ITU Seminar

Warsaw, Poland , 6-10 October 2003

Session 4.1

Service and applications matrix forecasting

Service matrix forecasting

Services :

Traditional

- Voice
- Data

Broadband

Business customers

- High speed Internet access
- LAN-to-LAN connectivity
- VPN
- E - commerce

Residential customers

- High speed Internet access
- On-line gaming

Introduction of a variety of new services and applications will be possible because of the open interfaces that are typical for NGN

Service matrix forecasting

Service type :

Circuit switched

- **POTS**
- **ISDN**
- **Dial-up Internet**

Defined by traffic in Erlang and required circuit bandwidth or bit rate

Permanent service

- **Leased line of a given bit rate**
- **Dedicated Gigabit Ethernet service without overbooking**

Permanent services are defined by required bandwidth or bit rate

Service matrix forecasting

Service type :

Elastic services (packet switched non real time)

- DSL Internet access
- FTP-based file transfer
- Internet access

Modelled into two layers: session layer and file transfer layer

Defined by access link data rate, guaranteed bandwidth, bandwidth at the file transfer layer and traffic (Erlang) and blocking probability at the session layer

Service matrix forecasting

Service type :

Real time CBR

- High quality voice over IP
- High quality videoconference over IP
- Telemedicine real time high speed service

Defined by the required bit rate, traffic in Erlang and loss probability

Real time VBR

- Voice over IP using compression and silence suppression
- Videoconferencing
- Interactive video and audio services with compression technics (e.g. Web games)

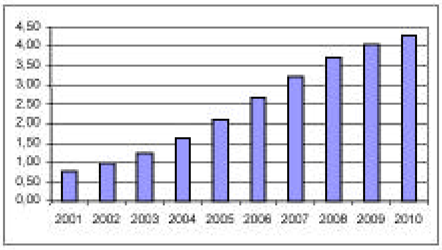
Defined by mean bit rate, pick bit rate, packet or sell loss ratio, traffic in Erlang and loss probability

Service matrix forecasting

Services -

Traffic from the services is transported on different network platforms or on leased lines

Important services for the transport network are: POTS/ISDN, Internet, Leased lines, PSDN (packet switched data network), Frame relay, ATM, IP Virtual private network(VPN), ADSL/SDSL, VDSL/LMDS, Fast Ethernet, Gigabit Ethernet, Lamda wavelength, Dynamic bandwidth allocation



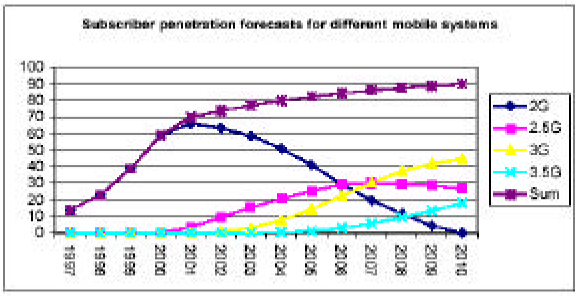
Evolution of predicted average downstream capacity in Mbs for ADSL subscriptions

Service matrix forecasting

Market segments

➢ An incumbent operator is leasing transport capacity to other operators

➢ In addition the incumbent offers transport capacity to the residential and the business market



Subscriber penetration forecasts for different mobile systems

Service matrix forecasting

A segmentation of the market will be:

Residential market: POTS, ISDN, Internet, ADSL, VDSL, LMDS, HFC

Business market: POTS, ISDN, IP VPN, Internet, PSDN, Frame Relay, ATM, ADSL, SDSL, VDSL, LMDS, Leased lines, Fast Ethernet, Gigabit Ethernet, Lamda wavelength, Dynamic bandwidth allocation.

