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Bursty Traffic Simulation by ON - OFF Model

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Introduction

The transmission of the voice signals makes a big part of the bandwidth of modern telecommunication systems. Therefore there is searched for the ways to reduce an amount of data needed for voice transmission. It has been ascertained that during the speech the short intervals of speech and silence are repeating alternately. The silence periods present about 60-65% of all speech time [1]. When not transmitting the voice data on silence periods, the part of bandwidth of communication channel is freed. This part of bandwidth can be used for transmission of another data. Improving the existing and creating the new telecommunication systems, it is important to have an exact model of data flow made by voice. Though first research results of the voice active – passive intervals are published in 1965, the investigations of voice signals have been going on. One of the reasons is that the created models are quite different from each other and depending on the usage fields the received results are interpreted differently.

Bursty traffic models are an essential component of performance analyses of telecommunication networks. Good models should be simple, accurate and applicable in both mathematical analysis and computer simulations. There are references [4, 5] that have classified and modeled bursty traffic in a wide variety of situations. Simulations have been used to demonstrate the validity of an analytic bursty traffic models. Internet traffic is very bursty, or equivalently, the ratio of the peak to average data rate is quite high. To handle the bursty traffic the network must be sized to handle the peak load. Most networks today do not attempt to carry the absolute offered peak bursty traffic, but provide some degree of buffering to smooth these peaks out. For this work we assumed that bursty traffic is generated from one source with alternating series of “ON” and “OFF” periods. Both the ON and OFF periods were distributed by different (Poisson, Lognormal, Weibull and others) distributions.

The purpose of paper is to create the simulation model of bursty traffic using the method of automata convolution.

Description of the model of bursty traffic

We will describe the conjunction of two servicing channels and one servicing channel (Fig. 1), that will generate the bursty traffic.

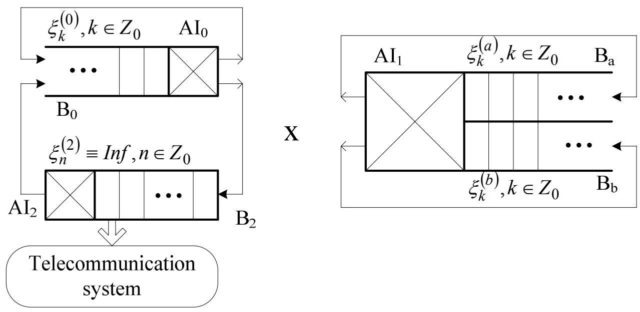


Fig. 1. The conjunction of automata for generation of bursty traffic

Channel AI_0 will generate „the full traffic“ $\xi_n^{(0)}, n \in \mathrm{N}$, AI_1 - active ($\xi_n^{(a)}, n \in \mathrm{N}$) and passive ($\xi_n^{(b)}, n \in \mathrm{N}$) windows. In AI_1 channel from buffers B_a and B_b arrived packets are served alternatively. The servicing time of packet from buffer B_a will be a random value $\xi_n^{(a)}$, together it will be the time of active window, and the servicing time of packet from buffer B_b – $\xi_n^{(b)}$ – it will be a time of passive window. The work of AI_1 channel influences a work of channel AI_0 – when an active window is generated (channel AI_1 serves a packet from buffer B_a), all in channel AI_0 served packets will get into buffer B_2; when a passive window will be generated (channel AI_1 serves a packet from buffer B_b), served packets in channel AI_0 will get into buffer B_0. An infinite time interval will be in channel AI_2, that is needed to serve a packet $\xi_n^{(2)} \equiv Inf, n \in \mathrm{N}$, i.e. the packets that got into buffer B_2 will stay here. Because we fix the times when packets got into this buffer, thus we get an imitation model of the bursty traffic.

The creation of imitation model of the bursty traffic

Here we present how the imitation model of generation of the active and passive windows – "the bursty traffic" – can be described using the convolution of Moore and Mealy automata [4].

