Advice of Charge in Telecommunication Services

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***Abstract*— The tariff packages in the mobile telecommunication industry got more and more complex in the last few years. The telecommunication companies have introduced several different services among with different discounts and allowances, and the price calculation of the service, and the understand of prices became harder for the subscribers. Because of this, the advice of charge functionality is sorely needed. Sadly, the legacy charging systems do not have the appropriate mathematical model to aid this functionality. In this paper we present a novel model for price calculation, which is capable of the advice of charge functionality. Moreover we present three different AoC models, and we show their advantages with a simulation.**

I. Introduction

The technological evolution and the stressed market-competition of the telecommunication industry lead to the change of approach in the price calculation of the different services in the last decade. Ten years ago, the price of the voice call (which was the only available service that time) depended mainly only on the time of the call, the called party and the duration of the call. The latter was a simple linear component in the price calculation.

Nowadays, the available tariff packages are much more complex. The price of the service depends on a lot of parameters, such as the called party, the calling party, the accumulated service consumption in the current billing period, the bought services, the type of the customer, the duration of the call and many other parameters. Not even mentioning the different allowances and discounts that can be purchased separately or can be bundled with other services. The tariff packages are so complex, that it is actually hard to compare them to each other.

From the billing system point of view, there are several possible solutions to keep up with the market driven evolution of complexity [1]. One is to keep the old, legacy billing system and try to squeeze the complex pricing mechanism into it. Another one is to redesign the whole system, and take the new circumstances and the new marketing approaches into consideration. Of course, there are several companies (like Amdocs, Siemens or Ericsson) that are selling their own solutions or products for this problem [2]. These new, off-the-shell billing systems are quite flexible, and provide the possibility to the end-users (the mobile network operators) to develop almost any marketing driven price calculation with minimal manual work. Sadly, this flexibility does not necessarily come together with a suitable mathematical model, and does not provide the possibility to do extra calculations with the tariff packages.

With the thousands of new services and with the advent of third party providers it is crucial to be able to define the price of the service in advance, and to display it to the end-users (subscribers) [3]. In this paper, we are presenting a high-level model, which is flexible enough, but holds quite a strong mathematical frame at the same time and thus, it guarantees the advice of charge (AoC) functionality.

This paper is organized as follows: Section II introduces our novel model for rating, Section III shows how this model can be used for the advice of charge functionality, while Section IV proves the applicability and efficiency of these AoC models.

II. Rating

One of the main modules of a billing system in a telecommunication company is the module, which is responsible for determining the actual prices of the requested services. The name of this module (according to the terminology of the corresponding standards, and the terminology used by the industry) is *rater*, and the process of the price determination itself is called *rating* [4] [1].

In the last few years, the task of rating has expanded. It is no longer limited to derive only the price of the service, but to calculate the *values* of the service consumption from every aspect. The value can be price, loyalty points, free gifts or anything else. These values are calculated from the deficient call detail records, the users' accumulated service consumption, the business logic, and from the user information stored in the databases of the billing- and operational system [5]. Although this seems to be a trivial problem, the technological implementation is much harder than it looks at the first glance. Finding the relevant subscriber in a database containing more than 3-5 million other entries requires huge number of reading operations, even with the correct database-indexes. Moreover, not only the subscriber, customer, but the relevant services, prices, discounts and allowances should by determined, which requires even more operations from the database, and calculation from the billing system itself. Since pre-paid subscribers need a real-time approach, this must be done in milliseconds [6] [1].

Giving a mathematical formulation, rating can be described as the following function for a specific (s) service:

$$\bar{v} = r_s(\bar{a}, \bar{c}, \bar{d}), \tag{1}$$

where $\bar{v}$ is the value vector of the call, $\bar{d}$ refers to the user information and business logic stored in the databases, $\bar{c}$ denotes the actual, and $\bar{a}$ denotes the accumulated service consumption information. After a call detail record ($\bar{c}$) arrives, the accumulated values should be updated as follows:

$$\bar{a}' = a_s(\bar{a}, \bar{c}, \bar{d}). \quad (2)$$

The input of function $r_s()$ can be several dimension deep and thus, it cannot be published to the subscribers. However, we can use two abstractions, in order to display the business logic in an understandable format, and to introduce a further mathematical computation method.

