OPTIMAL DIMENSIONING OF BROADBAND INTEGRATED SERVICES DIGITAL NETWORK

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Summary Tasks of this paper are research of input flow statistic parameters influence and parameters demands relating to VP (Virtual Path) or VC (Virtual Channel) dimensioning. However it is necessary to consider different time of flow arrival and different time of holding time during connection level. Process of input flow arrival is considered as Poisson process. Holding time is considered as exponential function. Permanent allocation of VP is made by separate VP, where each of VPs enable transmitting offered load with explicit bandwidth and explicit loss. The mathematic model was created to verify the above-mentioned dependences for different types of telecommunications signals and different input flows. "Comnet III" software was selected for experimental verification of process optimization. The simulation model was based on this software, which simulate ATM network traffic in behalf of different input flow.

1. INTRODUCTION

Nowadays telecommunications need a wide range of services. Basic classifications of these services are mentioned hereunder:

- Narrowband services, as public phone, facsimile, data transmission, audio signal transmission etc. Required transmission rate is up to 100 Kbps.
- Broadband services, as TV conferences, searching of video data, where required transmission rate is up to 100 Mbps for quality transmission.
- Multimedia services, as movable picture with high-quality sound. Required transmission rate exceed 100 Mbps.

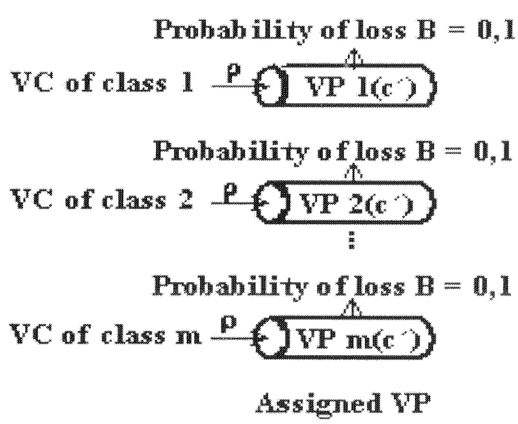
Implementation of the above mentioned services from an economical point of view need investment to networks erection. These networks enable transmission of different signals and provided different services. Therefore, the future activities will be focused to better utilization of network resources especially optimization of network traffic.

2. INFLUENCE OF INPUT FLOW STATISTIC PARAMETERS ON VP OR VC DIMENSIONING

Information is transfer by cells in ATM networks. The amount of network resources required by the user thus constantly changes in accordance with a number of cells generated per unit time. When resources are shared among users, the amounts required by individual users do not take their peak values simultaneously, so the network can reduce the total amount of network resources required for a fixed offered load-or it can accommodate more loads with the same, amount of resources. This phenomenon, called statistical multiplexing gain, is one of the main features of ATM networks.

2.1 The effect of resource sharing

The statistical multiplexing gain is caused by aggregation of cell streams (cell arrival process) in the resources shared by this aggregated stream. In this sense, the gain is a cell–level property. The gain resulting from resource sharing can occur also at the connection level and has been studied in analyses of circuit- switched network supporting heterogeneous traffic.



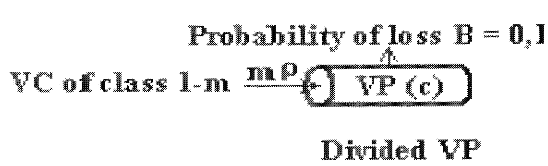


Figure 2.1 Resource sharing effect

However it is necessary to consider different times of flow arrival and different times of holding time during connection level. Process of input flow arrival is considered as Poisson process. Holding time is considered as exponential function. The expression "statistic multiplexing" on connection level is possible presented as follows on figure 2.1.

Permanent allocation of VP is made by separate VP, where each of VP enables the offered load transmission ρ with explicit bandwidth c' and explicit loss B. the function of above mentioned dependence is given by Erlang formula. The resource-sharing effect, defined by the ratio of the necessary bandwidth without resource sharing, a valid formula is $E = \frac{mc'}{c}$. The Erlang formula indicated dependence of the offered load ρ, and bandwidth c with constant loss B. This dependence is parametrical and following dependencies are considered for divided virtual path optimization:

- dependence of offered load and bandwidth with constant loss, $c = f(\rho)_{B=konst.}$,
- dependence of different bandwidth and load offer with constant loss, $c = f(\rho_1, \rho_2)_{B=konst.}$,
- dependence of offered load and loss with constant bandwidth, $B = f(\rho)_{c=konst.}$,
- dependence of different bandwidth and loss with constant load offer, $B = f(c)_{\rho=konst.}$.

These dependences are theoretically elaborated in [1].