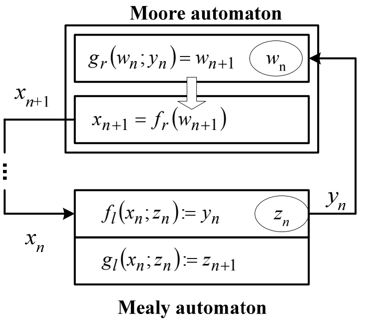


Fig. 2. The convolution of Moore and Mealy automata

The conjunction of Moore and Mealy automata (Fig. 2) is called the convolution of Moore and Mealy automata. Surjections:

$$\begin{cases} g_r: & Y\times W\to W, \quad f_r: \quad W\to X, \\ f_l: & X\times Z\to Y, \quad g_l: \quad X\times Z\to Z \end{cases} \tag{1}$$

describe the work of this convolution. Here W – the set of states of Moore automaton, X – the set of output signals of Moore automaton and input signals of Mealy automaton, Y – the set of output signals of Mealy automaton and input signals of Moore automaton, Z – the set of states of the Mealy automaton.

Besides, the convolution of automata starts operating after the initial states w_1 and z_0 are introduced. The implementation of the work of automata convolution can be presented as in Fig. 3:

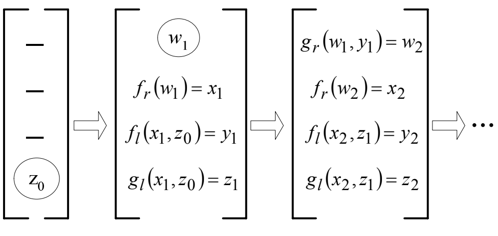


Fig. 3. The implementation of the work of automata convolution

Creating the relations' system, that describes the implementation of the convolution of Moore and Mealy automata, we use the closure of system (i.e. the generation of packets is treated as the work of servicing channel with infinite number of states).

Creating the surjections of automata conjunction (Fig.3) we use the variables: t_n ($t_n \ge 0$) – „timer"; logical variables: $v_n^{(i)}$ – ($v_n^{(i)}=0;1$, $i=0,a,b$) – if $v_n^{(i)}=1$, denotes the input of packet into buffer B_i at time t_n; $\chi_n^{(i)}$ – ($\chi_n^{(i)}=0;-1$, $i=0,a,b$) – if $\chi_n^{(i)}=-1$, denotes output of the served packet from channel AI_i (in this case $\chi_n^{(2)}\equiv 0$); $z_n^{(i)}$, $i=0,a,b$ – the number of packets in buffer B_i (in our case the number of packets is infinite $z_n^{(i)}$=*Inf*.); $S_n^{(0)}$ – the controlling variable of AI_0 defining the time of packet arrivals; $S_n^{(1)}$ – the controlling variable of AI_1 defining the changing of active and passive windows at time t_n ($S_n^{(0)}, S_n^{(1)} \ge 0$).

Then the state of Mealy automaton was described by such vector:

$$z_n = (Inf, Inf, Inf, z_n^{(2)}),\ z_n \in Z. \tag{2}$$

The state of Moore automaton:

$$w_n = (S_n^{(0)}; S_n^{(1)}; Inf),\ w_n \in W. \tag{3}$$

The signal of output from Moore – input of Mealy automata:

$$x_n = \left(t_n; \upsilon_n^{(0)}, \chi_n^{(0)}; \upsilon_n^{(a)}, \upsilon_n^{(b)}, \chi_n^{(1)}; \upsilon_n^{(2)}, 0\right),\ x_n \in X. \tag{4}$$

The signal of output from Mealy – input of Moore automata:

$$y_n = \left(t_n; \upsilon_n^{(0)}, z_{n-1}^{(0)}, \chi_n^{(0)}; \upsilon_n^{(a)}, z_{n-1}^{(a)}, \upsilon_n^{(b)}, z_{n-1}^{(b)}, \chi_n^{(1)}; \upsilon_n^{(2)}, z_{n-1}^{(2)}, \chi_n^{(2)}\right),\ y_n \in Y. \tag{5}$$

The initial states:

$$z_0^{(2)} = 0, \quad w_1 = \left(\xi_1^{(0)}, \xi_1^{(a)}, Inf\right), \quad m = j = 1. \tag{6}$$

Note that the third component of vector w_n always is equal *Inf*, because the channel AI_2 doesn't work and only the bursty traffic is garnered in his buffer.

