Common Virtual Path and Its Expedience for VBR Video Traffic

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Abstract. *The paper deals with utilization of common Virtual Path (VP) for variable bit rate (VBR) video service. Video service is one of the main services for broadband networks. Research is oriented to statistical properties of common and separate VPs. Separate VP means that for each VBR traffic source one VP will be allocated. Common VP means that for multiple VBR sources one common VP is allocated. VBR video traffic source is modeled by discrete Markov chain.*

Keywords

NGN, ATM, Quality of Service, common Virtual Path, VBR video traffic, Markov model.

1. Introduction

Video communication is one of main services for broadband networks. Variable bit rate (VBR) is typical for video traffic [3], [4], [5]. Output rates from coders can vary significantly, so allocation of a required channel bandwidth is problematic. Video traffic is relatively stable, but there are some time periods with significantly higher channel bandwidth requirements. This variability offers a possibility of statistical multiplexing gain improvement and it is an advantage of VBR coding. The disadvantage is that there is a probability of cell loss. These losses occur when multiple VBR sources will overload the multiplexer. A decrease of cell loss for sources with burst traffic is possible by use of buffers, but very high capacity can be required. Also a delay, which has impact on quality of video transmission, can occur when buffers are used.

The efficient channel bandwidth utilization offers a question if we can save some channel bandwidth by use of common Virtual Path over use of separate Virtual Paths for VBR traffic sources.

2. Model of VBR Video Traffic Source

Modeling of video traffic source is a necessary part of a traffic research. The traffic source model describes statistical properties of a traffic flow and it allows us to describe the traffic source by use of parametric values. It is necessary to state parameters of a mathematical model that meets traffic character. The final mathematical model will be used in simulation analysis in simulation environment MATLAB.

Parameters of video traffic model fit the real video sources Ice age DVD [1]. Based on the method proposed in [2], the following traffic model parameters are calculated:

- the transition matrix P = [$\hat{p}_{ij}$]
- the vector of the state values of the video traffic model s = [$s_1, \dots, s_M$]

where M represents the number of states in Markov chain, $s_1,\dots,s_M$ are the states of the video traffic model and represent generated cell rates.

The original sequence $\{x_t\}$ must be transformed to discrete states before computation of the transition matrix and the vector of states, according to the following formula:

$$\begin{aligned} y_t &= 1 && \textit{if } x_t = \min_t x_t \\ y_t &= \left[\frac{x_t - \min_t x_t}{\max_t x_t - \min_t x_t} \cdot M \right] && \textit{otherwise} \end{aligned} \qquad (1)$$

where $\min_t$ and $\max_t$ represent the minimal or maximal value in the original sequence $\{x_t\}$. We also need parameter M during transformation of the original sequence to the discrete states (the result is a set of digits 1...M).

For the created sequence we can calculate transition matrix $\boldsymbol{P}$ according to the following equation:

$$\hat{p}_{ij} = \frac{\sum_{t=1}^{N-1} \delta_p\left(y_t, i, y_{t+1}, j\right)}{\sum_{k=1}^{M} \sum_{t=1}^{N-1} \delta_p\left(y_t, i, y_{t+1}, k\right)} \qquad (2)$$

where $\hat{p}_{ij}$ are the components of the transition matrix **P**, δ_p (y_t, i, y_{t+1}, j) represents an indication function for $y_t = i$ and $y_{t+i} = j$ through $t = 1, \ldots, N\text{-}1$ and $i, j \in \{1, \ldots, M\}$.

The vector of states values $s = \left[s_1, \ldots, s_M\right]$ is calculated as follows:

$$s_i = \frac{\sum_{t=1}^{N} \delta_s\left(y_t, i\right) \cdot x_t}{\sum_{t=1}^{N} \delta_s\left(y_t, i\right)} \qquad (3)$$

where δ_s (y_t, i) represents the indication function for $y_t = 1$ through $t = 1, \ldots, N$ and $i \in \{1, \ldots, M\}$.