3. MATHEMATIC MODEL OF SIGNAL SOURCES

If we suppose a digital signal transmission, it is given an exactly defined discrete point for

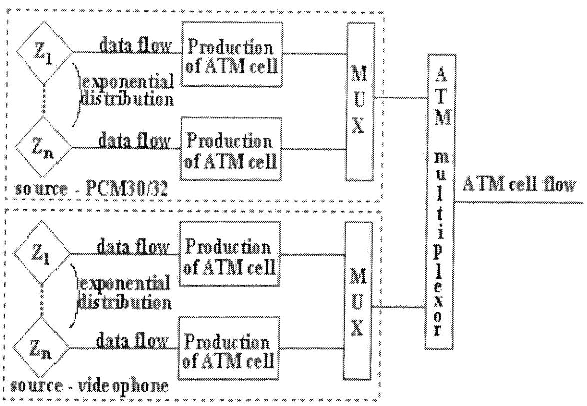


Figure 3.1 Block diagram of simulating model

transmission of the coded signal sample. The mass theory servicing calculates random value case with infinite arbitrary values. For mathematical description we can generally use the random value distribution function. If input flow for instance voice signal is random, it is possible to consider the sample arrival as a Poisson process with exponential distribution, where frequency function is valid as

$$f(x) = \lambda \cdot e^{-\lambda x}, \text{ for } x \geq 0; \quad \textit{and} \quad f(x) = 0, \text{ for } x < 0 , \qquad (3.1)$$

where parameter λ means the parameter of exponential. In case of continuously distributed random values, the average value is done by the formula $\mathbf{E}[X] = \int_{-\infty}^{\infty} x \cdot f(x) dx$. So far we substitute $f(x)$ by function (3.1) we obtain

$$\mathbf{E}[X] = \frac{1}{\lambda} . \qquad (3.2)$$

Similarly it is possible to write dispersion for various functions as $\mathbf{D}[X] = \int_{-\infty}^{\infty} x^2 \cdot f(x) dx$. After function integration (3.1) we obtain

$$\mathbf{D}[X] = \frac{1}{\lambda^2} . \qquad (3.3)$$

The mathematic model principally issue from RM (Reference Model) B-ISDN [2]. Based on RM particular contribution flows enter to network through higher layers. At adaptation layer are this flows and are adapted to ATM layer requirements at adaptation layer. The ATM cell is consequently handed over by physical layer from ATM layer to transmission medium.

To create a mathematical model we chose option [1], proceeding on AAL (ATM Adaptation Layer) level. The time for creating an ATM cell depends on the transmission rate of contribution flows and

deviation from mean transmission rate follows from scope of fluctuation. For the simulation demand we can use normal distribution and mean value corresponding with the basic transmission rate.

Mutual relation between particular sources of uniform signals is done by an exponential distribution with a parameter λ, whose value corresponds with signal period. the simulation model is created in accordance with figure 3.1 for this variant.

3.1 Mathematic model of voice flow

In ATM networks, there are two alternatives for the transmission of voice traffic. One method is to transmit the signal based on CBR (Constant Bit Rate); i.e. voice coding at a fixed rate, such as 64 Kbps PCM (Pulse Code Modulation) or 32 Kbps ADPCM (Adaptive differential PCM), and using the AAL type 1 protocol. The other method is to use a speech activity detector (SAD) and a digital speech interpolation (DSI) technique. In this case, voice traffic is VBR (Variable Bit Rate) traffic, and we therefore use the AAL type 2 protocol.

3.1.1 Constant bit rate voice transmission

When voice traffic is CBR traffic, the arrival of cells is periodic if CDV (Cell Delay Variation) can be neglected and we can use the models of CBR traffic. The period of generated signal T is made by the generated time of an ATM cell b and time a describing the time needed for transmission for the ATM cell. Whereas the signal is periodic, it is possible that ATM sources are considered with uniform distribution at (a, b) intervals. Table 3.1 shows calculated average value of both PCM and ADPCM signal and their dispersion.

Table 3.1. Parameters of voice signal CBR transmitted

Signal type	Signal parameters		E(X)	D(X)
	A	b		
PCM	0,34 μs	6 ms	$3.\ 10^{-3}$	$2{,}999.\ 10^{-6}$
ADPCM	0,34 μs	12 ms	$6.\ 10^{-3}$	$1{,}199.\ 10^{-5}$

In the case of normal distribution the voice signal is considered as bit flow. Multiplexing of ATM cells is than completely independent and the beginnings of generation are created by exponential distribution. To investigate the average value of exponential distribution λ the following method was used: Point of cell create by different multiplex sources is done by exponential distribution time of its creation (time interval b) and at the first approximation it stated alternatively for 50%, 65% and 90%. Than the average value of exponential distribution λ_{50}, λ_{65} a λ_{90} is counted for probability value. Arithmetic average $\overline{\lambda}$ issued from mentioned value and is used for simulated model calculation.