In this way for creating the imitation model of such system, it is sufficient to make corresponding surjections g_r, f_r, f_l, g_l. Calculation relations when $n=1,2,3,...$ are:

$$f_r(w_n) = x_n = \\ = \left(t_n; \upsilon_n^{(0)}, \chi_n^{(0)}; \upsilon_n^{(a)}, \upsilon_n^{(b)}, \chi_n^{(1)}; \upsilon_n^{(2)}, 0\right). \tag{7}$$

The present time is fixed:

$$t_n = \min\left\{S_n^{(0)}, S_n^{(1)}\right\}. \tag{8}$$

The time when the packet was served are fixed:

$$\chi_n^{(0)} = -\mathbf{1}\left(S_n^{(1)} - S_n^{(0)}\right), \tag{9}$$

$$\chi_n^{(1)} = -\mathbf{1}\left(S_n^{(0)} - S_n^{(1)}\right), \tag{10}$$

$$\chi_n^{(2)} = 0, \tag{11}$$

The time when packet arrives into buffer AI_2 is fixed:

$$v_n^{(2)} = -\chi_n^{(0)} \cdot \frac{1+(-1)^{m+1}}{2}. \tag{12}$$

$$f_l(x_n, z_{n-1}) = y_n = \big(t_n; \upsilon_n^{(0)}, z_{n-1}^{(0)}, \chi_n^{(0)}; \upsilon_n^{(a)}, z_{n-1}^{(a)}, \upsilon_n^{(b)}, z_{n-1}^{(b)}, \chi_n^{(1)}; \upsilon_n^{(2)}, z_{n-1}^{(2)}, \chi_n^{(2)}\big), \quad (13)$$

$$g_l(z_{n-1}, x_n) = z_n = (Inf, Inf, Inf, z_n^{(2)}). \quad (14)$$

The number of packets of bursty traffic is calculated:

$$z_n^{(2)} = z_{n-1}^{(2)} + v_n^{(2)}, \quad (15)$$

$$g_r(w_n, y_n) = w_{n+1} = (S_{n+1}^{(0)}; S_{n+1}^{(1)}; Inf), \quad (16)$$

$$j = j - \chi_n^{(0)}, \qquad m = m - \chi_n^{(1)}. \quad (17)$$

The time of event occurrence is fixed:

$$S_{n+1}^{(0)} = -\chi_n^{(0)}\left(t_n + \xi_j^{(0)}\right) + \left(1 + \chi_n^{(0)}\right)S_n^{(0)}, \quad (18)$$

$$S_{n+1}^{(1)} = -\chi_n^{(1)}\left(t_n + \xi^{(a)}_{m\cdot\frac{1+(-1)^m}{4}} + \xi^{(b)}_{(m+1)\cdot\frac{1+(-1)^{m+1}}{4}}\right) + \left(1 + \chi_n^{(1)}\right)S_n^{(1)}. \quad (19)$$

If a packet arrived from B_a buffer is served in AI_1 channel, then "an active window" is got; if a packet arrived from B_b buffer is served in AI_1 channel, then "a passive window" is got. $v_n^{(2)} = 1$ (m – an odd number) – at time t_n a packet arrived into buffer B_2, if $v_n^{(2)} = 0$ (m – an even number) – at time t_n a packet did not arrive. Note that

$$m \cdot \frac{1+(-1)^m}{4} = \begin{cases} k, & when \;\; m = 2k, \\ 0, & when \;\; m = 2k+1, \end{cases} \quad (20)$$

$$(m+1) \cdot \frac{1+(-1)^{m+1}}{4} = \begin{cases} 0, & when \;\; m = 2k, \\ k+1, & when \;\; m = 2k+1. \end{cases} \quad (21)$$

Note that the formula (19) is original for each system, and other formulas (7-18) are typical. Besides, creating the calculation algorithm the variables, that don‘t influence on calculation algorithm, were eliminated.

