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INFLUENCE OF THE CALL FORWARDING BUSY SERVICE ON THE TRAFFIC DISTRIBUTION IN THE GROUP OF TELEPHONE CHANNELS

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Abstract: In this paper we consider the influence of a call forwarding service on the traffic process in modern telecommunication networks. We analyse in detail only the case when the called user is busy. It is proved that call forwarding not only increases utilization of servers and the percent of successful calls but it also increases the call loss. On the simple example, we showed that this call loss increase is greater in the case of local (internal) and incoming calls, but smaller in the case of outgoing calls. The reason for such behaviour is in the role of call forwarding function in the case of internal and incoming traffic. In that situation call forwarding function decreases the effect of limited number of users on the decrease of offered traffic, comparing to the case of internal and incoming traffic without call forwarding (Engset traffic model). This statement is illustrated by comparative graphics of traffic loss without call forwarding function, and with this function when considering, separately, internal, incoming, and outgoing traffic.

Keywords: Call Forwarding Busy Service, External Connection, Internal Connection, Loss Probability, Telecommunication Traffic, Traffic Simulation.

MSC: 68U35, 68U20, 90B22, 90B18.

1. INTRODUCTION

New technologies and new services appear in modern telephone techniques. That is why traffic models that describe new telephone systems are also modified.

Detailed traffic analysis based on exact traffic model is very important in modern telecommunications. Let us mention only one example: precise modelling of traffic resources has great influence on the calculation of call blocking in mobile (GSM) network. The Erlang model, from classic telecommunications, cannot be used for the calculation of call blocking when internal traffic component (intra-cell traffic component, i.e. calls between users in the same cell) is significant, because it gives underestimated results [7, 12].

The other component, which is important to be considered in telephone traffic analysis, is the limited number of traffic resources. The area, where number of traffic resources has great influence, is also mobile network. One example of such an analysis is [11].

In [10] one can find the statement, which is related to Skype telephony: "Operators are usually interested in the nature of traffic, carried by their network in order to optimize network performance." The same statement can be also implemented when new telephone services are implemented, as is, for example, call forwarding in the network. This paper considers the call forwarding busy (CFB) service and its influence on the modification of traffic models. When traffic analysis is performed for the systems with function CFB, the same traffic elements: limited users' number and internal traffic must be considered as in mobile network [7, 11, 12]. Call forwarding in modern telephone networks increases the part of successful calls, [2]. The main goal is to increase the efficiency of call realization and to decrease the number of repeated call attempts (e.g. in GSM network). In the groups of channels, especially when the number of traffic sources is limited and comparable with the number of channels, this service changes the traffic distribution. It means that it has influence on traffic loss, i.e. on the calculation of the required number of service channels. In this short paper we shall analyze how the CFB service affects the number of necessary channels in the group. Section 2 deals with the traffic model, and section 3 deals with the influence of CFB on the traffic distribution. In section 4 we present numerical examples.

2. MODEL, DESIGNATIONS AND ASSUMPTIONS

Let us consider the group of N telephone channels, i.e. servers, loaded by the traffic of $M(>N)$ telephones, i.e. traffic sources. Here the word channel is used in wider meaning to define the resource, which establishes the connection. In this case we consider the value of M, which is not much greater than N. That's why the offered traffic depends on the state of the system, i.e. on the number of busy channels (traffic sources). There are two kinds of connections: local, i.e. internal (*ic*) and external (*ec*), Figure 1. In Figure 1 we present one external connection, starting from telephone MSc, and one local connection between telephones TSa and TSb. One unsuccessful attempt of connection realization, which is routed to the busy user TSa, is, also, presented in Figure 1. This attempt becomes the unsuccessful attempt of connection realization, because CFB does not exist. Each call may seize any channel (full availability), and both connection kinds seize one channel.

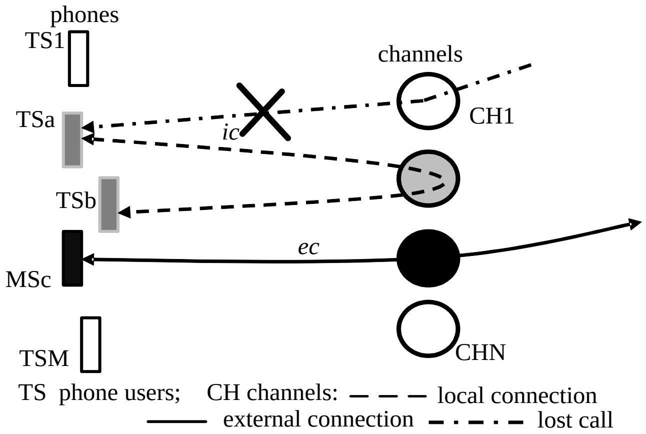

Figure 1: Classic model without CFB.