For M=7 we have the following mathematical model of VBR video traffic source:

$$P = \begin{bmatrix} 0.7888 & 0.1472 & 0.0439 & 0.0171 & 0.0028 & 0.0003 & 0 \\ 0.4178 & 0.4595 & 0.0976 & 0.0214 & 0.0031 & 0.0005 & 0 \\ 0.7256 & 0.2451 & 0.0185 & 0.0091 & 0.0017 & 0 & 0 \\ 0.7877 & 0.1872 & 0.0219 & 0.0011 & 0.0021 & 0 & 0 \\ 0.7933 & 0.1733 & 0.0233 & 0.0100 & 0 & 0 & 0 \\ 0.7500 & 0.2500 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1.0000 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \qquad (4)$$

The vector of states has the following values:

s_1= 26.873 kbit/s, s_2= 75.711 kbit/s, s_3= 135.687 kbit/s, s_4= 189.924 kbit/s, s_5= 241.409 kbit/s, s_6= 302.333 kbit/s, s_7= 389.520 kbit/s.

The course of the created traffic model for M=7 is shown in Fig. 1. From this figure we can see that we need significantly more states of the mathematical model of video traffic in order to catch all properties of real VBR traffic source, but for our research on expedience of common VP for VBR source this model is sufficient.

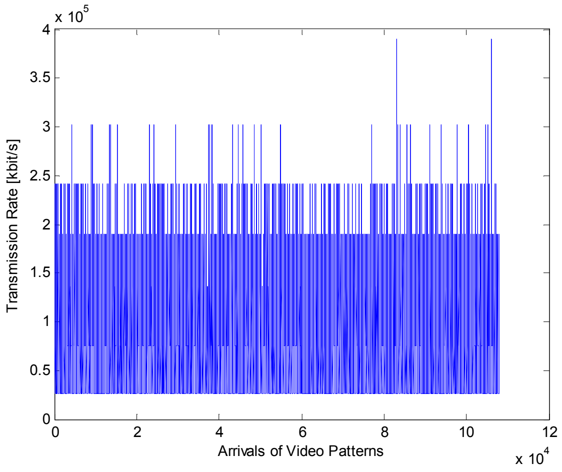

Fig. 1. The proposed model for VBR video source.

3. Presentation of the Mathematical Model of Video Traffic in a Simulation Programme

The simulation model consisting of VBR video traffic sources and ATM [10] network node without buffers was created and used in simulation analysis.

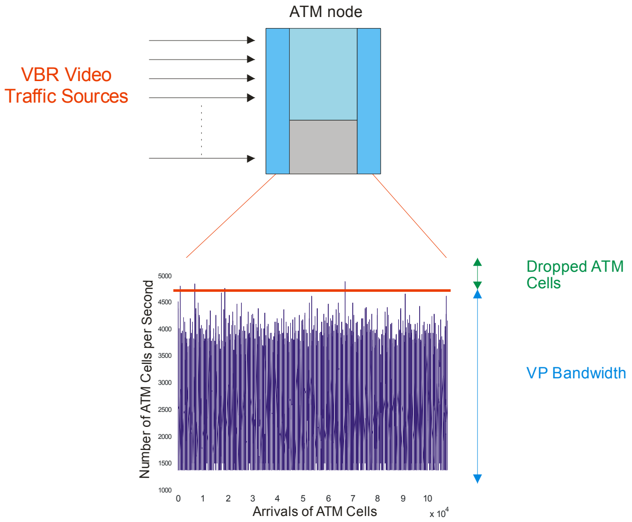

Fig. 2. The proposed model of ATM node.

