SECTION 4

DETERMINATION OF THE NUMBER OF CIRCUITS

IN AUTOMATIC AND SEMIAUTOMATIC OPERATION

Recommendation E.520

NUMBER OF CIRCUITS TO BE PROVIDED IN AUTOMATIC AND/OR SEMIAUTOMATIC OPERATION, WITHOUT OVERFLOW FACILITIES

This Recommendation refers to groups of circuits used:

— in automatic operation;

— in semiautomatic operation;

— in both automatic and semiautomatic operations on the same group of circuits.

1 General method

1.1 The CCITT recommends that the number of circuits needed for a group should be read from tables or curves based on the classical Erlang B formula (see Supplements Nos. 1 and 2 at the end of this fascicle which refers to full availability groups). Recommended methods for traffic determination are indicated in Recommendation E.500.

For *semi-automatic operation* the loss probability p should be based on 3% during the mean busy hour.

For *automatic operation* the loss probability p should be based on 1% during the mean busy hour.

Semiautomatic traffic using the same circuits as automatic traffic is to be added to the automatic traffic and the same parameter value of $p = 1\%$ should be used for the total traffic.

The values of 3% and 1% quoted above refer to the Erlang B formula and derived tables and curves. The 3% value should not be considered as determining a grade of service because with semiautomatic operation there will be some smoothing of the traffic peaks; it is quoted here only to determine the

value of the parameter p (loss probability) to use in the Erlang B tables and curves.

1.2 In order to provide a satisfactory grade of service both for the mean busy-hour traffic and for the traffic on exceptionally busy days, it is recommended that the proposed number of circuits should, if necessary, be increased to ensure that the loss probability shall not exceed 7% during the mean busy hour for the average traffic estimated for *the five busiest days* as specified in Recommendation E.500.

1.3 For *small groups of long intercontinental circuits* with automatic operation some relaxation could be made in respect to loss probability. It is envisaged that such circuits would be operated on a both-way basis and that a reasonable minimum for automatic service would be a group of six circuits. A table providing relaxation in Annex A is based on a loss probability of 3% for six circuits, with a smooth progression to 1% for 20 circuits. The general provision for exceptional days remains unchanged.

For exceptional circumstances in which very small groups (less than six intercontinental circuits) are used for automatic operation, dimensioning of the group should be based on the loss probability of 3%.

2 Time differences

Time differences at the two terminations of intercontinental circuits are likely to be much more pronounced than those on continental circuits. In order to allow for differences on groups containing both-way circuits it will be desirable to acquire information in respect to traffic flow both during the mean busy hour for both directions and during the mean busy hour for each direction.

It is possible that in some cases overflow traffic can be accepted without any necessity to increase the number of circuits, in spite of the fact that this overflow traffic is of a peaky nature. Such circumstances may arise if there is no traffic overflowing from high-usage groups during the mean busy hour of the final group.

3 Both-way circuits

3.1 With the use of both-way circuits there is a danger of simultaneous seizure at both ends; this is particularly the case on circuits with a long propagation time. It is advisable to arrange the sequence of selection at the two ends so that such double seizure can only occur when a single circuit remains free.

When all the circuits of a group are operated on a both-way basis, time differences in the directional mean busy hours may result in a total mean busy-hour traffic flow for the group which is not the sum of the mean busy-hour traffic loads in each direction. Furthermore, such differences in directional mean busy hour may vary with seasons of the year. However, the available methods of traffic measurement can determine the traffic flow during mean busy hour for this total traffic.

3.2 Some intercontinental groups may include one-way as well as both-way operated circuits. It is recommended that in all cases the one-way circuits should be used, when free, in preference to the both-way circuits. The number of circuits to be provided will depend upon the one-way and total traffic.

The total traffic will need to be determined for:

a) each direction of traffic;

b) both-way traffic.

This determination is to be made for the busy hour or the busy hours corresponding to the two cases a) and b) above.

In the cases where the number of one-way circuits is approximately equal for each direction, no special procedure is necessary, and the calculation can be treated as for a simple two-group grading [1].

If the number of one-way circuits is quite different for the two directions, some correction may be needed for the difference in randomness of the flow of calls from the two one-way circuit groups to the both-way circuit group. The general techniques for handling cases of this type are quoted in Recommendation E.521.

ANNEX A
(to Recommendation E.520)

Table A-1/E.520 may be applied to small groups of long intercontinental circuits. The values in column 2 are suitable for a random offered traffic with full availability access.

The table is based on 1% loss probability for 20 circuits and increases progressively to a loss probability of 2% at 9 circuits and 3% at 6 circuits (loss probabilities for these three values being based on the Erlang loss formula: see Supplement No. 1). The traffic flow values obtained from a smoothing curve coincide very nearly with those determined by equal marginal utility theory, i.e. an improvement factor of 0.05 Erlang for an additional circuit.

For groups requiring more than 20 circuits the table for loss probability of 1%, mentioned in Supplement No. 1, should be used.

H.T. [T1.520]

TABLE A-1/E.520

Number of circuits	Traffic flow (in erlangs)		
	Offered	Carried	Encountering congestion
(1)	(2)	(3)	(4)
6	2.54	2.47	0.08
7	3.13	3.05	0.09
8	3.73	3.65	0.09
9	4.35	4.26	0.09
10	4.99	4.90	0.09
11	5.64	5.55	0.10
12	6.31	6.21	0.10
13	6.99	6.88	0.10
14	7.67	7.57	0.10
15	8.37	8.27	0.11
16	9.08	8.96	0.11
17	9.81	9.69	0.11
18	10.54	10.42	0.11
19	11.28	11.16	0.12
20	12.03	11.91	0.12

Table A-1/E.520 [T1.520] p.1

Reference

[1] TANGE (I.): Optimal use of both-way circuits in cases of unlimited availability, *TELE* , English Edition, No. 1, 1956.

Recommendation E.521

CALCULATION OF THE NUMBER OF CIRCUITS IN A

GROUP CARRYING OVERFLOW TRAFFIC

A calculation of the number of circuits in a group carrying overflow traffic should be based on this Recommendation and on Recommendation E.522 dealing with high-usage groups.

The objective grade of service used is that the average blocking during the busy-hour of the 30 busiest days of the year will not exceed 1%.

To determine the number of circuits in a group carrying overflow traffic , three traffic parameters are required: the average traffic offered to the group, the weighted peakedness factor , and the level of day-to-day traffic variations.

The level of day-to-day traffic variations indicates the degree to which the daily busy-hour traffic deviates from the overall mean traffic, and is determined by the sample variance of the 30 busy-hour traffic.

The peakedness factor indicates the degree to which the variability of the traffic deviates from pure chance traffic within a single hour, and in statistical terms is the variance-to-mean ratio of the distribution of simultaneous overflow traffic.

1 Determination of the level of day-to-day traffic variations

Let M_1, M_2, . | | , $M_{3\backslash d0}$ denote the 30 busy-hour loads of the traffic offered to the final group. Determine the mean traffic M of the daily traffic by

$$M = \text{[Formula Deleted]} \sum_{j=1}^{0} M_j \text{ .bp}$$

Determine the sample variance V_d of the daily traffic by

$$V_d \text{ [Formula Deleted]} \sum_{j=1}^{0} (M_j - M)^2$$

Determine the point (M , V_d) on Figure 1/E.521; M on the horizontal axis, and V_d on the vertical axis.

i) If the point (M , V_d) is below the bottom curve, the level of variation is *Null* .

ii) If the point is between the lower two curves, the level of variation is *Low* .

iii) If the point is between the upper two curves, the level of variation is *Medium* .

iv) If the point is above the highest curve, the level of variation is *High* .

Default procedures: if the data are not available to compute the variance V_d use the following guidelines:

a) If no more than 25 per cent of the traffic offered to the final group is overflow from other groups, assume the level of day-to-day variation is Low.

b) Otherwise, assume a Medium level of variation.

Figure 1/E.521, p.2 (Recup.)

2 Determination of peakedness factor z

Peakedness factors depend principally upon the number of high-usage circuits over which random traffic has access. When the number of such high-usage circuits does not exceed 30, the actual peakedness of the traffic overflowing from a high-usage group will be only slightly below the maximum peakedness values ’ | Table 1/E.521.

H.T. [T1.521]

TABLE 1/E.521

Maximum peakedness factor

z

i

{		{	
1	1.17	16	2.44
2	1.31	17	2.49
3	1.43	18	2.55
4	1.54	19	2.61
5	1.64	20	2.66
6	1.73	21	2.71
7	1.82	22	2.76
8	1.90	23	2.81
9	1.98	24	2.86
10	2.05	25	2.91
11	2.12	26	2.96
12	2.19	27	3.00
13	2.26	28	3.05
14	2.32	29	3.09
15	2.38	30	3.14

Table 1/E.521 [T1.521] (Recup. + Corr.) p.3

Tables giving:

— the exact mean of the overflow traffic, and

— the difference between variance and mean of the overflow

have been computed and are set out in [1].

Curves giving the exact mean and variance of overflow traffic are given in [2]. See also a more detailed description of the method in [3] and [4].

For more than 30 circuits, the peakedness of the traffic overflowing from a high-usage group i of n_i circuits is given by

$$z_i = 1 - \beta_i + \frac{A_i}{n_i + 1 + \beta_i - A_i}$$

where

A_i is the mean (random) traffic offered to the n_i circuits and

β_i is the traffic overflowing. The overflow traffic β_i is found by employing the standard Erlang loss formula $E_{1,n_i}(A_i)$:

$$\beta_i = A_i E_{1,n_i}(A_i).$$

The weighted mean peakedness factor z, is then calculated from:

$$z = \frac{\sum_{i=1}^{h} \beta_i}{\sum_{i=1}^{h} \beta_i}$$

for the h parcels of traffic being offered to the final group.