The calls are generated randomly, i.e. their arrivals make Poisson process. The service CFB does not change this randomness, because the calls are forwarded „momentarily". The state of the system $\{i, e_o, e_i\}$ means that i internal, e_o external outgoing and e_i external incoming connections are realized in the considered moment of time. Traffic sources generate the traffic independently of each other, so local, external outgoing and external incoming traffic are mutually independent. The intensity of local calls from idle subscriber (source) towards other idle subscriber is designated as α_i, the intensity of generating external outgoing call from the idle source is α_{eo}, and the intensity of generating external incoming call to the idle source is α_{ei}. The duration of all three kinds of connections is random variable expressed by negative-exponential distribution with the mean value t_m. The product of the intensity of call generation (α) in some state and the mean duration of the call (t_m) is called traffic, $\alpha \cdot t_m = \lambda$. The total offered traffic is divided in three components: A_i internal, A_{eo} external outgoing and A_{ei} external incoming offered traffic. So, the total offered traffic is $A=A_i+A_{eo}+A_{ei}$. The probability of call loss due to the lack of idle resources is designated as B.

We shall consider this model in two cases: without CFB (Figure 1) and with CFB (Figure 2). The definition of CFB, according to [3], is: "Call Forwarding Busy Service (CFB) permits a served user to have the network send to another number all (offered) calls for the served user's ISDN number which meet busy at the served user's ISDN number". From this definition can be concluded that offered calls are not rejected if the called subscriber (TSa) is busy, but are forwarded to the other, idle telephone (or telephones) (TS1), Figure 2. For the sake of simplicity, we suppose that all forwarded calls are realized.

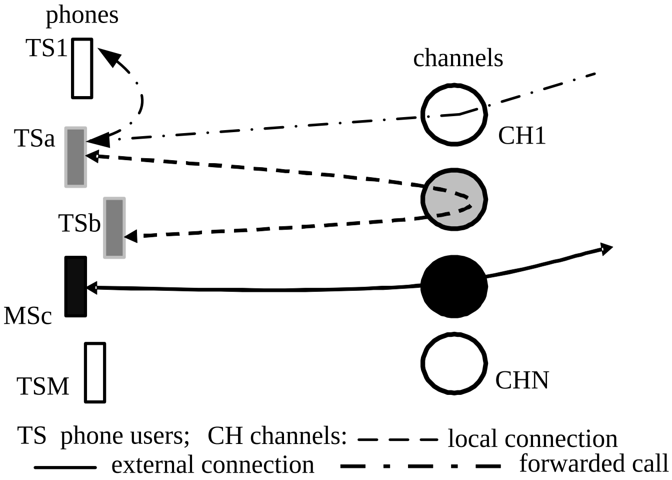

Figure 2: Model with CFB

3. TRAFFIC PROCESS

The detailed analysis of the considered model can be carried out using three-dimensional traffic process of internal, external outgoing and external incoming calls, [1], [8], [9], [6]. Evaluation of the formulas for the probabilities of (sub)states can be pretty complicated, especially in the cases like this one, where the characteristic of reversibility does not exist, ([6], section 7.2). That's why the results of the analysis will be proved by the results of the traffic process simulation. In order to notice the changes, which happen when introducing CFB service, the changes of traffic components will be considered separately for each traffic component, i.e. it will be supposed that two other traffic components do not exist. When proving the conclusions, we consider, of course, the model with real mixed traffic.

The traffic process will be analyzed taking the same call intensity of internal and external traffic when CFB service exists and when it does not exist.

