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SERIES E: OVERALL NETWORK OPERATION, TELEPHONE SERVICE, SERVICE OPERATION AND HUMAN FACTORS

Traffic engineering – Measurement and recording of traffic

ESTIMATION OF TRAFFIC OFFERED IN THE INTERNATIONAL NETWORK

Reedition of CCITT Recommendation E.501 published in the Blue Book, Fascicle II.3 (1988)

NOTES

1 CCITT Recommendation E.501 was published in Fascicle II.3 of the *Blue Book*. This file is an extract from the *Blue Book.* While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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* on 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-I/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 is estimated from the relationship

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

Here $E_N(A)$ is the Erlang loss formula, N is 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 is estimated from

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

where B is 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

$$N = N_O + N_{NR} + N_{LR}.$$

We must consider $N_O + N_{NR}$ which would be the call attempt rate if there were no congestion on the circuit group.

Let

$B = \dfrac{N_L}{N}$ = measured blocking probability on the circuit group.

$W = \dfrac{N_{LR}}{N_L}$ = proportion of blocked call attempts that re-attempt.

We have

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

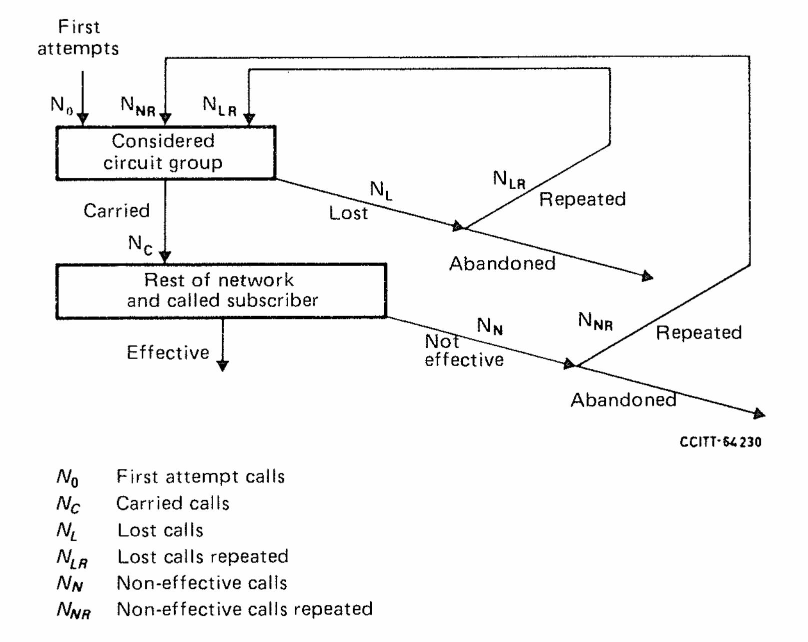

FIGURE A-1/E.501

Multiplying by the mean holding time of calls carried on the circuit group, *h*, gives

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

Where

A_c. the traffic carried on the circuit group.

The above model is actually a simplification since the rate N_{NR} would be changed by augmentation of the circuit group.

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

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

$$H = \frac{ß - 1}{ß(1 - r)}$$

$$ß = \frac{\text{All call attempts}}{\text{First call attempts}}$$

where *r*' is the completion ratio for seizures on the considered circuit group and *r* is 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).

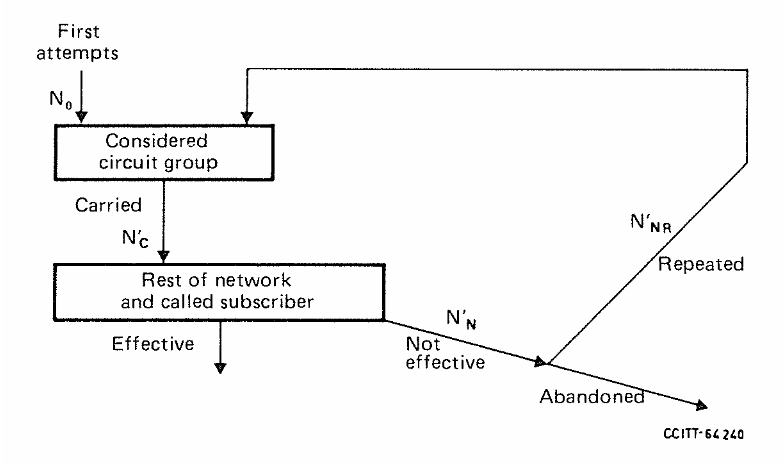

FIGURE A-2/E.501

It is required to estimate 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_O (before augmentation) and between N'_c, and N_O (after augmentation), since the first attempt rate N_O 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:

$$H = \frac{N_{NR} + N_{LR}}{N_N + N_L}$$

$$r' = \frac{N_c - N_N}{N_c}$$

After augmentation:

$$H = \frac{N'_{NR}}{N'_N}$$

$$r' = \frac{N'_c - N'_N}{N'_c}$$

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

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

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

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

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 $B \leq 0.2$ 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.

TABLE A-1/E.501

Values of $\frac{1 - WB}{1 - B}$

$H =$	0.70	0.75	0.80	0.85	0.90	0.95
$B = 0.1$						
$r' = 0.3$	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

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 *is* 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.

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