

A Simulation Model for the Cumulus Pricing Scheme

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Keywords:

Pricing Internet Services, Cumulus Pricing Scheme, Accounting, Simulation.

Abstract

The Cumulus Pricing Scheme (CPS) determines an important management functionality of commercial networks in future and it is the only approach known so far defining a clear relation between different time-scales of accounting periods, measurement periods, and charging periods. Prices in this scheme are based on flat fees and hence predictable and transparent. CPS is backed by the design and implementation of a generic and modular Internet Charging System (ICS), which offers a service-independent architecture and integrates economically controlled network management functions of charge calculation and pricing. In order to proof the major ideas of CPS, an initial simulation model has been built. It consists of a Traffic Data Recording (TDR) unit and Data Integrating and Analyzing (DIA) unit. The characteristics of a customer are analyzed in this model. So-called red and green Cumulus Points (CP) are used to judge the behavior of this customer. The simulation models enables the investigation of the importance of choosing a best value for those thresholds, which determine the assignment of CPs.

1 INTRODUCTION

The Cumulus Pricing Scheme (CPS) is basically a flat rate scheme (but rates may vary over long time-scales), it provides a feedback mechanism to bring market forces into play (where this feedback is not an immediate one, but requires the accumulation of discrete flags according to user behavior), and it allows a huge flexibility in terms of the technical prerequisites for metering and accounting mechanisms. Characteristic to this scheme is the combination of an initial contract between customer and ISP (which contains information about expected usage patterns) with a feedback mechanism that interacts with the customer behavior on different time-scales. With CPS, measurements take place over a short time-scale and allow evidence about user behavior on a medium time-scale. This evidence is expressed in terms of discrete

Cumulus Points (CPs), yet not triggering some sort of reaction by themselves, but only as a result of their accumulation over a long time-scale. The assignment of CPs works as follows: First of all, customer and ISP are supposed to agree on a contract specifying the expected user requirements in terms of bandwidth or delay as well as a price to be paid for this type of service. Following this agreement, the factual usage may not match the prediction given by the user (for whatever reason, be it an incorrect statement, changing habits, or new applications). As soon as these discrepancies exceed some threshold, the user receives feedback in terms of the mentioned CPs. They exist as red and green flags: a red CP indicates that the user has been overusing her capacities, a green one indicates the opposite, i.e. that the user might have been allowed to use more resources than she actually did. The larger the discrepancy between contract and reality, the more CPs may be assigned. CPs remain valid for a dedicated number of consecutive billing periods, and it is their accumulation that finally triggers certain consequences. Hence, receiving CPs requires no immediate reaction. However their successive accumulation over consecutive billing periods eventually may exceed a CP threshold and have consequences for the user, depending on ISP policies.

Now the important question to be answered is: how to define suitable thresholds? In order to find out a reasonable way of choosing such thresholds, a simulation model of Cumulus Pricing Scheme has been implemented. For the sake of practical sense of the simulation, customer's data have been taken from an existing router in an operational environment by means of SNMP (Simple Network Management Protocol). Then the data has been pre-processed to meet the needs of simulation. Here is assumed that the sampling data of $V(t)$ can be described by a stochastic process, which is in equilibrium, fluctuating around an (unknown) mean ξ with a standard deviation δ . The exact mean and deviation are calculated after the integration of $V(t)$ in a so called Probe Phase (usually for one month). CP thresholds are computed according to these values of the mean and deviation. However, for experiments, the manual setting thresholds is also allowed. In this way linear or non-linear thresholds can be

tested during the simulation. The aim of the simulation is to chase down suitable thresholds with the following three requirements:

- Use only a small number of thresholds either way, i.e. no more than three pairs for under- or over-utilization.
- Incorporate a hysteresis effect, i.e. prevent small oscillating deviations from resulting unnecessary awards of CPs.
- Choose thresholds in such a way that the resulting CPs are widely independent of the measurement method applied (mainly the measurement interval), i.e. the difference in terms of CPs must not exceed 1, if different measurement methods are used.

2 The CPS Simulation

The CPS simulation model consists of two parts: the Traffic Data Recording (TDR) unit and the Data Integrating and Analyzing (DIA) unit. The TDR unit is also composed of two parts. The first part (Data Acquisition) is a C-shell Script running in a Solaris Workstation to fetch the traffic data from a router periodically and save the data into an ASCII file. The second is a data pre-processing program, which changes the ASCII file into the required form and saves it as a data source for DIA unit. The relationship of these two units is shown in Figure 1.