- A1 Since the values of the service (the elements of $\bar{v}$) are independent from each other, these values can be calculated independently, and (more important) in parallel. These values should be published to the subscribers separately, and thus, it is enough if we focus on the computation of $\bar{v}_i = r_{si}(\bar{a}, \bar{c}, \bar{d})$.
- A2 Even if the input of $r_s()$ is quite complex, the return value is discrete with a finite value-space. For a given $\bar{d}$, the number of possible return values is finite (maximum 20-30 different values are realistic). The reason is, that a specific service for a specific subscriber should not have more than 20-30 different prices or values, in order to remain clear for the subscribers.

With these abstractions, we can use a state-graph instead of a regular function. The states in the state-graph represents the service with *similar* conditions, where the price of the service is constant u. The transitions between the states are triggered by the accumulated and by the current parameters of the call (let us denote them with transition-conditions). According to this, the price of the service can be calculated with the repetitive use of the following steps:

- S1 Calculate the actual state in the state graph, using the state-graph definition, the accumulated, and the current values (such as the length) of the call:

$$\bar{\alpha} = g(\bar{a}, \bar{c}, G_{d,s}) \quad (3)$$

- S2 Calculate the value of the service from the state, and from the current values of the call using some simple function:

$$v = p_s(\bar{\alpha}, \bar{c}, \bar{u}) \quad (4)$$

- S3 Update the accumulated values with the values of the current call according to the business logic:

$$\bar{a}' = a_s(\bar{a}, \bar{c}, \bar{d}), \quad (5)$$

where $G_{d,s}$ denotes the state-graph for a given service and for a given subscriber, and $\bar{\alpha}$ stands for the state indicator vector (where every element is 0 except one, which is 1).

The advantage of this representation, is that $p_s()$ is much more simple that $r_s()$, because the business logic is pushed into the standard state-graph, and not into this function. Mainly $p_s()$ is a very simple function, where the value of the state (u) is multiplied with the duration of the call. The other thing is, that $g()$, the state definition function, is uniform, and can be used for every service and for every subscriber.

III. Advice of Charge

Since the number of available services in a 3rd generational mobile network is significantly higher, than it was / it is in the GSM era, the price of the services should be presented to the subscribers before the actual service consumption in order to let the end-user decide whether to consume or cancel the requested service [3]. Since this information, this advice, should hold some kind of guarantee, our task is to approximate the price of the service as good as possible. The difference between the advised and the real price of the service can be paid by the subscriber or by the telecommunication company. Taking the first option, the subscribers should be aware, that the advice of charge has no guarantee, and it is only used as an informative service. If the deviation is paid by the provider (which means, that the AoC has its guarantee), the company should calculate this loss into its prices, in order to avoid loss of income. In this section, we will show, how our model can aid the advice of charge functionality.

Basically we can divide the available services in the mobile telecommunication industry into two sets: Event and Session based services. The advice of charge functionality is slightly different in these cases. For the event based services, the calculation of the price is quite easy. First we calculate the actual state in the state-graph with equation (3), and return the value of the actual state. Computing the expected value of the service in advance is much more complex with session based services, moreover, since the length of these calls and thus, their prices can have quite a large deviation, it is better, if we calculate the advice of charge for a fixed length call only. However, calculating the expected value with variable length (with a given probability density function) may aid the economical planning of prices, this option is out of the scope of the current paper, and may be a subject for further research.

We will introduce three different models for the AoC for session based services, which share the idea of using some well known solutions from queuing theory, but they differ in the computation requirements and in applicability. We will compare two from these three models in Section IV with a simulation.

Since we have defined the different tariff packages with a state-graph (see Section II), it is obvious to represent this graph with a state transition matrix. The elements of this matrix are the transition probabilities from one state (state i) to another (state j). If we denote this probability with p_{ij}, than the state transition matrix can be defined as:

$$\Pi = [p_{ij}]. \quad (6)$$

In this case, the transition probabilities and thus, the state-transition matrix is a function of the state-graph, the length and other parameters of the call, and the accumulated values in the current period:

$$\Pi = \Pi(G_{d,s}, \bar{c}, \bar{a}). \quad (7)$$

The value (unit price) of the service in the different states is represented with a value-vector, where the ith element of the vector represents the unit price in state i. The matrix can be calculated whenever an advice of charge functionality is initiated, and if $\bar{u}$ denotes the value-vector of the state-graph, and $\bar{\alpha}$ denotes the initial state, which is defined by equation (3) the expected value of a service can be evaluated with the following equation, if the call length is t ($t > 0$):

$$v(t) = \sum_{k=0}^{t-1} \bar{\alpha}\Pi^k \bar{u}. \tag{8}$$

Please note, that in case of the event based services $t = 1$, and the price of the service is $v(1) = \bar{\alpha}\bar{u}$, which is equal with the result mentioned earlier in this section.