Note that for the traffic directly offered to the final group, the peakedness factor is $z_i = 1$.

3 Determination of the mean traffic offered to the final group and the number of circuits required

3.1 For planning future network requirements, the traffic overflowing to a final group should be determined theoretically from forecasts of traffics offered to the high-usage groups.

The mean traffic overflowing to the final group from a high-usage group is determined in two steps:

i) the ‘‘single-hour’’ overflow traffic β_i overflowing from n_i circuits is given as above by

$$\beta_i = A_i \, E_{1, n_i}(A_i),$$

when A_i is the forecast of traffic offered to the i th high-usage group;

ii) the average overflow traffic $\bar{\beta}_i$ overflowing from the n_i circuits is then determined by adjusting the single-hour traffic β_i for the effect of day-to-day traffic variations.

$$\bar{\beta}_i = r_i \beta_i$$

The adjustment factor r_i is given in Table 2/E.521; it is a function of:

— the offered traffic A_i,

— the traffic $A_i E_{1, n-1}(A_i) - \beta_i$ carried by the last trunk i, and

— the level of day-to-day variations of the traffic offered to the high-usage group.

This level can be determined using the method described in § 1 above, but applying it to measurements of traffic offered to the high-usage group. If such measurements are not available a *medium* level can be used.

The mean traffic offered to the final group is then the sum of all $\bar{\beta}_i$ over the h parcels of traffic:

$$M = \sum_{i=1}^{h} \bar{\beta}_i$$

It can be assumed that the level of day-to-day traffic variations on the final group remains constant over the forecast time period.

Using the level of day-to-day traffic variation as determined in § 1 above on the final group and the peakedness factor of § 2 above, the appropriate table of Tables 3/E.521 to 6/E.521 is used to derive the number of circuits required.

Note 1 — This method of calculation of the mean traffic offered to the final group is valid only if the overflow traffic due to blocking encountered in the exchange in the attempts to connect to a high-usage, is negligible.

Note 2 — Table 3/E.521 differs slightly from the previous tables published by CCITT, although in Table 3.1/E.521 there is no allowance for day-to-day variations. The new table takes into account a systematic bias in the measurement procedure that is based on a finite period of time (1 hour), instead of an infinite period as was assumed in the previous table [5].

Note 3 — Tables 4/E.521, 5/E.521 and 6/E.521 are based on the calculation of the average blocking from the formula:

$$\beta = \int B(m)\, f(m)\, dm\,,$$

where

$B(m)$ is the single-hour expected blocking and

$f(m)$ is the density distribution of day-to-day traffic (m), assuming a Pearson Type III distribution:

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$$\left[f(m) = \frac{(M/V)(M^2/V_{\mathrm{f\,Id}})}{\gamma (M^2/V_{\mathrm{f\,Id}})} \mathrm{f\,R\,Id}\; m\; [(M^2/V_{\mathrm{f\,Id}}) - 1]\; e\; -M\; m f R / V_{\mathrm{f\,Id}} \right]$$

M and V_d are the mean and day-to-day variance of the traffic as calculated [5] in § 1 above.

H.T. [T2.521]

TABLE 2/E.521

Overflow adjustment for high-usage trunk groups

Factor r_i

{	Last trunk traffic Low daily variation	Medium daily variation	High daily variation	0.25	0.3	0.4	0.5	0.6	0.25	0.3	0.4	0.5
3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.0	1.0	1.2	1.2
7	1.0	1.0	1.0	1.0	1.0	1.2	1.2	1.1	1.1	1.0	1.4	1.3
10	1.1	1.1	1.1	1.0	1.0	1.3	1.2	1.2	1.1	1.1	1.5	1.4
15	1.2	1.1	1.1	1.1	1.0	1.5	1.4	1.2	1.2	1.1	1.8	1.6
20	1.2	1.2	1.1	1.1	1.0	1.6	1.5	1.3	1.2	1.1	2.0	1.8
25	1.3	1.2	1.2	1.1	1.1	1.8	1.6	1.4	1.3	1.1	2.3	2.0
30	1.3	1.3	1.2	1.1	1.1	1.8	1.7	1.4	1.3	1.2	2.4	2.1

Table 2/E.521 (Recup. + Corr.) [T2.521], p.4

Blanc

H.T. [T3.521]

TABLE 3/E.521

Single-hour capacity, in Erlangs, as a function of the number of

trunks

and of the peakedness factor

— | fINo allowance for day-to-day variation; } — | eighted mean peakedness factor. }	*Parameters:*	— | lockage 0.01; { {

Number of trunks required	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.4	3.8
1	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.53	0.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.94	0.69	0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.42	1.14	0.89	0.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.97	1.64	1.36	1.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	2.56	2.19	1.86	1.58	1.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.19	2.81	2.44	2.11	1.81	1.53	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.83	3.42	3.03	2.67	2.36	2.03	1.75	1.50	0.0	0.0	0.0	0.0	0.0
10	4.53	4.08	3.67	3.28	2.92	2.58	2.28	2.00	1.75	0.0	0.0	0.0	0.0
11	5.22	4.75	4.31	3.89	3.53	3.17	2.83	2.53	2.25	1.97	0.0	0.0	0.0
12	5.94	5.44	4.97	4.56	4.14	3.78	3.42	3.08	2.78	2.47	2.22	0.0	0.0
13	6.67	6.14	5.64	5.19	4.81	4.39	4.03	3.67	3.33	3.03	2.72	0.0	0.0
14	7.42	6.86	6.36	5.89	5.44	5.03	4.67	4.28	3.94	3.61	3.28	2.69	0.0
15	8.17	7.58	7.06	6.58	6.11	5.69	5.31	4.92	4.56	4.19	3.86	3.22	0.0
16	8.94	8.33	7.78	7.28	6.81	6.36	5.94	5.56	5.17	4.81	4.44	3.81	3.19
17	9.72	9.08	8.50	8.00	7.50	7.06	6.61	6.19	5.81	5.42	5.06	4.39	3.75
18	10.50	9.83	9.25	8.72	8.22	7.75	7.31	6.86	6.44	6.06	5.69	4.97	4.31
19	11.31	10.61	10.00	9.44	8.92	8.44	7.97	7.53	7.11	6.72	6.33	5.58	4.89
20	12.08	11.39	10.78	10.19	9.67	9.14	8.67	8.22	7.81	7.39	6.97	6.22	5.50
21	12.89	12.19	11.53	10.94	10.39	9.86	9.39	8.92	8.47	8.06	7.64	6.86	6.11
22	13.72	13.00	12.31	11.69	11.14	10.61	10.08	9.61	9.17	8.72	8.31	7.50	6.75
23	14.53	13.78	13.08	12.47	11.89	11.36	10.81	10.33	9.86	9.42	8.97	8.17	7.39
24	15.36	14.58	13.89	13.22	12.64	12.08	11.56	11.03	10.56	10.11	9.67	8.83	8.03
25	16.19	15.39	14.67	14.00	13.39	12.83	12.28	11.78	11.28	10.81	10.36	9.50	8.69
26	17.03	16.22	15.47	14.81	14.17	13.58	13.03	12.50	12.00	11.53	11.06	10.19	9.36
27	17.86	17.03	16.28	15.58	14.94	14.33	13.78	13.22	12.72	12.22	11.75	10.86	10.03
28	18.69	17.86	17.08	16.36	15.72	15.11	14.53	13.97	13.44	12.94	12.47	11.56	10.69
29	19.56	18.69	17.89	17.17	16.50	15.86	15.28	14.72	14.19	13.67	13.19	12.28	11.39
30	20.39	19.53	18.72	17.97	17.28	16.64	16.06	15.47	14.92	14.42	13.92	12.97	12.08
31	21.25	20.36	19.53	18.78	18.08	17.42	16.81	16.22	15.67	15.14	14.64	13.69	12.78
32	22.11	21.19	20.36	19.58	18.89	18.22	17.58	17.00	16.42	15.89	15.36	14.39	13.47
33	22.97	22.06	21.19	20.39	19.67	19.00	18.36	17.75	17.19	16.64	16.11	15.11	14.17
34	23.83	22.89	22.00	21.22	20.47	19.81	19.14	18.53	17.94	17.39	16.86	15.86	14.89
35	24.69	23.75	22.83	22.03	21.28	20.58	19.92	19.31	18.69	18.14	17.61	16.58	15.61
36	25.58	24.58	23.69	22.86	22.11	21.39	20.72	20.08	19.47	18.89	18.36	17.31	16.31
37	26.44	25.44	24.53	23.69	22.92	22.19	21.50	20.86	20.25	19.67	19.11	18.06	17.06
38	27.31	26.31	25.36	24.53	23.72	23.00	22.31	21.64	21.03	20.44	19.86	18.81	17.78
39	28.19	27.17	26.22	25.36	24.56	23.81	23.11	22.44	21.81	21.19	20.64	19.53	18.50
40	29.08	28.03	27.06	26.19	25.39	24.61	23.89	23.22	22.58	21.97	21.39	20.28	19.25
41	29.94	28.89	27.92	27.03	26.19	25.44	24.69	24.03	23.36	22.75	22.17	21.06	19.97
42	30.83	29.75	28.78	27.86	27.03	26.25	25.53	24.81	24.17	23.53	22.94	21.81	20.72
43	31.72	30.64	29.61	28.72	27.86	27.08	26.33	25.61	24.94	24.31	23.69	22.56	21.47
44	32.61	31.50	30.47	29.56	28.69	27.89	27.14	26.42	25.75	25.11	24.50	23.33	22.22
45	33.50	32.39	31.33	30.42	29.53	28.72	27.94	27.22	26.56	25.89	25.28	24.08	22.97
46	34.39	33.25	32.19	31.25	30.39	29.56	28.78	28.03	27.33	26.69	26.06	24.86	23.72
47	35.28	34.14	33.08	32.11	31.22	30.39	29.58	28.86	28.14	27.47	26.83	25.64	24.47
48	36.17	35.00	33.94	32.97	32.06	31.22	30.42	29.67	28.94	28.28	27.64	26.42	25.25
49	37.06	35.89	34.81	33.81	32.92	32.06	31.25	30.47	29.75	29.08	28.42	27.19	26.00
50	37.97	36.78	35.67	34.67	33.75	32.89	32.08	31.31	30.58	29.89	29.22	27.97	26.78