Distribution parameter	PCM signal, b = 6 ms	ADPCM signal, b = 12 ms
$\overline{\lambda}$	68	33,82

For distribution parameter $\overline{\lambda}$ it is possible to state the average value and signal dispersion:

$E_{PCM} = 14{,}7$ s
$E_{ADPCM} = 29{,}5$ s
$D_{PCM} = 220$ s^2
$D_{ADPCM} = 874$ s^2.

3.1.2 Variable bit rate voice transmission

This transmission type is typical, that voice signal is periodically sampled and the samples are not transmitted. The lengths of talk spurts and silence periods in a voice source are exponentially distributed. For signals PCM or ADPCM is b = 18 ms or 30 ms, as is obtained from statistics of sample reduction.

Distribution parameter	PCM signal, b = 18 ms	ADPCM signal, b = 30 ms
$\overline{\lambda}$	22,7	13,6

For distribution parameter $\overline{\lambda}$ it is possible to state the average value and signal dispersion:

$E_{PCM} = 44$ s
$E_{ADPCM} = 73{,}5$ s
$D_{PCM} = 1940$ s^2 D_{ADPCM} = 5406 s^2.

3.1.3 Voice transmission by format PCM 30/32

The flow 2 048 Kbps with PCM 30/32 format is considered for signal source. The basic time for ATM cell creation follows from cell information field generation (256 bits per 125 μs).

Distribution parameter	PCM 30/32 signal, T = 207 [μs]
$\overline{\lambda}$	1951

Utilization of 3.2 and 3.3 the mean values and signals dispersion is determined for $\overline{\lambda}$ distribution parameter, whereas

$E_{PCM} = 512$ s
$D_{PCM} = 262715$ s^2.

3.2 Mathematic model of video

This chapter consider only video signal transmission, without sound, in order to create a mathematic model. A sound track is considered as an independent signal, realized by a separate source and is either included in the voice signal (in case of commentary) or data signal (in case of musical interpretation). The mathematic model for video signal transmission is compiled for:

- transmission of constant bit rate (CBR),
- transmission of constant controlled rate,
- transmission on-off.

3.2.1 Transmission of video signal by CBR

Regarding the of constant bit rate, the creation of a mathematical model for video signal transmission is identical as voice signal transmission. With respect to signal character we consider fluent bit flow with transmission rate variation based on normal distribution compression. For time b (time of ATM cell creation) the calculation we commonly use is formula

$$v_p = \frac{N}{b}, \tag{3.4}$$

where transmission rate is marked v_p, N presents number of bits transmitted per time b.
Because time b is calculated for mean transmission rate, the time b will be changed in accordance with normal distribution with σ parameter. The same way we can calculate time for ATM cell creation to remaining considered signals and required dispersion values in time scale. Particular values are stated in the table 3.2.

Table 3.2. Video signal parameters transmitted by CBR

Signal type	Average Bit Rate [Mbps]	b [μs]	σ [μs]
Videoconference	4,6	83,5	56
CATV	16,8	22,9	14,3
Video phone	4,3	89,3	69,2
Studio TV	26,5	14,5	7
TV program	13,3	28,9	13,9

3.2.2 Transmission of constant controlled rate

The uniform model represents a system where coded cells are stored in a codec buffer and are sent to the subscriber cells with a controlled speed. This fact we can interpret as a constant period signal on exponential distribution with fixed intensity within a PCM frame. This alternative has no practical reason for VP and VC dimensioning, because it presents the fluent flow of approaching signals as a sample, which subsequently create ATM cells. This alternative crosses over to CBR transmission (chapter 3.2.1). If source ATM cells are realized in mathematic model directly, the alternative crosses over to on-off transmission model.

3.2.3 Model on-off

Multiplexing of ATM cells of similar sources by the on-off model and subsequent VBR transmission is identical as voice signal transmission and represents a system of continually stored cells to memory and from this memory are transmitted by the full rate of the cell. Because we considered the same types of video signals in chapter 3.2.1, the time b will assume values mentioned in table 3.2. The determination of exponential parameter distribution λ is identical to the way shown in chapter 3.1.2, whereas for the necessity of the simulation we arise to the arithmetic average $\bar{\lambda}$, mean value and dispersion all stated in table 3.3 for all signals.

