purposes. For this reason these measurement types are listed separately even if types 16 and 17 should belong to § 4.1 and measurement type 18 to § 4.2.

4.2.5.1 *On a per exchange basis*

Type 17: | verall delay grade-of-service parameters monitoring.

Object: | otality of subscriber lines.

Entities:

a) Total number of originating seizures;

b) Total number of originating seizures for which the required information for setting up a through connection is available for processing in the exchange;

c) Total number of originating seizures for which sufficient address information has been received, which are addressed to a certain outgoing circuit group and for which the seizing signal or the corresponding address information is sent to the subsequent exchange;

d) Total number of originating seizures for which the dial tone delay exceeds a predetermined threshold value;

e) Seizures already counted in b) for which the through-connection delay exceeds a predetermined threshold value;

f) Seizures already counted in c) for which the call set-up delay exceeds a predetermined threshold value.

Type 18: | verall delay grade-of-service parameters monitoring.

Object: | otality of incoming or both-way circuit groups.

Entities:

a) Total number of incoming seizures;

b) Total number of incoming seizures for which the required information for setting up a through connection is available for processing in the exchange for a certain circuit group;

c) Total number of incoming seizures for which sufficient address information has been received, which are addressed to a certain outgoing circuit group and for which the seizing signal or the corresponding address information is sent to the subsequent exchange;

d) Total number of incoming seizures for which the incoming response delay exceeds a predetermined threshold value;

e) Seizures already counted in b) for which the through-connection delay exceeds a predetermined threshold value;

f) Seizures already counted in c) for which the call set-up delay exceeds a predetermined threshold value.

4.2.5.2 *On per circuit group basis*

Type 19: | elay grade-of-service parameters monitoring.

Object: | ach incoming or both-way circuit group.

Entities:

a) Total number of incoming seizures;

b) Total number of incoming seizures for which the required information for setting up a through connection is available for processing in the exchange for a certain circuit group;

c) Total number of incoming seizures for which sufficient address information has been received, which are addressed to a certain outgoing circuit group and for which the seizing signal or the corresponding address information is sent to the subsequent exchange;

d) Total number of incoming seizures for which the incoming response delay exceeds a predetermined threshold value;

e) Seizures already counted in b) for which the through-connection delay exceeds a predetermined threshold value;

f) Seizures already counted in c) for which the call set-up delay exceeds a predetermined threshold value.

4.2.6 *Network performance monitoring*

Type 20: | Network management

Object: | otal exchange and its major components, e.g. processor.

Entities:

a) Bids;

b) Incoming call queue length and overflows;

c) Number and percentage of bids encountering switching delays;

d) Percentage of processor capacity available or in use;

e) Cross exchange delay measurements;

f) Switching loss;

g) Counts of calls blocked by automatic load shedding actions.

Type 21: | etwork management.

Although measurement type 21 is identified as being for network management, it is also required for traffic engineering purposes.

Object: | ommon channel signalling system and links.

Entities:

a) Counts of signalling units and percent occupancy of signal links;

b) Counts of outgoing Initial Address Messages (IAMs) and incoming answer signals (ANC and ANN);

c) Counts of incoming Initial Address Messages (IAMs) and outgoing answer signals (ANC and ANN);

d) Counts of changeovers;

e) Counts of occurrences and duration of terminal buffer overflow conditions;

f) Counts of circuit group congestion (CGC), National Network Congestion (NNC), and/or Switching Equipment Congestion (SEC) indications sent and received on the signalling link;

g) Counts of calls overflowed or lost due to terminal buffer overflow;

h) Counts of Transfer-Prohibited (TFP) signals sent and received on the link.

Type 22: | etwork management.

Object: | ach circuit group.

Entities:

a) Bids;

b) Seizures — outgoing and incoming;

c) Answer signals received;

d) Overflows;

e) Traffic carried;

f) Number of circuits made busy to traffic;

g) Transit bids;

h) Incoming transit seizures;

i) Counts of calls affected by network management control, by type of control.

Type 23: | etwork management.

Object: | estinations.

Entities:

a) Bids;

b) Seizures;

c) Answer signals received;

d) Overflows;

e) Counts of calls affected by network management controls, by type of control (*Note* — This includes code block and call gap controls).

4.2.7 *Measurement of the performance of common channel signalling systems*

Measurement Type 21 (see § 4.2.6) is required. Other measurement types are for further study.

4.2.8 *Measurement of the integrated services digital network and its services*

For further study.

5 Related Recommendations

The use of the analysed results will be dependent on the procedures in each Administration. The list of Recommendations below are those currently existing and covering many operational aspects. They are offered only as a guide rather than a comprehensive and complete set.