Table 3/E.521 (Recup.) [T3.521], p.5

H.T. [T4.521]

TABLE 4/E.521

Single-hour capacity, in Erlangs, as a function of the number of

trunks

and of the peakedness factor

— | fILow day-to-day variation allowance; } — | eighted mean peakedness factor. }	*Parameters:*	— | lockage 0.01; { {

Number of trunks required	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.4	3.8
1	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.53	0.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.94	0.69	0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.39	1.14	0.89	0.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.89	1.64	1.36	1.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	2.44	2.14	1.86	1.58	1.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.03	2.69	2.42	2.11	1.81	1.53	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.64	3.28	2.97	2.67	2.36	2.03	1.75	1.50	0.0	0.0	0.0	0.0	0.0
10	4.25	3.89	3.56	3.22	2.92	2.58	2.28	2.00	1.75	0.0	0.0	0.0	0.0
11	4.92	4.53	4.17	3.83	3.50	3.17	2.83	2.53	2.25	1.97	0.0	0.0	0.0
12	5.58	5.17	4.78	4.44	4.08	3.78	3.42	3.08	2.78	2.47	2.22	0.0	0.0
13	6.25	5.81	5.42	5.06	4.69	4.36	4.03	3.67	3.33	3.03	2.72	0.0	0.0
14	6.94	6.50	6.08	5.69	5.33	4.97	4.64	4.28	3.94	3.61	3.28	2.69	0.0
15	7.64	7.17	6.75	6.33	5.97	5.61	5.25	4.92	4.56	4.19	3.86	3.22	0.0
16	8.33	7.86	7.42	7.00	6.61	6.25	5.89	5.53	5.17	4.81	4.44	3.81	3.19
17	9.06	8.56	8.11	7.67	7.28	6.89	6.53	6.17	5.81	5.42	5.06	4.39	3.75
18	9.81	9.28	8.81	8.36	7.94	7.56	7.17	6.81	6.44	6.06	5.69	4.97	4.31
19	10.53	10.00	9.50	9.06	8.61	8.22	7.83	7.44	7.08	6.72	6.33	5.58	4.89
20	11.28	10.72	10.22	9.75	9.31	8.89	8.50	8.11	7.72	7.36	6.97	6.22	5.50
21	12.03	11.44	10.94	10.44	10.00	9.56	9.17	8.78	8.39	8.03	7.64	6.86	6.11
22	12.78	12.19	11.67	11.17	10.69	10.25	9.83	9.44	9.06	8.67	8.31	7.56	6.75
23	13.53	12.94	12.39	11.89	11.42	10.94	10.53	10.11	9.72	9.33	8.94	8.19	7.39
24	14.31	13.69	13.14	12.61	12.11	11.67	11.22	10.81	10.39	10.00	9.61	8.86	8.03
25	15.08	14.44	13.86	13.33	12.83	12.36	11.92	11.50	11.08	10.67	10.28	9.50	8.67
26	15.86	15.22	14.61	14.08	13.56	13.08	12.61	12.19	11.75	11.36	10.94	10.17	9.33
27	16.64	15.97	15.36	14.81	14.28	13.81	13.33	12.89	12.44	12.03	11.64	10.83	10.00
28	17.42	16.75	16.14	15.56	15.03	14.53	14.06	13.58	13.14	12.72	12.31	11.50	10.67
29	18.22	17.53	16.89	16.31	15.78	15.25	14.78	14.31	13.86	13.42	13.00	12.19	11.36
30	19.00	18.31	17.67	17.06	16.50	16.00	15.50	15.03	14.56	14.11	13.69	12.86	12.06
31	19.81	19.08	18.44	17.83	17.25	16.72	16.22	15.72	15.28	14.83	14.39	13.56	12.75
32	20.61	19.89	19.19	18.58	18.00	17.47	16.94	16.47	16.00	15.53	15.11	14.25	13.44
33	21.39	20.67	19.97	19.36	18.78	18.22	17.69	17.19	16.72	16.25	15.81	14.94	14.14
34	22.22	21.47	20.75	20.11	19.53	18.97	18.42	17.92	17.44	16.97	16.53	15.67	14.83
35	23.03	22.25	21.56	20.89	20.28	19.72	19.17	18.67	18.17	17.69	17.22	16.36	15.56
36	23.83	23.06	22.33	21.67	21.06	20.47	19.92	19.39	18.89	18.42	17.94	17.08	16.25
37	24.64	23.86	23.14	22.44	21.83	21.25	20.67	20.14	19.64	19.14	18.67	17.78	16.94
38	25.47	24.67	23.92	23.25	22.61	22.00	21.44	20.89	20.36	19.89	19.42	18.50	17.64
39	26.28	25.47	24.72	24.03	23.39	22.78	22.19	21.64	21.11	20.61	20.14	19.22	18.33
40	27.11	26.28	25.53	24.81	24.17	23.53	22.94	22.39	21.86	21.36	20.86	19.94	19.06
41	27.92	27.08	26.31	25.61	24.94	24.31	23.72	23.14	22.61	22.11	21.61	20.67	19.78
42	28.75	27.92	27.11	26.39	25.72	25.08	24.47	23.92	23.36	22.83	22.33	21.39	20.47
43	29.58	28.72	27.92	27.19	26.50	25.86	25.25	24.67	24.11	23.58	23.08	22.11	21.19
44	30.42	29.56	28.75	28.00	27.31	26.64	26.03	25.44	24.89	24.33	23.83	22.86	21.92
45	31.25	30.36	29.56	28.81	28.08	27.44	26.81	26.22	25.64	25.11	24.58	23.58	22.64
46	32.08	31.19	30.36	29.61	28.89	28.22	27.58	26.97	26.42	25.86	25.33	24.33	23.36
47	32.92	32.03	31.17	30.42	29.69	29.00	28.36	27.75	27.17	26.61	26.08	25.06	24.11
48	33.75	32.83	32.00	31.22	30.47	29.81	29.14	28.53	27.94	27.39	26.83	25.81	24.83
49	34.58	33.67	32.81	32.03	31.28	30.58	29.94	29.31	28.72	28.14	27.58	26.56	25.56
50	35.44	34.50	33.64	32.83	32.08	31.39	30.72	30.08	29.50	28.92	28.36	27.31	26.31

Table 4/E.521 (Recup.) [T4.521], p.6

H.T. [T5.521]
TABLE 5/E.521
Single-hour capacity, in Erlangs, as a function of the number of

trunks

and of the peakedness factor

— | fIMedium day-to-day variation allowance; } — | eighted mean peakedness factor. }	*Parameters:*	— | lockage 0.01; { {