Various VBR sources from the required channel bandwidth, losses and link utilization point of view are used as inputs to the ATM node. The output link has the defined parameters as channel bandwidth (i.e. the number of bits transferred per second - bit/s), cell loss requirement and link utilization. All these parameters were set according to the requirements based on the simulation needs. Video traffic generates information payload of size 48 B, then 5 B header is added. ATM node sends ATM cells from inputs to the output link. ATM cells that could not be accommodated to the output VP due to exceeded capacity will be lost. Parameters as VP utilization and cell loss have been evaluated in the simulations according to the following equations:

$$VPutilization = \frac{\sum_{i=1}^{pz} \sum_{j=1}^{108000} P_{i,j} - \sum_{i=1}^{pz} \sum_{j=1}^{108000} \left(P_{i,j} - \max_{VP}\right)}{\max_{VP} * 108000} * 100 \quad [\%], \qquad (5)$$

$$cell\_loss = \frac{\sum_{i=1}^{pz} \sum_{j=1}^{108000} \left(P_{i,j} - \max_{VP}\right)}{\sum_{i=1}^{pz} \sum_{j=1}^{108000} P_{ij}} * 100 \quad [\%] \qquad (6)$$

where pz is the number of VBR sources, $P_{i,j}$ is the number of generated cells from source i in time j, $\max_{VP}$ represents the maximal number of ATM cells that can be transmitted to the output per one second. $\sum_{i=1}^{pz} \sum_{j=1}^{108000} P_{i,j}$ represents the total number of ATM cells sent by all VBR sources (each VBR video traffic source generates 108000 ATM cells based on the parameters of a real video source [1]) and

$\sum_{i=1}^{pz}\sum_{j=1}^{108000}\left(P_{i,j}-\max_{VP}\right)$ represents the total number of the lost ATM cells. If $P_{i,j} < \max_{VP}$ then $(P_{i,j} - \max_{VP}) = 0$.

4. Simulations

The aim of this part is to observe an advantage of common VP over separate VPs for VBR video traffic sources. The observation is based on the parameters for loss – B [%], link utilization - ρ [%] and channel bandwidth – c [bit/s].

For evaluation whether the separate or the common VP is better the parameter ***U*** – efficiency was defined. Parameter U is defined as the ratio of the total required channel bandwidth for m separate VPs to the required channel bandwidth for common VP.

4.1 *M* Separate VP with an Equal Channel Bandwidth and Parameter *U*

We have m separate VPs with an equal channel bandwidth c_{sa} and cell loss requirement B. The task is to calculate the required channel bandwidth by one common VP - c_{sp} required for transmission of m VBR video sources and calculation of parameter U. Parameter U will say what is better - m separate VPs for each VBR source separately or one common VP.

The required channel bandwidth by common VP c_{sp} is generated by the simulation based on the given number of VBR video sources m=1,...10, c_{sa}=512, 1024 kbit/s and various losses B. The parameter U was calculated according to the equation.

$$U = \frac{(m * c_{sa})}{c_{sp}}. \tag{7}$$

m	***c*sp** [kbit/s]	***U***
1	**512**	**1**
2	**805.6**	**1.27**
3	**1086.28**	**1.41**
4	**1349.59**	**1.51**
5	**1604.41**	**1.59**
6	**1858.39**	**1.65**
7	**2103.46**	**1.70**
8	**2345.56**	**1.74**
9	**2585.12**	**1.78**
10	**2822.14**	**1.81**

Tab. 1. The calculated parameters c_{sp}, U for the given B = 0.05 %, c_{sa} = 512 kbit/s and ρ = 40.76 %.

m	c_{sp} **[kbit/s]**	***U***
1	**512**	**1**
2	**873.01**	**1.17**
3	**1216.45**	**1.26**
4	**1552.26**	**1.31**
5	**1882.98**	**1.36**
6	**2210.31**	**1.39**
7	**2535.09**	**1.41**
8	**2859.88**	**1.43**
9	**3181.27**	**1.44**
10	**3501.39**	**1.46**

Tab. 2. The calculated parameters c_{sp}, U for the given B = 1.09 %, c_{sa} = 512 kbit/s and ρ = 60.48 %.