Regarding the performance of the AoC functionality, it requires pre-processing and offline computation in order to have the state graphs to be built up (if it is not in this format from the beginning). Once the state graphs are ready the functionality requires smaller amount of resources (CPU power) as a normal rating even if we give the theoreticaly optimal approximation, since the actual rating functionality is simplified to a predefined number of addition.

The main problem with this model is that the exact transition conditions are mapped into simple probabilities, and this simplification may ruin the result of the AoC functionality and may raise the deviation significantly. The approximation of the price may be much better, if we can somehow code the transition-conditions in the state-graph or in the model itself. The following subsections will give some solution for this problem.

A. ESTM - Advice of Charge with Exploded State Transition Matrix

The idea of this model is to code the transition-conditions into the states of the state-graph. To be more exact, we create a new graph, were one state is exploded into as many states, as the pricing logic requires it, to hold some memory for the transition condition. For example, if the transition condition is to move from state i to state j after 5 units (seconds), then we substitute state i with a chain of five states (from state i_1 to state i_5). The probabilities of these transitions are 1. Once the new graph is created the price of the service can be calculated with:

$$v(t) = \sum_{k=0}^{t-1} \bar{\alpha}'\Pi'^k \bar{u}'. \tag{9}$$

Let us imagine a simple service, where the price of the service is 1€ per second, but if we receive an MMS during the service, the price will be 0.5€ for the next 5 minutes. This pricing graph is represented on the left side, while the exploded one represented on the right side of Fig.1.

The problem of this solution is that the state-graph may be enormous, if the required memory is huge and thus, it may have a significant impact on the computation speed and on the required memory from the IT system.

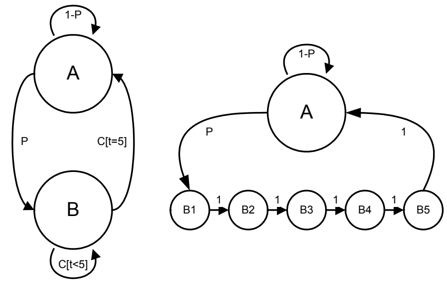

Fig. 1. Example for AoC with ESTM

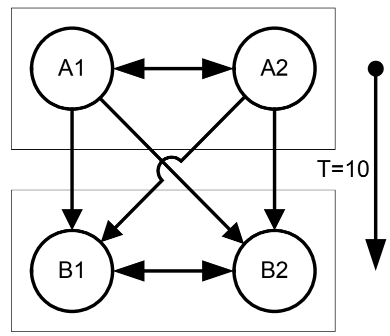

Fig. 2. Example for AoC with TLM

B. TLM - Advice of Charge with Time Layered Model

This model assumes that the transition-conditions are either can be mapped into probabilities without causing significant deviation from the theoretical optimum, or they are condition on the length of the call only. Nowadays, most of the available tariff packages fulfill this requirement.

We divide the state-graph into different layers. The transitions inside a layer will be mapped into probabilities, the transitions between the layers are deterministic, and they are depending only on the length of the call. If we divide the graph into G_1, G_2, G_3, $\ldots$ layers with T_1, T_2, T_3, $\ldots$ time, then the price of the service is:

$$v(t) = \sum_{k=0}^{T_1-1} \bar{\alpha_1}\Pi_1^k \bar{u_1} + \sum_{k=T_1}^{T_2-1} \bar{\alpha_2}\Pi_2^k \bar{u_2} + \sum_{k=T_2}^{T_3-1} \bar{\alpha_3}\Pi_3^k \bar{u_3} + \ldots \tag{10}$$

where Π_i is the standard state transition matrix representation of G_i, and its value vector is $\bar{u_i}$. $\bar{\alpha_i}$ represents the initial state transition probabilities in the ith layer. Fig.2 shows a simple example for this model, where we have layered the graph into $\{A1, A2\}$ and $\{B1, B2\}$ states, and $T1 = 10$.

The advantage of this model is that it uses less memory and less CPU resources, since the number of states remains low. Sadly, we cannot use this model directly, when the assumption on the transition-condition is not met. However, it is possible to use this model together with the ESTM model with the following simple algorithm: divide the graph into as many layers as possible and apply the ESTM model where necessary.