Number of trunks required	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.4	3.8
1	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.53	0.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.94	0.69	0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.39	1.14	0.89	0.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.86	1.61	1.36	1.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	2.39	2.11	1.83	1.58	1.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	2.94	2.64	2.36	2.08	1.81	1.53	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.53	3.19	2.89	2.61	2.33	2.03	1.75	1.50	0.0	0.0	0.0	0.0	0.0
10	4.11	3.78	3.47	3.17	2.86	2.58	2.28	2.00	1.75	0.0	0.0	0.0	0.0
11	4.72	4.39	4.03	3.72	3.42	3.14	2.83	2.53	2.25	1.97	0.0	0.0	0.0
12	5.36	4.97	4.64	4.31	4.00	3.69	3.39	3.08	2.78	2.47	2.22	0.0	0.0
13	6.00	5.61	5.25	4.89	4.56	4.25	3.94	3.67	3.33	3.03	2.72	0.0	0.0
14	6.64	6.22	5.86	5.50	5.17	4.83	4.53	4.22	3.92	3.61	3.28	2.69	0.0
15	7.31	6.89	6.47	6.11	5.78	5.42	5.11	4.78	4.47	4.19	3.86	3.22	0.0
16	7.97	7.53	7.11	6.75	6.39	6.03	5.69	5.39	5.06	4.75	4.44	3.81	3.19
17	8.64	8.19	7.78	7.36	7.00	6.64	6.31	5.97	5.64	5.33	5.03	4.39	3.75
18	9.33	8.86	8.42	8.03	7.64	7.28	6.92	6.58	6.25	5.92	5.61	4.97	4.31
19	10.03	9.53	9.08	8.67	8.28	7.89	7.53	7.19	6.86	6.53	6.19	5.58	4.89
20	10.69	10.19	9.75	9.33	8.92	8.53	8.17	7.81	7.47	7.14	6.81	6.17	5.50
21	11.42	10.89	10.42	9.97	9.56	9.17	8.81	8.44	8.08	7.75	7.42	6.75	6.11
22	12.11	11.58	11.11	10.64	10.22	9.83	9.44	9.06	8.69	8.36	8.03	7.36	6.72
23	12.83	12.28	11.78	11.33	10.89	10.47	10.08	9.69	9.33	8.97	8.64	7.97	7.33
24	13.53	13.00	12.47	12.00	11.56	11.14	10.72	10.36	9.97	9.61	9.25	8.58	7.94
25	14.25	13.69	13.17	12.69	12.25	11.81	11.39	11.00	10.61	10.25	9.89	9.19	8.56
26	14.97	14.42	13.86	13.39	12.92	12.47	12.06	11.64	11.28	10.89	10.53	9.83	9.17
27	15.69	15.11	14.58	14.08	13.61	13.14	12.72	12.31	11.92	11.53	11.17	10.44	9.78
28	16.44	15.83	15.28	14.78	14.28	13.83	13.39	12.97	12.58	12.19	11.81	11.08	10.39
29	17.17	16.56	16.00	15.47	14.97	14.53	14.08	13.64	13.25	12.83	12.47	11.72	11.03
30	17.92	17.28	16.72	16.17	15.67	15.19	14.75	14.31	13.92	13.50	13.11	12.36	11.64
31	18.64	18.03	17.42	16.89	16.39	15.89	15.44	15.00	14.58	14.17	13.78	13.03	12.28
32	19.39	18.75	18.14	17.58	17.08	16.58	16.11	15.67	15.25	14.83	14.44	13.67	12.92
33	20.14	19.47	18.86	18.31	17.78	17.28	16.81	16.36	15.92	15.50	15.11	14.33	13.58
34	20.89	20.22	19.61	19.03	18.50	18.00	17.50	17.06	16.61	16.17	15.78	14.97	14.22
35	21.64	20.97	20.33	19.75	19.22	18.69	18.19	17.75	17.28	16.86	16.44	15.64	14.86
36	22.39	21.69	21.06	20.47	19.92	19.42	18.92	18.44	17.97	17.53	17.11	16.31	15.53
37	23.14	22.44	21.81	21.19	20.64	20.11	19.61	19.14	18.67	18.22	17.81	16.97	16.19
38	23.89	23.19	22.53	21.94	21.36	20.83	20.31	19.83	19.36	18.92	18.47	17.64	16.86
39	24.64	23.94	23.28	22.67	22.08	21.56	21.03	20.53	20.06	19.61	19.17	18.33	17.53
40	25.42	24.69	24.03	23.39	22.81	22.25	21.75	21.25	20.75	20.31	19.86	19.00	18.19
41	26.17	25.44	24.78	24.14	23.56	22.97	22.44	21.94	21.47	21.00	20.56	19.69	18.86
42	26.94	26.19	25.50	24.86	24.28	23.72	23.17	22.67	22.17	21.69	21.25	20.36	19.53
43	27.72	26.97	26.25	25.61	25.00	24.44	23.89	23.36	22.86	22.39	21.94	21.06	20.19
44	28.47	27.72	27.00	26.36	25.75	25.17	24.61	24.08	23.58	23.08	22.64	21.75	20.89
45	29.25	28.47	27.78	27.11	26.47	25.89	25.33	24.81	24.31	23.81	23.33	22.44	21.56
46	30.03	29.25	28.53	27.86	27.22	26.64	26.06	25.53	25.00	24.50	24.03	23.14	22.25
47	30.81	30.00	29.28	28.61	27.97	27.36	26.78	26.25	25.72	25.22	24.75	23.83	22.94
48	31.58	30.78	30.03	29.36	28.72	28.11	27.53	26.97	26.44	25.94	25.44	24.53	23.64
49	32.36	31.56	30.81	30.11	29.44	28.83	28.25	27.69	27.17	26.64	26.17	25.22	24.33
50	33.14	32.31	31.56	30.86	30.19	29.58	29.00	28.42	27.89	27.36	26.86	25.92	25.03

Table 5/E.521 (Recup.) [T5.521], p.7

H.T. [T6.521]

TABLE 6/E.521

Single-hour capacity, in Erlangs, as a function of the number of

trunks

and of the peakedness factor

— | fIHigh day-to-day variation allowance; } — | eighted mean peakedness factor. }	*Parameters:*	— | lockage 0.01; { {

Number of trunks required	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.4	3.8
1	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.53	0.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.94	0.69	0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.36	1.14	0.89	0.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.86	1.61	1.36	1.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	2.36	2.08	1.83	1.58	1.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	2.89	2.61	2.33	2.06	1.81	1.53	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	3.44	3.14	2.86	2.58	2.31	2.03	1.75	1.50	0.0	0.0	0.0	0.0	0.0
10	4.03	3.69	3.39	3.11	2.83	2.56	2.28	2.00	1.75	0.0	0.0	0.0	0.0
11	4.61	4.25	3.94	3.64	3.36	3.08	2.81	2.53	2.25	1.97	0.0	0.0	0.0
12	5.19	4.83	4.50	4.19	3.89	3.61	3.33	3.06	2.78	2.47	2.22	0.0	0.0
13	5.81	5.42	5.08	4.78	4.44	4.17	3.86	3.58	3.31	3.03	2.72	0.0	0.0
14	6.42	6.03	5.67	5.33	5.03	4.72	4.42	4.14	3.83	3.58	3.28	2.69	0.0
15	7.03	6.64	6.28	5.92	5.61	5.28	4.97	4.69	4.39	4.11	3.83	3.22	0.0
16	7.67	7.25	6.86	6.53	6.19	5.86	5.56	5.25	4.94	4.67	4.36	3.81	3.19
17	8.31	7.86	7.47	7.11	6.78	6.44	6.11	5.81	5.50	5.22	4.92	4.36	3.75
18	8.94	8.50	8.11	7.72	7.36	7.03	6.69	6.39	6.08	5.78	5.47	4.89	4.31
19	9.58	9.14	8.72	8.33	7.97	7.64	7.31	6.97	6.64	6.33	6.03	5.44	4.89
20	10.22	9.78	9.36	8.94	8.58	8.22	7.89	7.56	7.22	6.92	6.61	6.00	5.44
21	10.89	10.42	9.97	9.58	9.19	8.83	8.50	8.14	7.83	7.50	7.19	6.58	6.00
22	11.53	11.06	10.61	10.22	9.83	9.44	9.08	8.75	8.42	8.08	7.78	7.17	6.56
23	12.19	11.72	11.28	10.83	10.44	10.06	9.69	9.36	9.00	8.67	8.36	7.72	7.14
24	12.86	12.36	11.92	11.47	11.08	10.69	10.31	9.94	9.61	9.28	8.94	8.31	7.69
25	13.53	13.03	12.56	12.11	11.69	11.31	10.94	10.56	10.22	9.89	9.56	8.92	8.28
26	14.19	13.69	13.22	12.75	12.33	11.94	11.56	11.19	10.83	10.47	10.14	9.50	8.86
27	14.89	14.36	13.86	13.42	12.97	12.58	12.19	11.81	11.44	11.08	10.75	10.08	9.44
28	15.56	15.03	14.53	14.06	13.64	13.22	12.81	12.42	12.06	11.69	11.36	10.69	10.03
29	16.25	15.69	15.19	14.72	14.28	13.86	13.44	13.06	12.69	12.33	11.97	11.31	10.64
30	16.92	16.36	15.86	15.36	14.92	14.50	14.08	13.69	13.31	12.94	12.58	11.89	11.22
31	17.61	17.06	16.53	16.03	15.58	15.14	14.72	14.33	13.94	13.56	13.19	12.50	11.83
32	18.31	17.72	17.19	16.69	16.22	15.78	15.36	14.94	14.56	14.19	13.83	13.11	12.44
33	18.97	18.42	17.86	17.36	16.89	16.44	16.00	15.58	15.19	14.81	14.44	13.72	13.06
34	19.67	19.08	18.53	18.03	17.56	17.08	16.67	16.25	15.83	15.44	15.08	14.36	13.67
35	20.36	19.78	19.22	18.69	18.22	17.75	17.31	16.89	16.47	16.08	15.69	14.97	14.28
36	21.06	20.47	19.89	19.36	18.89	18.42	17.97	17.53	17.11	16.72	16.33	15.61	14.89
37	21.75	21.14	20.58	20.06	19.56	19.08	18.61	18.19	17.78	17.36	16.97	16.22	15.50
38	22.44	21.83	21.25	20.72	20.22	19.72	19.28	18.83	18.42	18.00	17.61	16.86	16.14
39	23.17	22.53	21.94	21.39	20.89	20.39	19.94	19.50	19.06	18.64	18.25	17.50	16.75
40	23.86	23.22	22.64	22.08	21.56	21.06	20.58	20.14	19.72	19.31	18.89	18.11	17.39
41	24.56	23.92	23.33	22.75	22.22	21.75	21.25	20.81	20.36	19.94	19.53	18.75	18.00
42	25.28	24.61	24.00	23.44	22.92	22.42	21.92	21.47	21.03	20.58	20.19	19.39	18.64
43	25.97	25.31	24.69	24.14	23.58	23.08	22.58	22.14	21.67	21.25	20.83	20.03	19.28
44	26.67	26.03	25.39	24.81	24.28	23.75	23.25	22.78	22.33	21.92	21.47	20.67	19.89
45	27.39	26.72	26.08	25.50	24.94	24.44	23.94	23.44	23.00	22.56	22.14	21.33	20.53
46	28.08	27.42	26.78	26.19	25.64	25.11	24.61	24.14	23.67	23.22	22.78	21.97	21.17
47	28.81	28.14	27.47	26.89	26.33	25.81	25.28	24.81	24.33	23.89	23.44	22.61	21.81
48	29.53	28.83	28.19	27.58	27.00	26.47	25.97	25.47	25.00	24.56	24.11	23.28	22.47
49	30.22	29.53	28.89	28.28	27.69	27.17	26.64	26.14	25.67	25.19	24.75	23.92	23.11
50	30.94	30.25	29.58	28.97	28.39	27.83	27.31	26.81	26.33	25.86	25.42	24.58	23.75

Table 6/E.521 (Recup.) [T6.521], p.8

3.2 *Computer implementation*

When computer facilities are available, it is possible to automate the use of Tables 3/E.521 to 6/E.521. For that purpose, numerical algorithms have been developed and are described in [5].