— Recommendation E.500 defines the traffic intensity measurement principles;

— Recommendation E.175 defines the network model for planning purposes;

— E.410 Series of Recommendations provide information for network management;

— E.420 Series of Recommendations describe checking the quality of the international telephone service;

— Recommendation E.506 defines the forecasting methods for international traffic;

— Recommendation E.543 defines the grade of service in digital international telephone exchanges;

— Recommendation E.503 defines the traffic measurement data analysis;

— Recommendation E.504 defines the traffic measurement administration;

— the O Series of Recomendations outline specifications of measuring equipment;

— the M Series of Recommendations detail many maintenance aspects of international carrier and circuits;

— The Q Series of Recommendations cover all aspects relating to common channel signalling.

— Recommendation Q.544 deals with exchange measurements.

ANNEX A
(to Recommendation E.502)

The purpose of this Annex is to identify the measurements to be made at exchanges and the criteria needed to satisfy the basic measurement requirements, and is produced to assist the exchange designers to ensure that these measurements can be made.

Considering that an SPC digital exchange is mainly composed of software with few physical entities which can be identified as specific measurement points, it is not possible to identify exactly where measurements should be taken. However, the basic measurement types given in § 4.2 require that it be possible to differentiate between events occurring:

i) from a customer/previous exchange node, arriving at an exchange.

ii) from an exchange to another exchange node/customer.

iii) within an exchange.

In the three segments indicated above it is necessary to have the ability to record the entities independently in each segment, as well as being able to associate entities between segments.

The entities recorded are:

— bids;

— seizures;

— effective calls;

— congested bids;

— traffic volume.

An exchange should categorize failed call attempts according to the reason for the failure. However, the information available to the exchange for this purpose may depend on the signalling system used and the function and position of the exchange in the network relative to the failed call attempts.

It should be noted that measurement type 15 is a call record which has to be generated wholly within an exchange system. Also, measurement types 20, 21, 22 and 23 are specific to network management requiring slightly different criteria.

It shall be possible for any of the basic measurement types to be amalgamated to form a unique measurement program to meet an Administration’s requirements. It shall also be possible to output measurement information to more than one user. As an example, measurements may be in progress continuously for traffic engineering purposes and, at a particular time (say for one hour), measurements of the same type may be required for maintenance purposes. The output or recording of these two measurements must not interfere with each other or with any other measurements being made at the same time, e.g. for network management.

Recommendation E.503

TRAFFIC MEASUREMENT DATA ANALYSIS

1 Introduction

The aim of traffic measurements is to provide data that can be used by an Administration for planning, engineering and managing its network. The resulting measured data can be used to support various activities as stated in Recommendation E.502. In order to reduce the amount of data transfer and off-line processing, the exchange or operations system can be used to make preliminary analyses for purposes of:

— eliminating unnecessary data values;

— replacing missing or wrong values in an approriate way;

— performing simple calculations on the values of the basic measurement entities to derive characteristic parameter values of the traffic;

— storing some measured or calculated values, in particular, traffic data records;

— producing appropriate user friendly report printouts.

For each measurement object, there is a data record in which a certain number of traffic values are stored. Also, some calculated values, e.g. moving average, can be stored and updated in this data record area.

The internal functions of the analysis are not specified here. They depend on the requirements for the output results which are specified by the Administration. An acceptable method may be to collect and store the data in real time, either in a temporary data base file or directly in the traffic data record, and later perform the calculations and report printout during periods of low exchange processing activity. Alternatively, the records can be transferred to an off-line system for processing, to reduce the load on the exchange.

2 Potential applications

In order to provide bulk data for traffic and operational analysis, overall measurements can be performed on the totality of subscriber lines and/or circuits.

More specific information on traffic data relevant to the exchange and surrounding network performance can be provided by means of measurements on selected sets of circuit groups, subscriber line groups, common channel signalling links, auxiliary and control units.

Very detailed traffic data can be obtained by analysis of call records. These call records should be produced by the exchange, containing all the data (e.g. time of occurrence of signalling event, dialled digits, etc.) characterizing each individual call attempt.

The relationships between the above measurements and the potential applications are shown in Table 1/E.503. The basic measurement types are given in Recommendation E.502. Their applicability will depend on the function of the exchange (local, transit, international, etc.).

3 Traffic analysis model

Corresponding to a variety of measurements, there are a variety of analyses, some of which are typically running continuously from day to day. From the viewpoint of a particular measurement, there are one or more analyses for which the measured data are written in particular files which are

included in the output device list of a measurement as logical devices. These files are input files from the viewpoint of a traffic analysis and the process can be regarded as a transformation of the measurement entities into desired output information to the traffic analyst to aid in making various decisions.

For example, various criteria for dimensioning and verification of the grade of service could be produced by one or more analyses. A schematic picture of the flow of information is presented in Figure 1/E.503 as an activity diagram.

