ITU Seminar

Bangkok, Thailand , 11-15 November 2002

Session 4.1

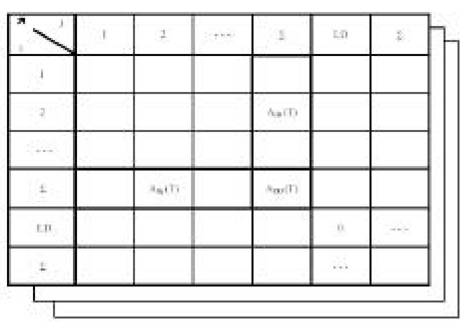
Service and applications matrix forecasting

Traffic matrix

The bases for effective network planning is the traffic data between each two nodes of the network

Such traffic values are typically shown in an origin-destination traffic matrix

Usually set of traffic matrices with one matrix for each services



Traffic matrix

Adding all the row-totals O(i), i.e. the entries in column SO (sum originating traffic) give the total traffic A.

The same result is obtained by adding all the column -totals T(j), i.e. the entries in the row ST (sum terminating traffic)

from \ to	1	i	j	n	SO
1	A(11)			A(1n)	O(1)
i		A(ii)	A(ij)		O(i)
j		A(ji)	A(jj)		O(j)
n	A(n1)			A(nn)	O(n)
ST	T(1)	T(i)	T(j)	T(n)	A(11)

Here: A(ij) is the traffic from i to j;
A(ji) is the traffic from j to i;
A(ii) is the local traffic in i;
O(i) is the sum of all traffic originating in i;
T(j) is the sum of all traffic terminating in j.

Traffic matrix forecasting

In the ideal case service matrices are the result of point-to point measurement of traffic and further mathematical traffic predictions

If complete data for a present (first) traffic matrix are not available be measurements they have to be created by other means

The generation of such first traffic matrix is based on information about the subscribers and corresponding traffic per subscriber (also Calling rate)

Traffic matrix forecasting

$$TCR = \alpha_{tot}$$

$$PO = \frac{\alpha_{orig}}{\alpha_{tot}}$$

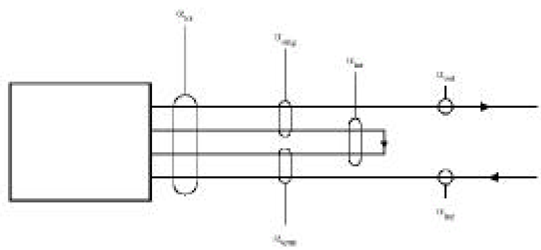
$$PI = \frac{\alpha_{int}}{\alpha_{tot}}$$

according to the definitions

Traffic per subscriber / calling rate

Traffic per subscriber line (main line)

$$\alpha_{tot} = TCR$$
$$\alpha_{orig} = TCR \cdot PO$$
$$\alpha_{term} = TCR \cdot (1 - PO)$$
$$\alpha_{out} = TCR \cdot (PO - PI/2)$$
$$\alpha_{inc} = TCR \cdot (1 - PO - PI/2)$$
$$\alpha_{int} = TCR \cdot PI$$



Example:

a_{orig} = 0.05 Erlang for Voice ir

a_{orig} = 5 Kbit/sec for VoIP

Traffic matrix forecasting

Estimation of total traffic

Taking into account that different categories of subscribers initiate different amounts of traffic, it may sometimes be possible to estimate a future traffic from:

$$A(t) = N_1(t) \cdot a_1 + N_2(t) \cdot a_2 + - -$$

Where, $N_1(t), N_2(t)$, etc., are the forecasted number of subscribers of category 1, 2, etc.,

and α_1, α_2, etc., are the traffic per subscriber of category 1, 2, etc

Traffic matrix forecasting

Estimation of total traffic

If it is not possible to separate the subscribers into categories with different traffic, the future traffic may simply be estimated as:

$$A(t) = A(0)\frac{N(t)}{N(0)}$$

Where, $N(t)$ and $N(0)$ are the number of subscribers at times t and zero

Traffic matrix forecasting

Distribution of point-to-point traffic

$A_{ij} = K(d_{ij}) \cdot N_i \cdot N_j$ **Homogenous distribution**

For estimation of point-to-point traffic various formulae may be applied

$$G_i = \frac{N_i(t)}{N_i(0)}$$

$$A_{ij}(t) = A_{ij}(0)\frac{W_i G_i + W_j G_j}{W_i + W_j}$$

General is to take into account the increase of subscribers in the two nodes and apply certain weight factors

$$G_j = \frac{N_j(t)}{N_j(0)}$$

Traffic matrix forecasting

Distribution of point-to-point traffic

$$A_{ij}(t) = A_{ij}(0)\frac{W_i G_i + W_j G_j}{W_i + W_j}$$

Where, W_i and W_j are the weights and G_i is the growth of subscribers in node i, and G_j in node j

$$G_i = \frac{N_i(t)}{N_i(0)} \qquad G_j = \frac{N_j(t)}{N_j(0)}$$

Different methods exist for W_i and W_j calculation

Traffic matrix forecasting

Distribution of point-to-point traffic

Distribution according to the gravity model

$$A_{ij} = K(d_{ij}) \cdot N_i \cdot N_j$$

,where $K(d_{ij})$ is interest factor and can be calculated from a known traffic matrix

It may be necessary to adjust the expression for A_{ij} for pairs of nodes with special relations to each other, e.g. a big factory in one part of a country and the head office in another part

Traffic matrix forecasting

Distribution of point-to-point traffic

- Fixed percentage of internal traffic
- Interest factor or destination factor method
- Percentage of outgoing/incoming long-distance, national, international traffic
- Kruithof double factor method

Traffic matrix forecasting

Distribution of point-to-point traffic

Kruithof double factor method

The values, at present, are assumed to be known and so is the future row and column sums

The procedure is to adjust the individual $A(i, j)$ so as to agree with the new row and column sums

$A(i, j)$ is changed to $A(i, j)\frac{S_1}{S_o}$

Where, S_o is the present sum and S_1 the new sum for the individual row or column.