4 Example

4.1 *Level of day-to-day traffic variations*

If the traffics offered to a final group over the 30 busiest days are given (M_1 to $M_{3\d0}$) and if the mean load and variance are calculated to be 10 and 20 respectively, then applying Figure 1/E.521, a *high* level of day-to-day traffic variations should be used.

4.2 *Future traffic offered to the final group and peakedness factor*

If the forecast of future traffics indicates that three parcels of traffic will be offered to the final group:

— the overflow from 6 circuits offered 7.8 Erlangs,

— the overflow from 12 circuits offered 10 Erlangs,

— 7 Erlangs offered directly,

then Table 7/E.521 can be developed.

Table 7/E.521 (Recup. + Corr.) T7.521 p.9

Note that the values of r_i are derived from Table 2/E.521 for *medium* level of day-to-day traffic variations; if the 30 busiest day traffics for each of the high-usage groups were available, a more appropriate level could be used for each group.

Now all the information required is available: using the capacity Table 6/E.521 for *high* level of day-to-day traffic variations, the average traffic offered to the final group $M = 11.39$ and a peakedness factor $z = 1.3$ (from interpolating between $z = 1.2$ and $z = 1.4$), it is calculated that 23 circuits are required.

Note that if the measurements used in § 4.1 above were not available, then to determine the level of day-to-day traffic variations it would have been necessary to use the default procedure of § 1 above.

Overflow traffic offered to the final group = 4.15 Erlangs.

Total traffic offered to the final group = 11.15 Erlangs.

The ratio 4.15/11.15 = 0.37 is higher than 0.25 and hence a *medium* level of day-to-day traffic variations would have been used.

References

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Recommendation E.522

NUMBER OF CIRCUITS IN A HIGH-USAGE GROUP

1 Introduction

For the economic planning of an alternate routing network the number of circuits in a high-usage group should be determined so that the annual charges for the whole network arrangement are at a minimum. This is done under the constraint that given requirements for the grade of service are fulfilled. In the optimum arrangement, the cost per erlang of carrying a marginal amount of traffic over the high-usage route or over the alternative route is the same.

Figure 1/E.522 p.10

The optimum number of high-usage circuits, n , from one exchange (1) to another exchange (2) is therefore obtained from the following expression when the overflow traffic is routed over a transit exchange T (route 1-T-2, see Figure 1/E.522).

$$F_n(A) = A\{\mathrm{fI}E_{1,n}(A) - E_{1,(n+1)}(A)\} = M \times \frac{nnual\ charge\,(1\text{-}2)}{nnual\ charge\,(1\text{-}T\text{-}2)}$$

A is the traffic flow offered, for the relation ''1-2'', in the Erlang loss formula for a full availability group $F_n(A)$ gives the marginal occupancy (improvement function) for the high-usage group, if one more circuit were added.

M is the *marginal utilization factor for the final route* ''1-T-2'' (which has nothing to do with cost ratio), if one additional circuit were provided. The annual charges are marginal charges for adding one additional circuit to route ''1-2'' and likewise to route ''1-T-2''.

Planning of an alternate routing network is described in the technical literature (see [1] to [10]).

Annual charge as used in this Recommendation refers to investment costs.

Marginal occupancy is often called LTC (last trunk capacity).

Marginal utilization factor is often called ATC (additional trunk capacity).

2 Recommended practical method

2.1 *Field of application*

It must be recognized that the conditions applying to alternative routing will vary widely between the continental network and the intercontinental network. Significant differences between the two cases apply to the length and cost of circuits, the traffic flow and the different times at which the busy hours occur. The method described attempts to take account of these factors in so far as it is practicable to do so in any simplified procedure.

2.2 *Traffic statistics*

The importance of reliable traffic estimates should be emphasized. Traffic estimates are required for each of the relations in question, for both the busy hour of the relation and for the busy hour of each link of the routes to which the traffic overflows. Since this may be affected by the

high-usage arrangements finally adopted, it will be necessary to have traffic estimates for each relation covering most of the significant hours of the day. This applies particularly to the intercontinental network where the final routes carry traffic components with widely differing busy hours.

2.3 *Basis of the recommended method*

The method is based on a simplification of the economic dimensioning equations described under 1. Introduction. The simplifying assumptions are:

i) the ratios of the alternative high-usage annual charges are grouped in classes and a single ratio selected as representative for each class. This is acceptable because total network costs are known to be relatively insensitive to changes in the annual charges ratio;

ii) the marginal utilization factor M applicable to the overflow routes is regarded as constant within a range of circuit group sizes;

H.T. [T1.522]

{ Size of group (number of circuits) }	Value of M
For less than 10	0.6
For 10 or more	0.8

Table 1/E.522 (Recup.) [T1.522], p.11

iii) each high-usage group will be dimensioned against the cheapest alternative route to which traffic overflows. (That is, the effect of parallel alternative routes is ignored.)

Where greater precision is required in either network or individual route dimensioning, more sophisticated methods may be employed (see [5] and [7]).

2.4 *Determination of cost ratio*

In continental and intercontinental working, the number of circuits to be provided in high-usage circuit groups depends upon the ratio of the annual charges estimated by the Administrations involved. The annual charge ratio (see Table 1/E.522) is defined as:

$$R = \frac{nnual\ charge\ of\ one\ additional\ circuit\ on\ the\ alternative\ route}{nnual\ charge\ of\ one\ additional\ circuit\ on\ the\ high\text{-}usage\ route}$$

The ‘‘annual charge of one additional circuit on the alternative route’’ is calculated by summing:

— the annual charge per circuit of each link comprising the alternative route, and

— the annual charge of switching one circuit at each intermediate switching centre.

When a third Administration is involved, it may be necessary to calculate the annual charge for switching at the intermediate centre from the transit switching charge per holding minute

$$\text{Annual charges for switching} = M \times 60 \times F \times 26 \times 12 \times \text{transit switching charge per holding minute.}$$

In the calculation of the conversion factor F from busy hour to day, its dependence on the traffic offered to the high usage route, the overflow probability and the time difference should be taken into account. As a guideline, Table 1/E.522, which is calculated using the standard traffic profiles of Table 1/E.523, may be used.

H.T. [T2.522]

TABLE 1/E.522

Offered traffic (erlangs)	Overflow probability (%)	Time difference												
		0	1	2	3	4	5	6	7	8	9	10	11	12
	1	2.6	3.2	3.7	3.8	2.7	2.3	2.3	1.7	3.2	2.4	2.2	2.0	2.7
	10	3.7	4.5	4.8	4.7	3.5	3.1	3.0	2.5	4.1	3.2	2.9	2.8	3.6
	20	4.5	5.2	5.4	5.3	4.0	3.7	3.5	3.1	4.7	3.8	3.4	3.4	4.2
5	30	5.1	5.8	6.0	5.8	4.6	4.2	4.0	3.7	5.1	4.3	3.9	4.0	4.8
	40	5.7	6.4	6.5	6.3	5.1	4.7	4.5	4.2	5.6	4.8	4.4	4.6	5.3
	50	6.3	6.9	7.0	6.8	5.6	5.2	5.0	4.7	6.0	5.3	5.0	5.1	5.8
	1	2.1	2.6	3.3	3.5	2.5	2.1	2.1	1.4	2.8	2.0	2.0	1.8	2.4
	10	3.2	4.0	4.4	4.3	3.1	2.7	2.6	2.1	3.8	2.8	2.6	2.4	3.2
	20	4.0	4.8	5.1	4.9	3.6	3.3	3.1	2.7	4.3	3.4	3.0	3.0	3.8
10	30	4.7	5.4	5.6	5.4	4.2	3.8	3.6	3.3	4.8	3.9	3.4	3.6	4.4
	40	5.3	6.0	6.1	5.9	4.7	4.4	4.2	3.8	5.3	4.4	4.0	4.2	4.9
	50	5.9	6.6	6.7	6.4	5.3	4.9	4.7	4.4	5.7	5.0	4.6	4.8	5.5
	1	1.6	2.0	2.8	3.1	2.2	1.8	2.0	1.2	2.4	1.7	1.8	1.6	2.1
	10	2.7	3.3	3.9	3.9	2.7	2.4	2.3	1.7	3.3	2.4	2.3	2.0	2.7
	20	3.5	4.2	4.6	4.4	3.2	2.8	2.7	2.2	3.9	3.0	2.6	2.5	3.3
25	30	4.2	5.0	5.2	5.0	3.7	3.4	3.2	2.8	4.4	3.5	3.0	3.1	3.9
	40	4.8	5.6	5.8	5.5	4.3	3.9	3.8	3.4	4.9	4.0	3.5	3.7	4.5
	50	5.5	6.2	6.3	6.1	4.9	4.5	4.3	4.0	5.4	4.6	4.1	4.4	5.1
	1	1.3	1.7	2.4	2.9	2.1	1.6	2.0	1.1	2.1	1.5	1.6	1.4	2.0
	10	2.3	2.8	3.5	3.6	2.5	2.2	2.1	1.4	3.1	2.2	2.2	1.8	2.4
	20	3.1	3.9	4.3	4.2	3.0	2.6	2.4	1.9	3.7	2.7	2.5	2.2	3.0
50	30	3.9	4.7	5.0	4.8	3.4	3.1	2.9	2.5	4.2	3.3	2.8	2.8	3.6
	40	4.6	5.4	5.6	5.3	4.0	3.7	3.5	3.2	4.7	3.8	3.2	3.5	4.3
	50	5.3	6.0	6.1	5.9	4.7	4.3	4.2	3.8	5.2	4.3	3.8	4.2	4.9

Note — Linear interpolation may be used to obtain intermediate results.

Table 1/E.522 [T2.522], p.12

It may be necessary to calculate transit switching charge per holding minute from charge per conversation minute (efficiency factor is described in Recommendation E.506).