Cuadro 1/E.503 [T1.503], p.

Figura 1/E.503, p.

The following information is associated to each traffic analysis:

— identities of the related measurements;

— parameter values which are user-selectable to define the desired option or mode of the analysis;

— report dates of such report types for which the user must define the printout schedule;

— output devices for all report types.

4 Traffic analysis administration

4.1 In order to administer traffic analysis, the operator should perform a series of related activities and the system should support such activities by suitable system functions. Details are given below.

4.2 *List of tasks*

The following list of tasks is not intended to be complete; it aims to cover the operator's main activities in the area of traffic analysis administration:

a) to define parameter values in the parameter list of the analysis and to modify old values;

b) to define report dates for each type of report in a report date list as required and to modify it;

c) to define output routing for each type of report by an output routing list, as required, and to modify the dates;

d) to activate and/or deactivate the performance of the analysis;

e) to retrieve different kinds of information related to the existing traffic analysis;

f) to administer traffic data records of the measurement object which are included in the analysis.

4.3 *List of system functions*

The system should offer the following functions to support the jobs of the operator and the analysis itself:

a) transfer of the measured data to the analysis;

b) scheduling of various functions within the analysis, e.g. end-of-day calculation, report printout on report dates, etc.

c) management of traffic data records;

d) management of analysis description data;

e) transfer of the identification and capacity information of the measurement object to the analysis, e.g. title of a circuit group and the number of circuits assigned to it ;

f) management of the printout of reports;

g) supervision control on the time delay of the various operations associated with the analysis.

4.4 *List of man-machine language (MML) functions*

Only a preliminary list of MML functions is presented below, and the complete specifications of such functions will appear in the Z-Series Recommendations:

— define analysis parameters;

— define a report date list;

— define an output routing list;

— administer traffic data records;

— activate a traffic analysis;

— deactivate a traffic analysis;

— interrogate a traffic analysis;

— interrogate a traffic analysis versus measurements;

— interrogate an output routing list;

— interrogate analysis parameters;

— interrogate a report date list.

Recommendation E.504

TRAFFIC MEASUREMENT ADMINISTRATION

All this information may or may not be available in the collection of the measured data.

1 Introduction

Traffic measurement administration includes the scheduling and control of traffic data collection, and production of reports for analysis. The data collected by means of traffic measurements performed by the exchange is output in a form suitable for on-line or deferred analysis.

It may be useful to consider the concept of a generic Traffic Measurement System (TMS) for purposes of administering traffic measurements. Such a system may comprise elements of an exchange working in conjunction with some combinations of remote data processors and associated devices for output of measurement reports.

In order to administer traffic measurements, a series of related man-machine activities (referred to as ‘‘tasks’’) will need to be performed

through one or more man-machine interfaces, and supported by appropriate system functions. Details are given below.

The traffic measurement output should contain the measured data together with reference information about network conditions at the time of the measurement which would assist in the data analysis, for example the number of blocked devices on a route or temporary alternative routing in effect.

2 List of tasks

The following list of tasks is not intended to be complete; however, it aims to cover the essential activities in the area of the traffic measurements administration. The TMS will provide functions to support these tasks:

a) to create new measurements or measurement components and to modify old ones, by selecting the measurement types, schedules, object identities and parameters of the measurements (WHAT, WHEN and HOW to measure);

b) to delete measurements or measurement components which are no longer useful;

c) to define output routing and scheduling of measurement results (WHEN and WHERE the result will be output);

d) to activate and/or to deactivate the scheduling of the measurements that have been previously defined;

e) to retrieve the required categories of data related to the existing measurements.

3 List of system functions

To support the man-machine tasks, the TMS should offer the following functions:

a) a menu of traffic measurements;

b) scheduling of traffic measurement execution and results output;

c) management of measurement's description data;

d) retrieving of measurement's description data.

4 Man-machine functions

A preliminary list of man-machine functions needed to control the TMS functions previously given is listed below; the complete specification of such functions appears in the Z-Series Recommendations:

— create a measurement;

— create a measurement set;

— create an object list;

— create a time data list;

— create an output routing list;

— create a results output schedule;

— modify a measurement;

— modify a measurement set;

— modify an object list;

— modify a time data list;

— modify an output routing list;

— modify a results output schedule;

— delete a measurement;

— delete a measurement set;

— delete an object list;

— delete a time data list;

— delete an output routing list;

— delete a results output schedule;

— activate a measurement;

— deactivate a measurement;

— interrogate a measurement;

— interrogate a measurement set;

— interrogate a measurement type;

— interrogate an object list;

— interrogate a time data list;

— interrogate an output routing list;

— interrogate a results output schedule.

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