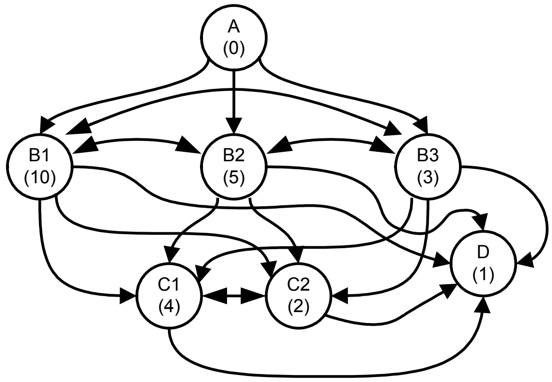

Fig. 3. Price-graph of the tariff package

C. *SAoC - Stratified Advice of Charge*

The main idea of this model is that some transitions may be left out from the transition graph, when we calculate the AoC. This simplification / condition should be published to the customers. Moreover, if the transition probability is quite small, but the value of the new state differs significantly from the previous one, than the precise advice of charge may even cause problems. Let us see the following example:

- The price of the voice call is 1€ per minute.
- If the subscriber receives an SMS during the service, then the voice call is free.

If we would calculate the AoC for a 3 minutes long call, it would be less then 3€, which may cause some confusion. So, we may cut down these transitions, publish to the subscribers, that the AoC does not take the SMS into consideration, and give 3€ as the AoC. This idea can be used for all the above mentioned models.

IV. SIMULATION

Let us give a simple example. We will calculate the price of a data service (a video on demand service for instance) in advance. This service has kilobyte (KB) as unit of measure, has three different quality levels (high, medium and low) and the unit-price depends on the QoS. Let us define the tariff package as follows:

- The first 200KB is free in the month.
- The first 300KB of every call can have three different unit-prices according to the quality: 10, 5 and 3 cents per KB for high, medium and low quality level.
- The price of the rest of the call has two different prices: 4 cents per KB if the call has high or medium, and 2 cents per KB if the call has low quality level.
- The price of the service is 1 cents per KB if the subscriber receives a special SMS from someone. This price is only applied, after the first 200KB allowance consumed (if remained any).

According to this specification, the price-graph of this service has 7 different states as displayed on Fig.3. We have created a simulation (with 4000 runs), and we have calculated the price of the service with the Time Layered Model and with the Stratified Advice of Charge model. In the SAoC model, we have omitted the probability of receiving an SMS during the service. However, for the computations we had to make some further assumptions for the properties of the service and for the subscriber as well. We have assumed that the hidden state-transition matrix of the service quality is the following:

$$P = \begin{pmatrix} 0.89 & 0.1 & 0.01 \\ 0.1 & 0.8 & 0.1 \\ 0.01 & 0.1 & 0.89 \end{pmatrix} \quad (11)$$

and the subscriber already consumed 80KB from the 200KB allowance. The probability of receiving an SMS is $p = 0.0004$ during every unit.

The simulation was done in two phases. First, some simplified CDRs (Call Detail Records) were generated with a script. The mentioned parameters (probabilities, state-transition matrix, etc.) were used in order to generate life-like CDRs. As a second phase, these CDRs were rated by a simplified rater. In parallel, the TLM and SAoC models were used to predict the price of the services. The result of the simulation (average price) and the results of the two models (TLM and SAoC) are given in Table I.

Fig.4 displays the histogram of the simulation run. The X axis represents the price of the service, and the Y axis represents the number of simulation run resulted the given price. The local peak value on the left indicates the minimum price of the service, when the subscriber received the special SMS during the first 120KB traffic. The low, constant values on the left are caused by the received SMS after 120KB. The deviation of the histogram is determined by the probability of receiving an SMS (p), the state transition matrix (P) of the quality and the value vector ($\bar{u}$) of the service.

From Table I it is clear, that the simple TLM is more efficient, if we would like to measure the efficiency with the average, however, the author thinks, that a much better quality indicator is the *number of subscribers / simulation runs within a given threshold*. These results are represented on Fig.6 for the TLM (right) and SAoC (left) model. The bottom of the graph represents the number of simulation runs (CDRs), that were rated exactly at the same price as the model suggested, a bit above the number of CDRs represented, which were rated within an 40-50 eurocent range, and so on). For example, the simulation has 54 results with 250-260 eurocent difference from the result of the SAoC model, which means, that 54 simulations ended with 1660-1670 or 1150-1160 eurocents.