The value determined for R should then be employed to select in Table 2/E.522 the precise (or next higher) value of annual charges ratio for use in traffic tables. The value of annual charges ratios may be grouped in the following general sets:

a) Within a single continent or other smaller closely connected land mass involving distances up to 1000 miles, high traffic and frequently one-way operation:

These values are
tentative. Ranges and representative values of
annual charges ratio require further study.
Annual charges ratio: R = 1.5;
2.0
;
3.0; 4.0; 5.0; 6.0 and 7.0

b) Intercontinental working involving long distances, small traffic and usually two-way operation:

Annual charges ratio: R = 1.1;
1.3
; 1.5; 2.0; 3.0;
4.0 and 5.0.

2.5 *Use of method*

High-usage circuit groups carrying random traffic can be dimensioned from Table 2/E.522.

Step 1 — Estimate the annual charges ratio R as described under 2.4 above. (There is little difference between adjacent ratios.) If this ratio is difficult to estimate, the values underlined in a) and b) of § 2.4 above, should be used.

Step 2 — Consult Table 2/E.522 to determine the number of high-usage circuits N .

Note — When two values of N are given the right-hand figure applies to alternative routes of more than 10 circuits, the left-hand figure applies to smaller groups. The left-hand figure is omitted when it is no longer possible for the alternative route to be small.

3 24-hour traffic profiles

The traffic value used in the method in § 2 should be the value of traffic offered to the high-usage route during the busy hour of the final

route. In the case that some of the busy hours of the circuit groups or links forming an alternative route do not coincide with the busy hour of the relation, the ensuing method should be followed to take 24-hour traffic profiles into account (see [6], [8] and [9]).

The method consists of the following three basic steps:

i) prepare hourly traffic demands for which dimensioning is to be done;

ii) size all circuit groups, high usage and final, for one hourly traffic demand;

iii) iterate the process in step ii) for each additional hourly matrix.

3.1 *Preparation of hourly traffic demands*

Each Administration gathers historical traffic data on an hourly basis in accordance with Recommendations E.500 and E.523. Using historical data and information contained in Recommendation E.506, hourly traffic demand forecasts are made, resulting in a series of hourly demands for each exchange to every other exchange.

3.2 *Sizing circuit groups for one-hourly traffic demand*

Using the methods in § 2 and Recommendation E.521, trunk group sizes are prepared for the first hourly traffic demand disregarding other hourly traffic demands.

H.T. [T3.522]

TABLE 2/E.522
{
Number of high-usage circuits for different values of offered traffic, annual charges ratios and sizes of overflow groups
}

{	Annual charges ratios 1.1 { 0.545/0.727 {								
1.5	1/0	1/0	2/1	2/2	3/2	3/3	4/3	4/3	4/4
1.75	1/0	2/1	2/1	3/2	3/3	4/3	4/4	4/4	4/4
2.0	1/0	2/1	2/2	3/2	4/3	4/4	4/4	5/4	5/5
2.25	2/0	2/1	3/2	3/3	4/4	5/4	5/4	5/5	5/5
2.5	2/0	3/1	3/2	4/3	5/4	5/5	5/5	6/5	6/5
2.75	2/1	3/2	3/2	4/3	5/4	5/5	6/5	6/6	6/6
3.0	3/1	3/2	4/3	4/4	5/5	6/5	6/6	6/6	7/6
3.5	3/1	4/2	4/3	5/4	6/5	7/6	7/6	7/7	7/7
4.0	4/2	4/3	5/4	6/5	7/6	7/7	8/7	8/7	8/8
4.5	4/2	5/3	6/4	6/6	7/7	8/7	8/8	9/8	9/8
5.0	5/3	6/4	6/5	7/6	8/7	9/8	9/9	9/9	10/9
5.5	5/3	6/5	7/5	8/7	9/8	9/9	10/9	10/10	10/1
6.0	6/3	7/5	7/6	8/7	9/9	10/9	11/10	11/10	11/1
7.0	7/4	8/6	8/7	10/8	11/10	11/11	12/11	12/12	13/1
8.0	8/5	9/7	10/8	11/10	12/11	13/12	13/13	14/13	14/1
9.0	/6	/8	/9	/11	/12	/13	/14	/14	/15
10.0	/7	/9	/10	/12	/14	/15	/15	/16	/16
12.0	/9	/11	/12	/14	/16	/17	/18	/18	/19
15.0	/12	/14	/16	/18	/20	/21	/21	/22	/22
20.0	/16	/19	/21	/23	/25	/27	/28	/28	/29
25.0	/21	/24	/26	/29	/31	/33	/33	/34	/35
30.0	/26	/29	/31	/34	/37	/38	/39	/40	/41
40.0	/36	/39	/42	/45	/48	/50	/51	/52	/52
50.0	/45	/49	/52	/55	/59	/61	/62	/63	
60.0	/55	/60	/62	/66	/70	/72	/73		
80.0	/74	/80	/83	/87	/92	/94	/95		
100.0	/94	/100	/103	/108	/113	/116			
120.0	/113	/120	/124	/129	/134	/137	{		
Direct final circuit groups are									
}	138								
150.0	/143	/150	/154	/160	/166	/169	economical within this area.	170	
200.0	/192	/200	/205	/212	/219				
250.0	/241	/250	/256	/263	/271				
300.0	/290	/300	/306	/315	/323				

Table 2/E.522 (Recup. + Corr.) [T3.522], p.13 MONTAGE **à l'italienne, reprendre des originaux**

3.3 *Iterating for each additional hourly traffic matrix*

In sizing the circuit groups for the second hourly traffic demand, the method is provided with the circuit quantities resulting from the previous step, and is constrained solely to increasing circuit group sizes; i.e., if the circuit group sizes for the first hourly traffic demand were greater than for the second hourly demand, then the circuit group sizes for the first hourly traffic demand would be retained.

All additional hourly traffic demands are processed in the same iterative manner. The resulting circuit group sizes then satisfy the traffic demands for all hours being considered (see Annex A for a computational example).

3.4 *Processing sequence*

Processing may start with the first hour of traffic demand,

however, experiments have indicated that efficiencies of the network can be improved if processing starts with the hour with the smallest total traffic demand. It should be noted that this method gives us suboptimal networks, which may be improved by manual refinements.

4 Minimum outlay alternate routing networks

The method below allows Administrations to adjust alternate routing networks to take into account existing revenue accounting divisions.

The method consists of the following steps:

i) Obtain 24-hour traffic profiles in accordance with Recommendations E.500 and E.523;

ii) Compute circuit quantities and costs for a no-overflow network in accordance with Recommendation E.520;

iii) Compute monthly overflow minutes (holding time) at varying percentages of busy-hour overflow. This is done by applying three conversion factors to the busy hour overflow erlangs:

— Ratio of holding minutes to erlangs: a fixed value of 60.

— Daily overflow to busy-hour overflow ratio: a value that depends on the 24-hour traffic profile and the degree of overflow.

— Monthly overflow to daily overflow ratio (Recommendation E.506): a value that depends on the day-to-day pattern within a month and the degree of overflow.

iv) Starting with the network calculated in step ii):

— reduce the high usage circuits by one circuit,

— calculate overflow to final circuit groups,

— dimension final circuit groups in accordance with Recommendation E.521,

— calculate circuit costs and transit charges;

v) Iterate step iv) until the minimum outlay (circuit costs plus transit charges) for terminal administrations is reached (see Annex B for computational example).

5 Service considerations

On intercontinental circuits, where both-way operation is employed, a minimum of two circuits may be economical. Service considerations may also favour an increase in the number of direct circuits provided, particularly where the annual charges ratio approaches unity.

Although the dimensioning of high-usage groups is normally determined

by traffic flows and annual charges ratios, it is recognized that such groups form part of a network having service requirements relative to the subscriber. The ability to handle the offered traffic with acceptable traffic efficiency should be tempered by the overall network considerations on quality of service.

The quality of service feature, which is of primary importance in a system of high-usage and final circuit groups, is the advantage derived from direct circuits versus multi-link connections. A liberal use of direct high-usage circuit groups, taking into account the economic factors, favours a high quality of service to the subscriber. It is recommended that new high-usage groups should be provided whenever the traffic flow and cost ratios are not conclusive. This practice may result in direct high-usage groups of two circuits or more.

The introduction of high-usage groups improves the overall grade of service and provides better opportunities of handling traffic during surges and breakdown conditions. When high-usage links bypass the main final routes the introduction of high-usage routes can assist in avoiding expenses which might otherwise be incurred in keeping below the maximum number of long-distance links in series. In the future, more measurements of traffic flows may be necessary for international accounting purposes and high-usage circuits should make this easier.

ANNEX A

(to Recommendation E.522)

Example of network dimensioning taking into account

24-hour traffic profiles

A.1 *Assumptions* (see also Figure A-1/E.522)

Calculations are performed under the following conditions:

1) Time difference:

A is 9 hours west of B

C is 5 hours west of A

B is 10 hours west of C

2) Traffic profiles:

24-hour traffic profiles as per Table 1/E.523 are used.

3) Busy hour traffic:

A-B 50 erlangs

A-C 100 erlangs

C-B 70 erlangs

4) Cost ratio:

R = 1.3

Figure A-1/E.522 p.14

A.2 *Numerical results*

24 hourly traffic demands are processed. The order of processing are from the hour with the smallest total traffic demand to the hour with the largest total traffic demand. Computational results are given in Table A-1/E.522.