In literature [5] the investigations were accomplished only with exponential data flows. But this model lets modeling of the bursty traffic using the various probabilistic distributions or their combinations, accordingly choosing the parameters of distributions and the parameters for extracting of the active and passive windows from „full" traffic (here they will be interpreted as the service of packets).

Case study

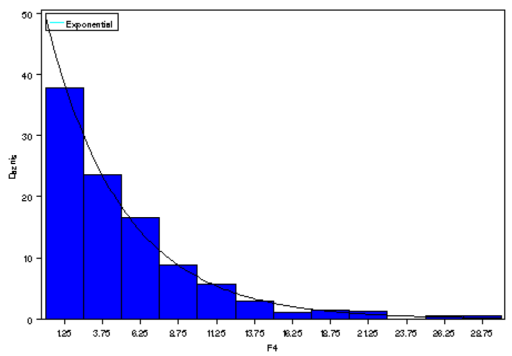
The bursty traffic was received by such model.

Hypotheses about distribution of points were verified using the criterions of compatibility of Chi-square and Kolmogorov and Smirnov that are in programming packets Statgraphics and SAS.

The results in Table 1 and in Fig. 4 show that after the verification of the hypothesis about the belonging of the distributions' points to exponential or lognormal probabilistic distribution, using the criterions of Chi-square and Kolmogorov and Smirnov, this hypothesis is accepted (the statistics d_n was got smaller than the quantum of distribution $k_{0.95}$).

Table 1. Verification of hypotheses (with $\alpha = 0.05$)

	Traffic – exponential	m=3 σ=1.732	Mean m	Standard derivation σ	Chi-square criterion			Criterion of Kolmogorov and Smirnov	
	Service -				Statistics	k-1	χ^2 quantum	Statistics	quantum
1.	Weibul		5.0477	5.05613	6.47024	10	19.675	0.03312	0.06675
2.	Paret		5.7688	5.69713	16.0195	11	21.026	0.04467	0.0525
	Traffic – Lognormal	m=12.182 σ=255.02	Mean m	Standard derivation σ	Chi-square criterion			Criterion of Kolmogorov and Smirnov	
	Service -				Statistics	k-1	χ^2 quantum	Statistics	quantum
3.	exponential		14.9216	20.525	9.0587	10	19.675	0.01879	0.04987



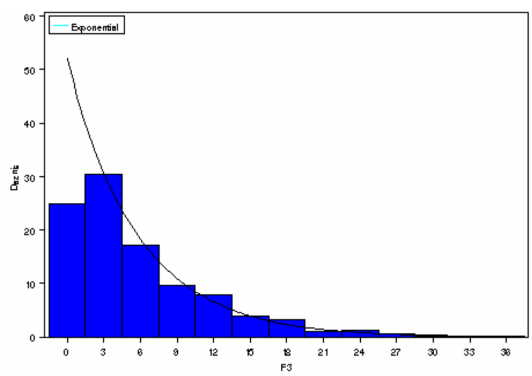
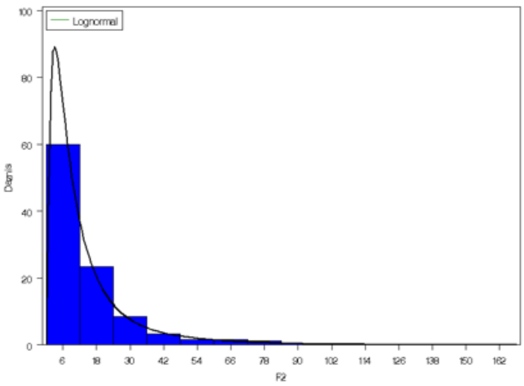