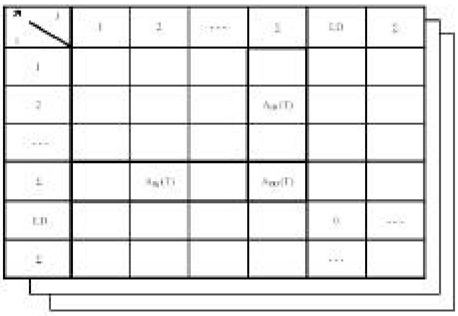
Operators: ADSL, SDSL, VDSL, LMDS, Leased lines, Fast Ethernet, Gigabit Ethernet, IP-VPN, Lamda wavelength, Dynamic bandwidth allocation. (mobile operators, ISPs, other operators)

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



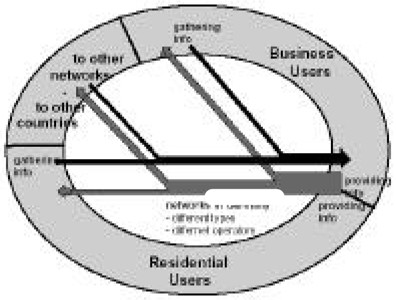
Traffic matrix forecasting

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

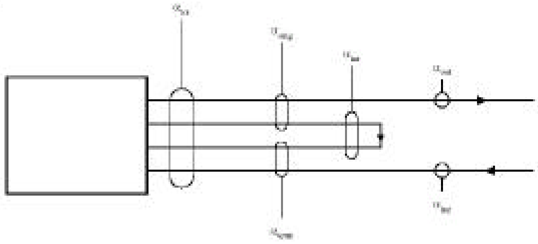
If complete data for a present (first) traffic matrix are not available be measurements they have to be created by other means

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



Traffic per subscriber / calling rate



Example:

$a_{orig} = 0.05$ Erlang for Voice in PSTN

$a_{orig} = 5$ 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:

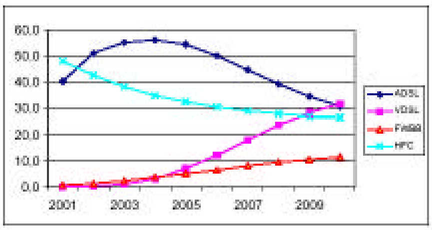
$$A(t) = A(0)\,\frac{N(t)}{N(0)}$$

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

Traffic matrix forecasting

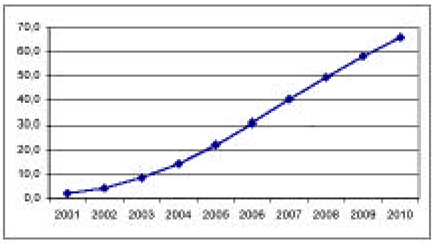
Traffic from the residential market

The residential market generates different type of traffic:
Voice traffic, Dialled Internet traffic, ADSL traffic, VDSL/LMDS traffic



***Market share** evolution of ADSL, VDSL, FWBB (Fixed wireless broadband) and HFC/cable modem for West European countries*

***Broadband penetration** forecasts for the residential market*



Traffic matrix forecasting

Traffic from the residential market

Which traffic is carried in the incumbent's transport network:

- cable TV/HFC traffic is carried usually outside
- market share of each of the other technologies will be carried

Traffic volume $\mathbf{V_R(t)}$ for the residential busy hour traffic :

$$V_R(t) = N_t \Sigma_{i=1,2,3} b_{it} u_{it} A_{it} C_{it} M_{it} p_{it}$$

i = ***1*** *(voice),* ***2*** *(Dialled Internet),* ***3*** *(ADSL),* ***4*** *(VDSL),* ***5*** *(FWBB)*

$\mathbf{N_t}$ *is number of households in year* ***t***

$\mathbf{b_{it}}$ *is busy hour concentration factor for technology* ***i*** *in year* ***t***

$\mathbf{u_{it}}$ *is packet switching concentration factor for technology* ***i*** *in year* ***t***

$\mathbf{A_{it}}$ *is the access capacity utilisation for technology* ***i*** *in year* ***t***

$\mathbf{C_{it}}$ *is mean downstream access capacity for technology* ***i*** *in year* ***t***