H.T. [T4.522]

TABLE A-1/E.522

Numerical results

Hour Number of circuits obtained by single hour dimensioning (disregarding lower bounds imposed by the previous iterative stage) } Number of circuits obtained considering lower bounds imposed by the previous iterative stage } Number of circuits required to meet multiple hourly traffic demands }	Hourly traffic demand { {	{		

A-B	A-C	C-B	A-B	A-C	C-B	A-B	A-C	C-B	A-B	A-C	C-B	
6	17.50	5.00	3.50	17	19	17	17	19	17	17	19	17
7	20.00	5.00	3.50	19	20	18	19	20	18	19	20	18
5	2.50	5.00	28.00	1	14	41	19	11	39	19	20	39
4	2.50	5.00	35.00	1	14	49	19	11	47	19	20	47
8	37.50	5.00	3.50	37	23	22	19	38	37	19	38	47
9	40.00	5.00	3.50	39	24	23	19	41	40	19	41	47
3	2.50	5.00	45.50	1	14	61	19	11	59	19	41	59
18	2.50	50.00	3.50	1	66	12	19	64	9	19	64	59
10	50.00	5.00	3.50	49	26	25	9	61	59	19	64	59
19	2.50	60.00	3.50	1	77	12	19	75	9	19	75	59
20	2.50	60.00	3.50	1	77	12	19	75	9	19	75	59
22	12.50	30.00	24.50	12	45	39	12	45	39	19	75	59
2	2.50	5.00	63.00	1	14	80	19	11	78	19	75	78
17	2.50	70.00	3.50	1	87	12	19	85	9	19	85	78
1	2.50	5.00	70.00	1	14	87	19	11	85	19	85	85
23	20.00	20.00	42.00	19	36	60	19	36	60	19	85	85
11	47.50	25.00	17.50	47	46	38	3	85	77	19	85	85
21	12.50	55.00	24.50	12	73	39	12	73	39	19	85	85
12	42.50	30.00	21.00	42	50	41	3	85	76	19	85	85
16	2.50	90.00	3.50	1	109	12	19	107	9	19	107	85
0	20.00	20.00	66.50	19	36	87	19	36	87	19	107	87
13	30.00	65.00	35.00	29	86	54	5	107	76	19	107	87
15	17.50	100.00	28.00	17	121	44	19	120	43	19	120	87
14	27.50	95.00	38.50	27	117	57	19	124	64	19	124	87

Table A-1/E.522 [T4.522], p.15

This example relates to an intercontinental network where busy hours of the three traffic relations are widely different among each other. The busy hour of the relation A-C, i.e. hour 15, is a low traffic period for the relations A-B and C-B. The busy hour of the relation C-B, i.e. hour 1, is a low traffic period for the relations A-B and A-C. Similarly, the busy hour of the relation A-B, i.e. hour 10, is a low traffic period for the relations A-C and C-B.

In this case, the single hour dimensioning method, where traffic data during the busy hour of the final circuit group are used for dimensioning, cannot be applied. If the single hour dimensioning method is applied, this results in considerable under-dimensioning.

If all the circuit groups are dimensioned as final, the required number of circuits are 64, 117 and 85 for the circuit groups A-B, A-C and C-B, respectively. About 14% of the total number of circuits is saved by the use of alternate routing.

ANNEX B

(to Recommendation E.522)

Example of minimum outlay network dimensioning

Figure B-1/E.522 p.16

B.1 *Assumptions* (see also Figure B-1/E.522)

Calculations are performed under the following conditions:

1) Time difference:

A is 3 hours west of B

A is 3 hours west of C

No time difference between B and C

2) Traffic profiles:

24-hour traffic profiles as per Table 1/E.523 are used.

3) Busy hour traffic:

A-B 16 erlangs

A-C 33 erlangs

C-B 33 erlangs

4) Each Administration monthly cost per circuit:

A-B 1000 units

A-C 1000 units

C-B 800 units

5) Transit charge per holding minute to each terminal Administration:

1/2 unit

6) Conversion factors:

i) Holding minutes/erlangs: 60

ii) Daily overflow/busy hour overflow

This conversion factor (*F*) is calculated according to the guideline given in § 2.4.

iii) Monthly overflow/daily overflow: 26

where medium social contact per Recommendation E.502 is assumed.

7) Grade-of-service (GOS) on final circuit groups: 0.01

B.2 *Numerical results*

Numerical results are shown in Table B-1/E.522. The number of circuits C-B does not increase because of the 24-hour traffic profiles matching. The number of high usage circuits A-B in the minimum outlay network is larger than that in the minimum cost network. The impact of considering transit charges in dimensionings is always in the direction of less overflow.

H.T. [T5.522]
TABLE B-1/E.522
Numerical results

Network results Economic results (× 1000 units/month) }	{

{
Busy-hour overflow probability
}
	Number of circuits	Circuit costs	Transit charges	Total outlay

A-B	A-C	C-B	A	B	C	A	B	C	A	B	C	
0.0000	25	45	45	70	61	81	—	—	—	70.0	61.0	81.0
0.0090	25	45	45	70	61	81	0.3	0.3	(0.7)	70.3	61.3	80.3
0.0151	24	45	45	69	60	81	0.6	0.6	(1.3)	69.6	60.6	79.7
0.0221	23	45	45	68	59	81	0.9	0.9	(1.9)	68.9	59.9	79.1
0.0331	22	46	45	68	58	82	1.4	1.4	(2.9)	69.4	59.4	79.1
0.0471	21	46	45	67	57	82	2.1	2.1	(4.2)	69.1	59.1	77.8
0.0641	20	46	45	66	56	82	3.0	3.0	(6.0)	69.0	59.0	76.0
Minimum outlay for A and B 0.0861	19	47	45	66	55	83	4.2	4.2	(8.4)	70.2	59.2	74.5
0.1121	18	47	45	65	54	83	5.7	5.7	(11.5)	70.7	59.7	71.5
Minimum cost network 0.142	17	48	45	65	53	84	7.6	7.6	(15.1)	72.6	60.6	68.9

Table B-1/E.522 [T5.522], p.17

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STANDARD TRAFFIC PROFILES FOR

INTERNATIONAL TRAFFIC STREAMS

The worldwide nature of the international telephone network, spanning as it does all possible time zones , has stimulated studies of the traffic streams between countries in different relative time locations. These studies have led to the development of standardized 24-hour traffic profiles which, theoretically based and verified by measurements, would be useful for engineering purposes. In fact, these concepts can be applied to a variety of network situations:

i) variable access satellite working where a large number of traffic streams with possibly differing traffic profiles share the pool of satellite circuits;

ii) combining of traffic streams on groups of terrestrial circuits which may be either high-usage or final choice routes;

iii) detour routing of traffic between origin and destination countries to take advantage of prevailing low load conditions on the detour path.

In developing any such applications, account must be taken of the International Routing Plan (Recommendation E.171 [1]) and of accepted accounting principles (Recommendation D.150 [2]).

It must be recognized that the preferred basis for dimensioning consists of traffic profiles based on real traffic. Nevertheless, many countries have found the standard profiles presented in this Recommendation very useful where streams are too small to obtain reliable measurements or where no measurements are available.

For both-way profiles , two equivalent methods of presentation are given in chart and tabular form. In Figure 1/E.523 hour-by-hour traffic volumes are shown in diagrammatically as percentages of the total daily traffic volume; such percentages are particularly convenient for tariff studies. In Table 1/E.523, hourly traffics are expressed as percentages of the busy hour traffic , and this is convenient for engineering purposes. Time zone differences are given in whole hours only. Directional profiles are given in Tables 2/E.523 and 3/E.523.

Although tables are given for both-way and directional traffic streams, it must be emphasized that at this stage only the both-way profiles can be regarded as soundly supported by measurement. The directional profiles are theoretically based and supported by some measurements, but should be used with caution until adequate verification has been achieved.

The theoretical basis for the profiles presented here is contained in Annex A. It depends on a convenience function $f(t)$ which represents the profile of *local* daily traffic , where of course no time zone difference exists. The function $f(t)$ used for computation of the standard profile was derived by mathematical manipulation of measurements of the Tokyo-Oakland and Tokyo-Vancouver streams. Although these results have been supported by other measurements, it leaves open the possibility that the convenience function may vary from one country to another and that, strictly, these should be derived independently and then used to obtain a calculated profile for the international relation. It also seems that the convenience function for the country of destination should be given greater weight than that for the country of origin. These remarks suggest possible refinements, but are not quantified in this Recommendation.

Figure 1/E.523 p.18

H.T. [T1.523]

TABLE 1/E.523

Standard hourly bothway traffic patterns

Local time in the more westerly country

	BH
{	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
%	
}	

Unable to Convert Table

Note 1 — The 24-hour profile of both-way traffic between any two countries is read from left to right from the appropriate row of the table; all time differences can be expressed in the range 0-12 hours. Each entry is expressed as a percentage of the busy hour traffic.

Note 2 — The *more westerly* country of a traffic relation is the one from which we can proceed eastwards to the other through time zones not exceeding 12 hours.

Note 3 — For network planning studies, UTC (Universal Coordinated Time) would normally be used so that all traffic streams are processed time consistently. Clearly if the more westerly country is *W* hours ahead of UTC (ignoring the international dateline), then the traffic at 0000-0100 UTC is obtained from the row corresponding to the time difference between the two countries at the column headed *W*) to (25-*W*).

Example: For the traffic stream between the U.K. (UTC | | hour) and the central zone of USA (UTC + | 8 hours), the time difference is 7 hours and the USA is regarded as the more westerly country, hence *W*
| | 8. Thus from the table, the traffic during 0000-0100 UTC is 5 | of the busy hour traffic, and the busy hour is 1500-1600 UTC.

Note 4 — The column headed ‘‘BH %’’ gives the busy hour traffic volume as a percentage of the daily traffic volume.

MONTAGE Time difference (in hours) between two countries

Table 1/E.523 [T1.523] p.19

H.T. [T2.523]

TABLE 2/E.523

Diurnal distributions of eastbound international telephone traffic

Local time in the more westerly country

Unable to Convert Table

Note — This table is based on *p*
| | .4, *q*
| | .6, i.e. greater weight is given to the convenience function of the called party (see Annex A).