Fig. 4. Histograms of empirical data:

a) Location of points got from exponential traffic with $\Delta t_{\exp} = 3$ and service by Paret_a with $a_{par}^{(a)} = 1.2$ and $b_{par}^{(a)} = 2$, and Paret_b with $a_{par}^{(b)} = 1.3$ and $b_{par}^{(b)} = 3$

b) Location of points got from exponential traffic with $\Delta t_{\exp} = 3$ and service by Weibul_a with $\alpha_{veib}^{(a)} = 0.5$ and $s_{veib}^{(a)} = 3$, and Weibul_b with $\alpha_{veib}^{(b)} = 2$ ir $s_{veib}^{(b)} = 2$



c) Location of points got from lognormal traffic with $m = 2$ ir $\sigma = 1$, and the service by exponential with $\Delta t^{(a)} = 8$, $\Delta t^{(b)} = 2$

The experiments showed that the traffic is not exponential in the common case. For instance, choosing the corresponding parameters to eliminate "the silence windows" from "the full traffic", exponential bursty traffic can be received from exponential traffic, but in most cases the another distribution is received. So it's expedient to investigate this traffic.

Executing the statistical researches with programs SAS and Statgraphics and establishing the traffic parameters, later this traffic may be successfully applied for the telecommunication networks modeling.

Conclusions

The generation methodology of the bursty traffic has been created using the special combination of convolutions of Moore and Mealy automata.

The experiments showed that this traffic significantly differs from "the full traffic" by its properties. Choosing the corresponding parameters to eliminate "the silence windows" from "the full traffic", the exponential or Weibull bursty traffic can be received from exponential traffic, lognormal bursty traffic – from lognormal "full traffic", etc.

The bursty traffic model presented here is provocative, but should be regarded as only speculative because it relies on the results of a simple model, extended with some quite strong assumptions.

To improve this analysis, it would be desirable to consider alternative models of bursty traffic and simulate a variety of bursty traffic models.

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The proposed generation methodology of the bursty traffic has been created using the special combination of convolutions of Moore and Mealy automata. This model permits modeling of the bursty traffic using the various probabilistic distributions or their combinations. Executing the statistical researches with programs SAS and Statgraphics and establishing the traffic parameters, later this traffic may be successfully applied for the telecommunication networks modeling. Il. 4, bibl. 5 (in English; summaries in English, Russian and Lithuanian).

А. Жвиронене, З. Навицкас, Р. Риндзявичюс. Анализ пульсирующего трафика используя ON – OFF модель // Электроника и электротехника. – Каунас: Технология, 2006. – № 6(70). – С. 65–68.

Методология имитирования пульсирующего трафика была создана используя специальную комбинацию свертки автоматов Мура и Миля. Это имитирование позволяет использоватъ разные вероятностные распределения или их комбинации. При этом можно провести статистические исследования с программами SAS и Statgraphics и установитъ параметры трафика, позже этот трафик можно успешно использовать для моделирования телекоммуникационных сетей в целом. Ил. 4, библ. 5 (на английском языке; рефераты на английском, русском и литовском яз.).

A.Žvironienė, Z.Navickas, R.Rindzevičius. Pliūpsninio srauto ON - OFF modelio analizė // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr. 6(70). – P. 65 – 68.

Pasiūlyta „pertrauktojo“ srauto generavimo metodika, sukurta naudojant specialų Muro ir Milio automatų sąsūkų darinį. Šis modelis įgalina modeliuoti pertrauktąjį srautą įėjimo paraiškų srautams imant įvairius atsitiktinius skirstinius ar jų mišinius. Atlikus šio srauto statistinius tyrimus programomis SAS ir Statgraphics ir nusistačius srauto parametrus, vėliau jį galima panaudoti atliekant telekomunikacinių tinklų tyrimus. Il. 4, bibl. 5 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).