$\mathbf{M_{it}}$ *is incumbent's access market share for technology* ***i*** *in year* ***t***

$\mathbf{p_{it}}$ *is the access penetration forecasts (%) for technology* ***i*** *in year* ***t***

Traffic matrix forecasting

Traffic from the business market

The business market generates following type of traffic/capacity: *Voice traffic, Dialled Internet traffic, PSDN,ATM, Frame Relay, DSL traffic, IP Virtual Private Networks (IP VPN) traffic, Leased lines, Fast and Gigabit Ethernet*

Traffic volume $\mathbf{V_b(t)}$ for the business market busy hour traffic :

$$V_B(t) = N_t \Sigma_i b_{it} u_{it} A_{it} C_{it} M_{it} p_{it}$$

- *Significant substitution effects between DSL, IP VPN, Leased lines, fast and Gigabit Ethernet, which have to be taken into account*
- *Leased lines are used to establish fixed connections between sites often based on head office and branch offices or between different enterprises*
- *Leased lines constitute significant part of the transport network capacity*
- *Some part of leased lines capacity will be transferred to IP VPN or DSL because of cheaper tariffs and in spite of reduced service quality*

Traffic matrix forecasting

Traffic generated by other operators

Different operators like mobile operators, ISPs, other fixed network operators lease necessary capacity in the transport network.
The capacity demand depends on type of services offered and the market share to the operators.

Traffic volume $\mathbf{V_m(t)}$ for mobile operators is:

$$V_M(t) = N_t \ \Sigma_i \ b_{it} \ u_{it} \ A_{it} \ C_{it} \ M_{it} \ p_{it}$$

i = ***1*** *(2G),* ***2*** *(2.5G),* ***3*** *(3G),* ***4*** *(3.5G)*
$\mathbf{N_t}$ *is number of persons in year* ***t***

If $\mathbf{V_O(t)}$ is busy hour traffic forecasts for the other operators, total traffic $\mathbf{V(t)}$ is :

$$V(t) = V_R(t) + V_B(t) + V_M(t) + V_O(t)$$

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	1
B	65.04	8.67	6.07	86.72	9.03	11.42	6.86	7.23	8.67	70.10	78.77	[illegible]
C	45.53	6.07	4.25	60.70	6.32	7.99	4.81	5.06	6.07	49.07	55.14	[illegible]
D	650.37	86.72	60.70	867.16	90.33	114.18	68.65	72.26	86.72	700.95	787.67	2
E	67.75	9.03	6.32	90.33	9.41	11.89	7.15	7.53	9.03	73.02	82.05	[illegible]
F	85.63	11.42	7.99	114.18	11.89	15.03	9.04	9.51	11.42	92.29	103.71	[illegible]
G	51.49	6.86	4.81	68.65	7.15	9.04	5.43	5.72	6.86	55.49	62.36	[illegible]
H	54.20	7.23	5.06	72.26	7.53	9.51	5.72	6.02	7.23	58.41	65.64	[illegible]
I	65.04	8.67	6.07	86.72	9.03	11.42	6.86	7.23	8.67	70.10	78.77	[illegible]
J	525.71	70.10	49.07	700.95	73.02	92.29	55.49	58.41	70.10	566.60	636.70	2
K	590.75	78.77	55.14	787.67	82.05	103.71	62.36	65.64	78.77	636.70	715.46	2
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	[illegible]
N	785.85	104.78	73.35	1047.81	109.15	137.96	82.95	87.32	104.78	846.98	951.76	3
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	[illegible]
Q	61.24	8.17	5.72	81.66	8.51	10.75	6.46	6.80	8.17	66.01	74.17	[illegible]
R	405.45	54.20	37.94	541.97	56.46	71.36	42.91	45.16	54.20	438.08	492.29	1
S	54.20	7.23	5.06	72.26	7.53	9.51	5.72	6.02	7.23	58.41	65.64	[illegible]