MONTAGE Time difference (in hours) between two countries

Table 2/E.523 [T2.523] p.20

H.T. [T3.523]

TABLE 3/E.523

Diurnal distributions of westbound international telephone traffic

Local time in the more westerly country

Unable to Convert Table

Note — This table is based on *p*
| | .4, *q*
| | .6, i.e. greater weight is given to the convenience function of the called party (see Annex A).

MONTAGE Time difference (in hours) between two countries

Table 3/E.523 [T2.523] p.21

ANNEX A

(to Recommendation E.523)

Mathematical expression for the influence of time differences

on the traffic flow

A telephone call is initiated when a person wishes to call someone else, but both parties have to be on the line before the call is established. It is considered that a telephone call is made at a time which tends to be convenient for both the calling and called parties. The *degree of convenience* for making a telephone call is considered to be a periodical function of time t, whose period is 24 hours. When the time difference between both parties is zero, the degree of convenience is denoted by $f(t)$, where t is local standard time. The graphic shape of the basic function $f(t)$ will be determined by the daily pattern of human activities, and will resemble, or fairly closely coincide with, the hour by hour traffic distribution in the national (or local) telephone network.

It is assumed that the hourly traffic distribution $F_\tau(t)$, when a time difference of τ hours exists between the originating and called locations, is expressed as the geometric mean of convenience functions of two locations τ hours apart:

$$F_\tau(t) = k\left\{f(t) \times f(t+\tau)\right\}^{1/2}$$

where

$$k = 1 \Big/ \int_{24\ hours} \left\{f(t) \times f(t+\tau)\right\}^{1/2} dt \qquad \text{(A-1)}$$

The sign of τ is positive when the time at the destination is ahead of the reference time, and negative when the time of destination is behind the reference time.

The distribution of equation (A-1) represents the sum of the outgoing and incoming traffics. Expressions for the one-way hourly traffic distributions can also be obtained by extending the concept of convenience function as follows.

Define convenience functions both for the caller $f_0(t)$ and for the called party $f_i(t)$. Then the one-way traffic distributions of east-bound and west-bound telephone calls, for the case of τ hour time-difference, are similarly expressed as follows:

$$F_{\tau,\,east}(t) = k\left\{f_0(t) \times f_i(t+\tau)\right\}^{1/2}$$

$$k = 1 \Big/ \int_{24\ hours} \left\{f_0(t) \times f_i(t+\tau)\right\}^{1/2} dt \qquad \text{(A-2)}$$

$$F_{\tau,\,west}$$

$$(t) = \mathrm{k}$$

$$\left\{ f_{\mathrm{f\,Ii}}(t) \times f_{0}(t + \tau) \right\}_{1/2}$$

$$\mathrm{k} = 1/\int_{24\ hours}$$

$$\left\{ f_{\mathrm{f\,Ii}}(t) \times f_{0}(t + \tau) \right\}_{1/2}\, dt$$

(A-3)

where

t is the local standard time of the west station and

τ is positive.

It is natural that a caller makes a call considering the convenience of the called person, and therefore the convenience function of the called person f_i contributes more than the convenience of the caller f_0 to the directional distribution F. They can be written as follows:

$$f_i(t) = k_1 \{f(t)\}^p, \quad f_0(t) = k_2 \{f(t)\}^q, \tag{A-4}$$

where

$$p > q \quad \text{and} \quad p + q = 2,$$

and where k_1 and k_2 are normalizing coefficients to ensure that:

$$\int_{24\ hours} f_i(t)\, dt = 1,$$
$$\int_{24\ hours} f_0(t)\, dt = 1.$$

As to the values of p and q in equation (A-4), it has been found empirically that the convenience of the called side p is considerably larger than that of originating side q, and appropriate values are roughly $p = 1.4$ and consequently $q = 0.6$.

References

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[2] CCITT Recommendation *New system for accounting in international telephony* , Rec. D.150.

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Recommendation E.524

OVERFLOW APPROXIMATIONS FOR NON-RANDOM INPUTS

1 Introduction

This Recommendation introduces approximate methods for the calculation of blocking probabilities for individual traffic streams in a circuit group arrangement. It is based on contributions submitted in the Study Period 1984-1988 and is expected to be amended and expanded in the future (by adding the latest developments of methods).

The considered methods are necessary complements to those included in the existing Recommendation E.521 when it is required to take into account concepts such as cluster engineering with service equalization, service protection and end-to-end grade of service. Recommendation E.521 is then insufficient as it is concerned with the grade of service for only one non-random traffic stream in a circuit group.

Design methods concerning the above-mentioned areas are subject to further study and this Recommendation will serve as a reference when, in the future, Recommendation E.521 is complemented or replaced.

In this Recommendation the proposed methods are evaluated in terms of accuracy, processing time, memory requirements and programming effort. Other criteria may be relevant and added in the future.

The proposed methods are described briefly in § 2. Section 3 defines a set of examples of circuit group arrangements with exactly calculated (exact resolution of equations of state) individual blocking probabilities, to which the result of the methods can be compared. This leads to a table in § 4, where for each method the important criteria are listed. The publications cited in the reference section at the end contain detailed information about the mathematical background of each of the methods.

2 Proposed methods

The following methods are considered:

a) Interrupted Poisson Process (IPP) method,

b) Equivalent Capacity (EC) method,

c) Approximative Wilkinson Wallstr"om (AWW) method.

2.1 *IPP method*

IPP (Interrupted Poisson Process) is a Poisson process interrupted by a random switch. The on-/off-duration of the random switch has a negative exponential distribution. Overflow traffic from a circuit group can be accurately approximated by an IPP, since IPP can represent bulk characteristics of overflow traffic. IPP has three parameters, namely, on-period intensity and mean on-/off-period durations. To approximate overflow traffic by an IPP, those three parameters are determined so that some moments of overflow traffic will coincide with those of IPP.

The following two kinds of moment match methods are considered in this Recommendation:

— three-moment match method [1] — where IPP parameters are determined so that the first three moments of IPP will coincide with those of overflow traffic;

— four-moment ratio match method [2] where IPP parameters are determined so that the first moment and the ratios of the 2nd/3rd and 7th/8th binomial moments of IPP will coincide with those of overflow traffic.

To analyze a circuit group where multiple Poisson and overflow traffic streams are simultaneously offered, each overflow stream is approximated by an IPP. The IPP method is well suited to computer calculation. State transition equations of the circuit group with IPP inputs can be solved directly and no introduction of equivalent models is necessary. Characteristics of overflow traffic can be obtained from the solution of state transition equations. The main feature of the IPP method is that the individual means and variances of the overflow traffic can be solved.

2.2 *EC method*

The EC (Equivalent Capacity) method [3] does not use the traffic-moments but the transitional behaviour of the primary traffic, by introducing a certain function ρ"(n) versus the equivalent capacity (n) of the partial overflow traffic, as defined by the recurrent process:

if n | is a positive integer and approximated by linear interpolation, if not.

A practical approximation, considering the predominant overflow congestion states only, leads to the equations:

with:

$$D_i(n) = 1 + a_i \left[\rho_i(n) - \tilde{\rho}_{fIi}(n - 1) \right]$$

(2-3)

defining the equivalent capacity (n_i) of the partial overflow traffic labelled i , and influenced by the mutual dependency between the partial overflow traffic streams.

The mean value of the partial second overflow is:

$$O_i = a_i \pi \rho''_i(n$$

(2-4)

where π is the time congestion of the overflow group.

The partial GOS (grade of service) equalization is fulfilled if:

$$\rho''_i(n_i) = C$$

(2-5)

C | eing a constant to be chosen.

2.3 *AWW method*

The AWW (Approximative Wilkinson Wallstr"om) method uses an approximate ERT (Equivalent Random Traffic) model based on an improvement of Rapp’s approximation. The total overflow in traffic is split up in the individual parts by a simple expression, see Equations (2-7) and (2-9). To calculate the total overflow traffic, any method can be used. An approximate

Erlang formula calculation for which the speed is independent of the size of the calculated circuit group is given in [4].

The following notations are used:

M mean of total offered traffic;

V variance of total offered traffic;

Z V/M;

B mean blocking of the studied group;

m_i, v_i, z_i, b_i corresponding quantities for an individual traffic stream;

~ is used for overflow quantities.

2.3.1 *Blocking of overflow traffic*

For overflow calculations, an approximate ERT-model is used. By numerical investigations, a considerable improvement has been found to Rapp's classical approximation for the fictitious traffic. The error added by the approximation is small compared to the error of the ERT-model. It is known that ERT underestimates low blockings when mixing traffic of diverse peakedness [2]. The formula, which was given in [4] (although with one printing error), is for $Z > 1$:

$$A^* = V + Z(Z-1)(2+\gamma^{D}lF')$$

where

$$\gamma = (2.36Z - 2.17)\log\{ + (z-1)/[M(Z+1.5)\}$$

and

$$\beta = Z/(1.5M + 2Z - 1.3)$$

(2-6)

2.3.2 *Wallstr"om formula for individual blocking*

There has been much interest in finding a simple and accurate formula for the individual blocked traffic $\tilde{m}_i$. Already in 1967, Katz [5] proposed a formula of the type

$$\tilde{m}_i = m_i B(1 - w + wz_i/Z)$$

(2-7)

with w | eing a suitable expression. Wallstr"om proposed a very simple one but with reasonable results [6], [2]:

$$w = 1 - B$$

(2-8)

One practical problem is, however, that a small peaked substream could have a blocking $b_i > 1$ with this formula. To avoid such unreasonable results a modification is used in this case. Let $z_{m\backslash da\backslash dx}$ be the largest individual z_i.

Then the value used is [Formula Deleted]