m	c_{sp} **[kbit/s]**	***U***
1	**1.024**	**1**
2	**1.707**	**1.19**
3	**2.349**	**1.3**
4	**2.967**	**1.38**
5	**3.570**	**1.43**
6	**4.162**	**1.47**
7	**4.753**	**1.5**
8	**5.338**	**1.53**
9	**5.914**	**1.55**
10	**6.493**	**1.57**

Tab. 3. The calculated parameters c_{sp}, U for the given B = 0.015 % , c_{sa} = 1,024 Mbit/s and ρ = 50.9 %.

m	c_{sp} **[kbit/s]**	***U***
1	**1.024**	**1**
2	**1.824**	**1.12**
3	**2.599**	**1.18**
4	**3.364**	**1.21**
5	**4.120**	**1.24**
6	**4.871**	**1.26**
7	**5.619**	**1.27**
8	**6.366**	**1.28**
9	**7.109**	**1.29**
10	**7.852**	**1.30**

Tab. 4. The calculated parameters c_{sp}, U for the given B = 0.69 %, c_{sa} = 1,024 Mbit/s and ρ = 70.82 %

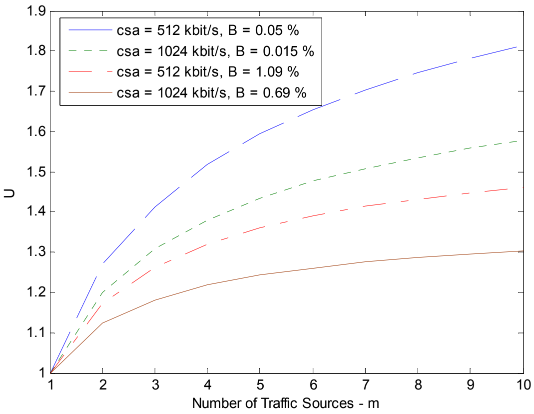

Fig. 3. Relation between U parameter and the number of VBR video sources m.

From Tabs. 1 - 4 and Fig. 3 it is obvious that parameter c_{sp} for common VP has lower values than the total required channel bandwidth for m separate VPs for the given number of sources. With the rising number of VBR video sources the significance of common VP use is rising. Parameter U gets lower values with the rising channel bandwidth c_{sa}. On the contrary, parameter U gets higher values with stricter cell loss requirements.

For illustration, if $U = 1.7$ (in case for B=0.05 %, c_{sa} = 512 kbit/s and m=7) then for transmission of seven VBR sources through seven separate VPs the total required channel bandwidth is by 70 % higher than the channel bandwidth required by common VP for these 7 video sources.

4.2 Two Separate VPs with an Equal Channel Bandwidth and Different Requirements on Cell Loss and Parameter U

We have two separate VPs with an equal channel bandwidth c_{sa}, but with different cell loss requirement B. The task is to calculate the required channel bandwidth c_{sp} which is calculated for the stricter parameter B. Parameter U will say in which cases the common VP will still have justification.

Reflections are made for c_{sa} = 512, 1024 and 2048 kbit/s, but with different cell loss requirements. Loss of separate VPs B_1 and B_2 are presented in Tab. 2. Parameter c_{sp} will set for stricter loss parameter B (minimum from B_1 and B_2) and consequently parameter U is calculated (also final link utilization is calculated for common VP - ρ).

From Tab. 5 and Fig. 4 we can clearly see the expedience of common VP based on the parameter U. The value of parameter U grows in $B_1 \geq B_2$. In the case of $B_1 < B_2$ the cell loss parameter was unchanged. Also it is obvious that common VP has higher justification in the case of lower required channel bandwidths of separate VPs.