3.1. CFB service does not exist, internal traffic

Let us suppose that external traffic can be neglected. Let i internal connections exist in some random moment of time. As it is known, [1], [8], in small user groups the offered call intensity depends on the number of idle outgoing (M-$2{\cdot}i$) and incoming users (M-$2{\cdot}i$-1). The total internal offered call intensity, if i internal (local) connections exist, is $\alpha_{it}(i)$:

$$\alpha_{it}(i) = (M - 2 \cdot i) \cdot (M - 2 \cdot i - 1) \cdot \alpha_i \, . \tag{1}$$

This property can be called the double influence of limited number of users. It is presented in [9] that the probability of j local connections existence is in this case:

$$P_j = \frac{\dfrac{\lambda_i^{\,j}}{j! \cdot (M - 2 \cdot j)!}}{\sum_{k=0}^{N} \dfrac{\lambda_i^{\,k}}{k! \cdot (M - 2 \cdot k)!}} \, . \tag{2}$$

3.2. CFB service exists, internal traffic

If the CFB service exists, then the call intensity depends on the number of idle users only in the outgoing direction. In the incoming direction the connections are always realized owing to the call forwarding service to the idle user. That's why the total call intensity ($\alpha'_{it}(i)$) is in this case, when there are i internal (local) connections:

$$\alpha_{it}'(i) = (M - 2 \cdot i) \cdot (M - 1) \cdot \alpha_i \tag{3}$$

Here the value $\alpha_{iM} = (M - 1) \cdot \alpha_i$ can be called call intensity from the idle user, as at Engset model, [6], where this value is designated by γ.

The distribution of the state probabilities in this case can be called modified Engset distribution. It is expressed as:

$$P_j = \frac{\dfrac{\lambda_{iM}^{\,j}}{j! \cdot (M - 2 \cdot j)!!}}{\sum_{k=0}^{N} \dfrac{\lambda_{iM}^{\,k}}{k! \cdot (M - 2 \cdot k)!!}} \tag{4}$$

where it is $\lambda_{iM} = \alpha_{iM} \cdot t_m$ and

$$\left(M - 2 \cdot k\right)!! = \prod_{i=1}^{(M-2\cdot k)/2} 2 \cdot i = $$
$$= 2 \cdot 4 \cdot 6 \cdot \dots \cdot \left(M - 2 \cdot k - 2\right) \cdot \left(M - 2 \cdot k\right) \quad for\ M\ even$$

$$\left(M - 2 \cdot k\right)!! = \prod_{i=1}^{(M-2\cdot k+1)/2} (2 \cdot i - 1) = $$
$$= 1 \cdot 3 \cdot 5 \cdot \dots \cdot \left(M - 2 \cdot k - 2\right) \cdot \left(M - 2 \cdot k\right) \quad for\ M\ odd$$

It can be concluded from equations (3) and (1) that $\alpha_{it}'(i) > \alpha_{it}(i)$. It is obvious that the offered internal traffic is in all states greater if CFB service exists. That's why we can expect the increase of the loss of internal calls when CFB service is introduced.

3.3. CFB service does not exist, external traffic

Let us consider now the model under the assumption that internal traffic could be neglected. The total call intensities (in the state when $e = e_o + e_i$ external connections exist) are:

$$\alpha_{eot}(e) = (M - e) \cdot \alpha_{eo}, \tag{5}$$

$$\alpha_{eit}(e) = (M - e) \cdot \alpha_{ei}, \tag{5'}$$

$$\alpha_{et}(e) = (M - e) \cdot \alpha_e \tag{5''}$$

In this case the model for the outgoing external traffic and for incoming external traffic becomes the classic Engset's model. For this model holds the known distribution:

$$P_j = \frac{\dfrac{\lambda_e^{\,j}}{j! \cdot (M - j)!}}{\sum_{k=0}^{N} \dfrac{\lambda_e^{\,k}}{k! \cdot (M - k)!}} \tag{6}$$

where is $\lambda_e = \alpha_e \cdot t_m$.

3.4. CFB service exists, external traffic

Let us again consider the situation when only external traffic exists. The outgoing external traffic depends on the number of idle sources, as in the case when CFB service does not exist, equation (5):

$$\alpha_{eot}(e) = (M - e) \cdot \alpha_{eo} \tag{7}$$

So, in this case the Engset equation (6) (truncated binomial distribution, [6]) would be used.

The realization of incoming external connections does not depend on the number of idle users, because implementation of the CFB service enables realization of all incoming external connections. That's why the intensity of incoming external calls is:

$$\alpha_{eit}(e) = M \cdot \alpha_{ei} \tag{8}$$

i.e. it has the constant value, which does not depend on the number of busy channels. It means that its value is greater when CFB service exists than when it does not exist, equation (5'). In this case the truncated Poisson distribution, which is used in Erlang model, suits for the expression of state probabilities. As the offered incoming external traffic does not decrease when the number of busy users increases, we conclude that the loss of external traffic increases when we introduce CFB service.