Table 3.3. Parameters of video signal distribution

Signal type	b [μs]	Distribution parameter λ [μs^{-1}]		E(X) [s]	D(X) [s^2]
Videoconference	83,5	$\bar{\lambda}$	4906	203	41547
CATV	22,9	$\bar{\lambda}$	17926	56	3111
Video phone	89,3	$\bar{\lambda}$	4587	220	47527
Studio TV	14,5	$\bar{\lambda}$	28259	35	1252
TV program	28,9	$\bar{\lambda}$	14175	71	4977

3. 3 Mathematic model of date traffic

To create a basic mathematic model for date traffic it is sufficient that, the subscriber can generate long and short packet. Long packed correspond with file transport mode and short packed can correspond with instructions packet. These modes are normally substituted by cluster.
As a source of a long cluster we considered files (for instance .avi, .mp3, .vaw, etc.) and we selected a mode represents down loading of a particular file type. Because the length of a file affects the message length, the connection rate is the critical factor for creating a mathematic model. This is the reason why we consider permanent connection with transmission rates of 100 Mbps and 10 Mbps. If an ATM cell will be create from this flow, it can be possible to calculate the time necessary for its creation. If the transmission rate is 100 Mbps the time b = 3,84 μs, and for transmission rate 10Mbps b = 38,4 μs. Necessary time to ATM cell transmission follows from maximal transmission rate of the network and is valid a = 0,34 μs.
Short cluster is a possible substitute in the mathematic model by 2-Kb files, where the ATM creation rate corresponds with the connection transmission rate and is identical as for long cluster.

3.4 Mathematic model of source superposition

All specified telecommunication signal sources keep random character and behavior as described by Poisson distribution. In the case of continuously distributed random values we are thinking about frequency functions of random values $f(x)$ a $g(x)$. If this function will be different parameters of distribution λ_1 a λ_2 we can use for the resulting function $h(z)$ write

$$h(z)=\int_0^z \lambda_1 \cdot \lambda_2 \cdot e^{-x\lambda_1 - z\lambda_2 + x\lambda_2} dx = = \frac{\lambda_1 \cdot \lambda_2}{\lambda_1 - \lambda_2}\left[e^{-z\lambda_2} - e^{-z\lambda_1}\right]. \tag{3.5}$$

Signal superposition is calculated by formula 3.5 in simulating model.

4. COMPILATION OF SIMULATING MODEL

For experimental verification of the optimization we have applied a simulation method using the Comnet III program. The simulation model is based on a two node ATM network. One is the source node and the second is the destination node. The mutual connection is considered by line with transmission rate STM 1, i.e. 155,52 Mbps. Several sources characterized by bit flow are connected to the source ATM node through a virtual network - see chapter 3. For simulating the model signals mentioned in table 4.1. we used the performed experiments in based on [1]. Based on the number of signal comparisons of shared VP (calculated from ratio of transmission rate) and not shared VP (calculated from mathematic model) we can state, that the number of signals correspond to each other. The exception is only for the compressed voice signal transmitted by VBR, where the error is up to 10% - see table 4.1. We also use in table 4.1 the stated number of VC required for given signal transmission as a ratio of average transmission rate to selected transmission rate VC 64 Kbps. Stated values are valid for shared VP.

The following simulation established the maximum number of VC for two types of signals. Based on [4], we chose the voice and video signal. The number of signals obtained by the simulations were used for calculating the required number of VC and consequently for the calculations for the shared resources effect. All simulations provided for full network utilizations (over 99%), where the effect of shearing shall be shown. In case that the network shall not be fully utilized, it is no necessary to consider not shared VP at all, because the transmission capacity is constantly available.

Table 4.1 Comparison of signal number of shared and not shared VP

Signal type	**Shared VP** Signal number	**Not shared VP** Signal number	**Shared VP** VC number
PCM 30/32 signal	68	69	32
VBR PCM signal	5832	6500	1
VBR ADPCM signal	9997	11000	1
Videoconference signal	10	10	72
CATV signal	3	3	263
Video phone signal	7	7	68
Studio TV signal	2	3	414
TV program signal	5	5	208

5. SIMULATION RESULTS EVALUATION

The main task of simulations was not shared VP verification and sharing effect calculation. We can state, that mathematically calculated shared effects comply with results of the simulation. Calculated values are approximately 20% higher than values obtained during the simulation. This is done by mathematic model voice signal of transmitted VBR and selected basic transmitted channel rate of 64Kbps. Results indicated, that if we select lower transmitting rate for instance 32 Kbps, the calculated number of particular signals VC shall be precisely divided and so the VP sheering effect shall be lower. Nevertheless the number of transmitted signals between ATM nodes remains unchanged.

Based on performed simulations we can state, that not shared VP has a higher utilization of transmitted capacity and we can expect more than 10% higher transmitted capacity.

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