Traffic matrix forecasting

Distribution of point-to-point traffic

Extended Kruithof method – Weighted least squares method

Assumes all values in a traffic matrix (point-to-point traffic, sum of outgoing/incoming traffic) are uncertain

It makes traffic estimations by weighting the forecasts according to their uncertainty

If ***M*** is unequalized traffic matrix, search a new equalized traffic matrix ***E*** which minimize the deviation of the two with regard of:

- each traffic relation
- the sum of outgoing traffic per node
- the sum of incoming traffic per node

Traffic matrix forecasting

Kruithof double factor method

Example of the use of Kruithof's Double Factor Method

Given: The present traffic interests $A_{ij}(0)$

i \ j	1	2	sum
1	10	20	30
2	30	40	70
sum	40	60	100

Forecast of the future total originating and terminating traffic per node: $A_{i.}(t)$ and $A_{.j}(t)$:

i \ j	1	2	sum
1			45
2		?	105
sum	50	100	150

Problem: Estimate the traffic values $A(i, j/t)$

Traffic matrix forecasting

Kruithof double factor method

Example of the use of Kruithof's Double Factor Method

Solution: Iteration 1: Row multiplication

i j	1	2	sum
1	15	30	45
2	45	60	105
sum	60	90	150

$$A_{ij}(1) = \frac{A_{ij}(0)}{A_{i\cdot}(0)} A_{i\cdot}(t)$$

Iteration 2: Column multiplication

$$A_{ij}(2) = \frac{A_{ij}(1)}{A_{\cdot j}(0)} A_{\cdot j}(t)$$

i j	1	2	sum
1	12.5	33.33	45.83
2	37.5	66.67	104.17
sum	50	100	150

Traffic matrix forecasting

Kruithof double factor method

Example of the use of Kruithof's Double Factor Method

Iteration 3: Row multiplication

i j	1	2	sum
1	12.27	32.73	45
2	37.80	67.20	105
sum	50.07	99.93	150

Iteration 4: Column multiplication

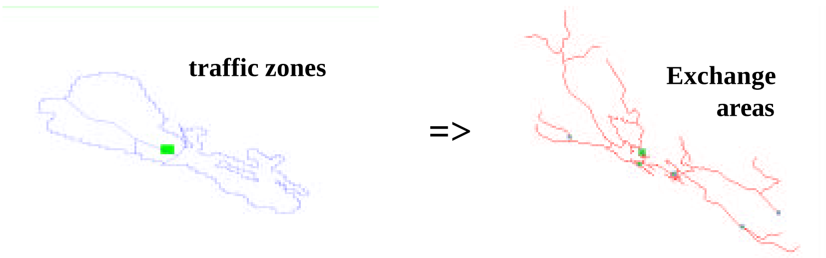
i j	1	2	sum
1	12.25	32.75	45
2	37.75	67.25	105
sum	50	100	150

After 4 iterations, the sums of rows and columns are equal to the forecasted values

Application matrix forecasting

Recalculation of traffic matrix

Convert service matrix (between traffic zones) to application matrix (between exchange/node areas) based on areas / subscribers relation



Application matrix forecasting

Traffic matrix between exchanges/nodes

MM	A	B	C	D	E	F	G	H	I	J	K
A	487.78	65.04	45.53	650.37	67.75	85.63	51.49	54.20	65.04	525.71	590.75
B	65.04	8.67	6.07	86.72	9.03	11.42	6.86	7.23	8.67	70.10	78.77
C	45.53	6.07	4.25	60.70	6.32	7.99	4.81	5.06	6.07	49.07	55.14
D	650.37	86.72	60.70	867.16	90.33	114.18	68.65	72.26	86.72	700.95	787.67
E	67.75	9.03	6.32	90.33	9.41	11.89	7.15	7.53	9.03	73.02	82.05
F	85.63	11.42	7.99	114.18	11.89	15.03	9.04	9.51	11.42	92.29	103.71
G	51.49	6.86	4.81	68.65	7.15	9.04	5.43	5.72	6.86	55.49	62.36
H	54.20	7.23	5.06	72.26	7.53	9.51	5.72	6.02	7.23	58.41	65.64
I	65.04	8.67	6.07	86.72	9.03	11.42	6.86	7.23	8.67	70.10	78.77
J	525.71	70.10	49.07	700.95	73.02	92.29	55.49	58.41	70.10	566.60	636.70
K	590.75	78.77	55.14	787.67	82.05	103.71	62.36	65.64	78.77	636.70	715.46
L	189.69	25.29	17.70	252.92	26.35	33.30	20.02	21.08	25.29	204.44	229.74
M	65.04	8.67	6.07	86.72	9.03	11.42	6.86	7.23	8.67	70.10	78.77
N	785.85	104.78	73.35	1047.81	109.15	137.96	82.95	87.32	104.78	846.98	951.78
O	48.78	6.50	4.55	65.04	6.77	8.56	5.15	5.42	6.50	52.57	59.08
P	69.37	9.25	6.47	92.50	9.64	12.18	7.32	7.71	9.25	74.77	84.02
Q	61.24	8.17	5.72	81.66	8.51	10.75	6.48	6.80	8.17	66.01	74.17
R	406.46	54.20	37.94	541.97	56.46	71.36	42.91	45.16	54.20	438.08	492.29
S	54.20	7.23	5.06	72.26	7.53	9.51	5.72	6.02	7.23	58.41	65.64