	B_2 [%]	**ρ_2 [%]**	**B [%]**	**c_{sp} [kbit/s]**	**ρ [%]**	**U**
c_{sa} = 512 kbit/s B_1 = 0.057 % ρ_1 = 40.7 %	**$6*10^{-5}$**	**20.4**	**$6*10^{-5}$**	**908.2**	**34.47**	**1.12**
	0.005	**30.6**	**0.005**	**840.79**	**43.42**	**1.21**
	0.057	**40.7**	**0.057**	**803.9**	**51.86**	**1.27**
	0.285	**50.8**	**0.057**	**873.86**	**53.48**	**1.17**
	1.02	**60.5**	**0.057**	**945.52**	**55.12**	**1.08**
c_{sa} = 1024 kbit/s B_1 = 0.015 % ρ_1 = 50.93 %	**$3*10^{-5}$**	**35.65**	**$3*10^{-5}$**	**1798**	**49.32**	**1.13**
	0.003	**45.33**	**0.003**	**1752**	**56.53**	**1.16**
	0.015	**51**	**0.015**	**1709**	**61.03**	**1.19**
	0.14	**61**	**0.015**	**1837**	**62.45**	**1.11**
	1.27	**75.4**	**0.015**	**2031**	**64.16**	**1.00**
c_{sa} = 2048 kbit/s B_1 = 0.006 % ρ_1 = 61.62 %	**$15*10^{-5}$**	**49.67**	**$15*10^{-5}$**	**3619**	**61.95**	**1.13**
	0.002	**58.58**	**0.002**	**3599**	**68.08**	**1.13**
	0.006	**61.62**	**0.006**	**3558**	**70.34**	**1.15**
	0.17	**73.73**	**0.006**	**3855**	**71.71**	**1.06**
	1.016	**83.19**	**0.006**	**4092**	**72.65**	**1.00**

Tab. 5. Parameter U for two separate VPs with the equal channel bandwidth and different losses.

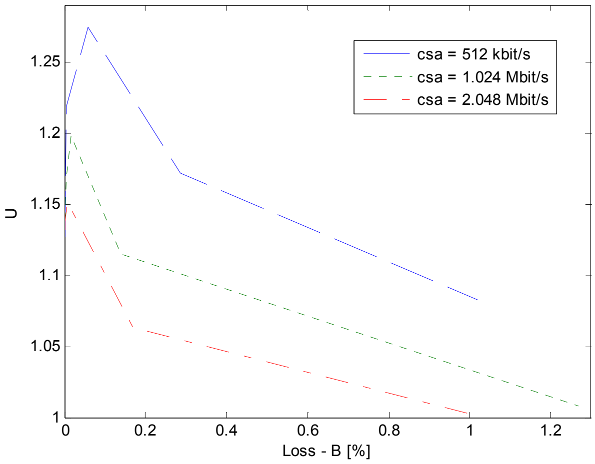

Fig. 4. Parameter U for two independent VP with the same channel bandwidth and various cell losses.

5. Discussion of Results

Based on the comparison of the results for separate and common VPs we can say that common VP has the greatest justification in the case of multiple VBR video sources:

- that have the same requirements for cell loss,
- their requirement for channel bandwidth is small,
- VBR video sources have strict requirements on cell loss.

The higher number of VBR sources, the higher value of parameter U, so we can save a significant channel bandwidth.

In the case of multiple VBR video sources with different loss requirements it is appropriate to classify these sources into multiple classes (each class will contain sources with the equal loss requirement). After then it is better to use common VP from channel bandwidth saving point of view. There will be not mix of traffic sources with different loss requirements in one common VP, so parameter U will get higher values than in the case of one common VP for all sources.

We demonstrated expedience of common VP for variable bit rate traffic use over separate VPs from significant channel bandwidth saving point of view. Utilization of common VP can contribute to total cost savings for telecommunication traffic.

6. Conclusion

There is a number of important areas within the NGN (Next Generation Networks) field that draw attention of telecommunication researchers and experts. It is mainly the improvement of QoS (Quality of Service) parameters, management systems, multimediality, routing in NGN networks, network dimensioning, optimization of system parts of NGN networks and many other areas.

This paper dealt with network dimensioning. It shows the advantage of use of common VP over separate VPs for VBR video traffic sources. Verification is based on the simulation analysis in MATLAB environment by use of mathematical model of VBR traffic source based on Markov chain.

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