From the description of these models it can be noticed that, when more connections are realized, offered traffic is greater when the CFB service exists than when it does not exist. Based on this fact, we conclude that, for the same offered traffic, the call loss will be greater when the CFB service exists than without it. This conclusion can be proved by computing and by simulation. As is the model with internal, outgoing external and incoming external traffic pretty complex for computation (the reversibility of the process does not exist in the model with CFB service), the conclusion will be proved by the simulation.

4. THE RESULTS OF VERIFICATION

Figures 3, 4 and 5 present the results of simulation in the group, which consists of 5 resources (channels) for connection realization and 10 traffic sources.

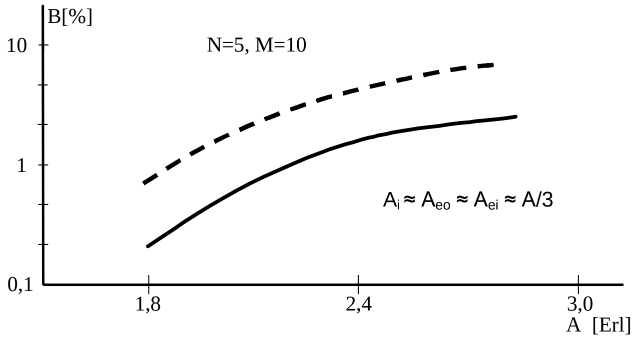

Figure 3: The loss of internal traffic, without CFB service (full line) and with CFB service (dashed line)

The traffic characteristics refer to the values, obtained by simulation. The mean values of the obtained results for loss probability are presented. Three simulation runs are performed.

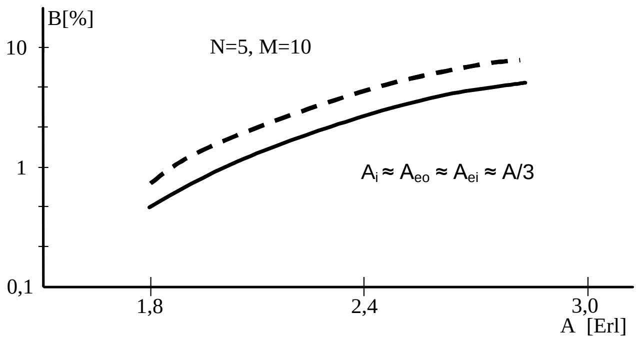

Figure 4: The loss of external outgoing traffic, without CFB service (full line) and with CFB service (dashed line)

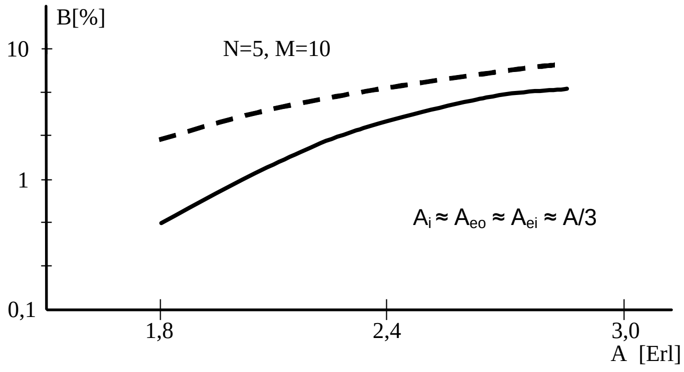

Figure 5: The loss of external incoming traffic, without CFB service (full line) and with CFB service (dashed line)

The simulation is performed using the known Roulette method in the model with mixed traffic. The instantaneous number of idle traffic sources takes into account all kinds of connections, i.e. it is ($M\text{-}2{\cdot}i\text{-}e_o\text{-}e_i$). The values of offered internal, external outgoing and external incoming traffic are equated, meaning that their values are one third of the total offered traffic for each traffic component.

5. CONCLUSION

The application of CFB service increases the part of realized calls, meaning that for the same values of offered traffic and the same number of service channels the carried traffic increases, but also the loss increases. The influence of busy called users on the call loss decreases, and the total carried traffic increases. The effect of limited number of users decreases in a small user group, so the loss of internal and incoming external traffic increases more than the loss of outgoing external traffic. In the case of outgoing external traffic the increase of loss is only the consequence of total carried traffic increase.

Similar analysis can be performed in the case of the call forwarding no reply (CFNR) service and call forwarding unconditional (CFU) service, [4], [5].

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