Method	Result	Approximation
Simulation	1256.10875	1260
TLM	1240.1455	1240
SAoC	1413.3333	1410

TABLE I
ADVICE OF CHARGE RESULTS

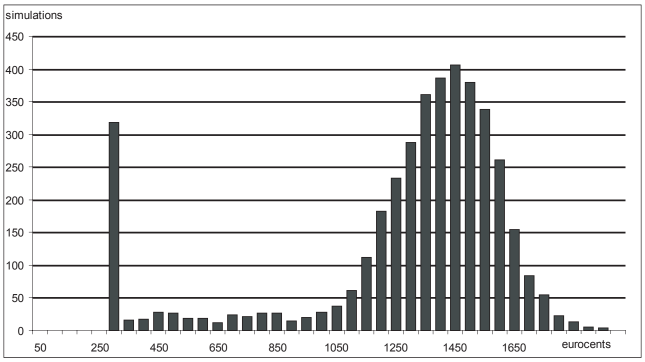

Fig. 4. Number of simulation runs resulted the given price

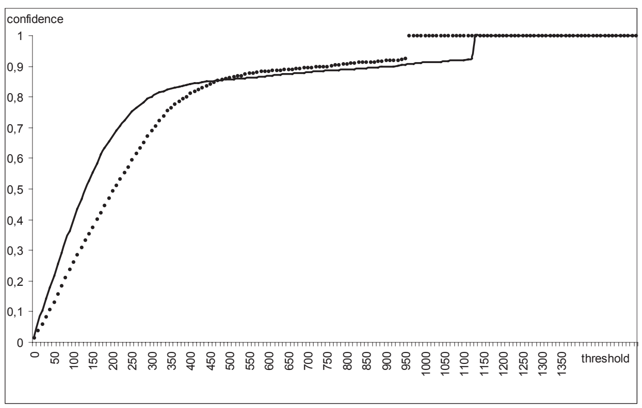

Fig. 5. Percentage of simulation runs covered by a given threshold for the SAoc (line) and TLM (dots) model

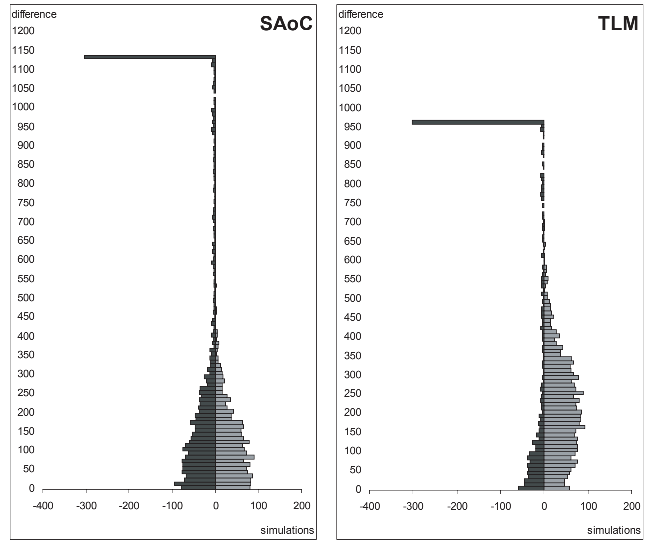

Fig. 6. Number of simulation runs with a given difference from the result of the SAoC (left) and TLM (right) model

This is indicated by the vertical line at position 250 on the left graph.

Fig.5 represents the percentage of simulation runs within a given tolerance. It can be seen, that the TLM model reaches the 100% confidence with a lower threshold (960 eurocents instead of 1130 eurocents), but the SAoC model reaches the 80% confidence earlier (300 eurocents instead of 390 eurocents). Since we defined the SAoC model, not to take the received SMS in consideration, and it is published to the customers, it can be more precise than the simple TLM model, since the variation caused by the SMS is removed.

V. Conclusion and Future Work

However, although the advice of charge functionality is defined in the 3GPP (3rd Generation Partnership Project) standards [7] [8] [9], it is still absent from the wide range of available services. This is most probably because the available tariff packages are evolved in complexity, but the legacy charging systems of the telecommunication providers was not upgraded in a way, to assist this functionality with the required mathematical background. In this paper, we have introduced a novel concept for rating, which aids the AoC functionality and we had also proof the advantages of these models with a simulation.

This work was supported by the Mobile Innovation Center, Hungary. As a future project, we would like to implement our rating model with AoC functionality. We would also like to develop a better quality indicator function, to be able to measure and compare the different solutions. The development of the use of our model for the economical planning of prices should also be an interesting issue, and might be a subject for further studies and researches.

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