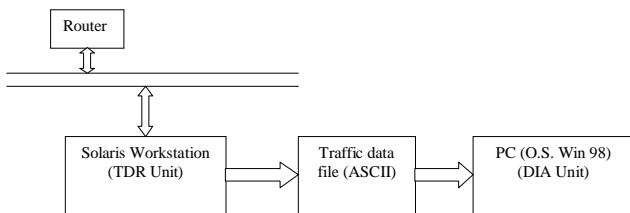


Figure 1: Real-world Data Sampling for the Simulation

2.1 Traffic Data Recording (TDR) Unit

Traffic Data recording is realized by means of SNMP. The database, controlled by the SNMP agent, is referred to as the SNMP Management Information Base (MIB) and defined a standard set of statistical and control values. Through the use of private MIB variables, SNMP agents can be tailored for a myriad of specific devices, such as network bridges, gateways, and routers. The definitions of MIB variables supported by a particular agent are incorporated in descriptor files. The monitoring MIB object of interest in this case is “ipForwDatagrams” (mgmt/mib-2/ip/ipForwDatagrams.0), which is a read-only counter that indicates the number of datagrams that have been forwarded. The sampling granularity is 5 seconds.

Therefore, for a working week (from Monday to Friday) 86400 integers are taken from router and stored in the data file “traffic.dat”. A C shell script has been used to acquire working data of two weeks and then merged the files in one.

The data pre-processing program has three functions. It calculates the difference between the two border-upon data in the ASCII file and divides the results by 1000 (to form kilo packets/s). Based on the original data file, a new data file with the chosen granularity can be formed, i.e. the time, scale is extended to the required length. The specification of traffic data can be adapted globally or locally. As what above mentioned about “ipForwDatagrams”, the original data has the property of a monotonous increment. Only the difference between the border-upon data reveals the traffic states simultaneously.

2.2 Data Integrating and Analyzing (DIA) Unit

The implemented GUI of the CPS simulation model is illustrated in Figure 2. When the button “Start” is selected, the simulation model starts and the respective data file can be chosen from a pop-up menu. The data of the file are transferred into an internal vector for the further processing in DIA unit. The integration of the sampling data of function V(t) in DIA changes into accumulation, since the sampling data are discrete.

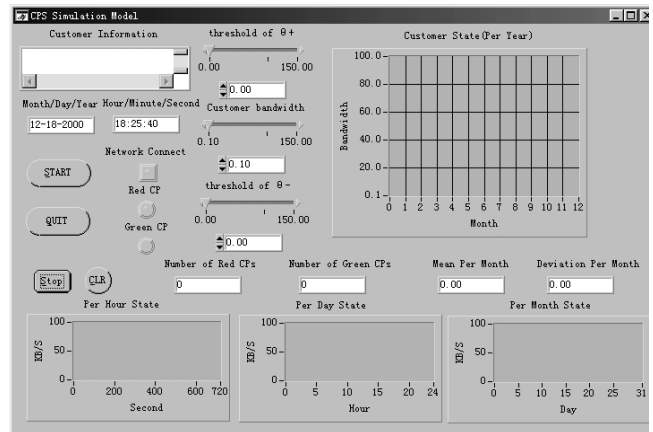


Figure 2: Simulation GUI

These simultaneous data of hourly, daily, and monthly values are displayed in three separate graphs respectively. The four command buttons on the panel are controlling buttons, with which the user may operate the simulation model. If the user does not know the function of a command button, she can simply right-click on it and a pop-up menu will tell her briefly about that button. Three point slides determine controls and indicators for customer bandwidth and thresholds. A user can set these parameters manually or watch these values when the simulation user lets the simulation model calculate them. Characteristics of a customer will be computed during the simulation. The results (mean and deviation of the customer data utilization per month) will be displayed on the respective indicators. The numbers of red and green CPs are shown on their indicators. If these values were higher than certain limits, there will be a text message

appearing on the text box. There is a system timer inside this simulation model, whose duty is to control the integration length according to the calendar. The current date and time are also displayed on two string indicators.

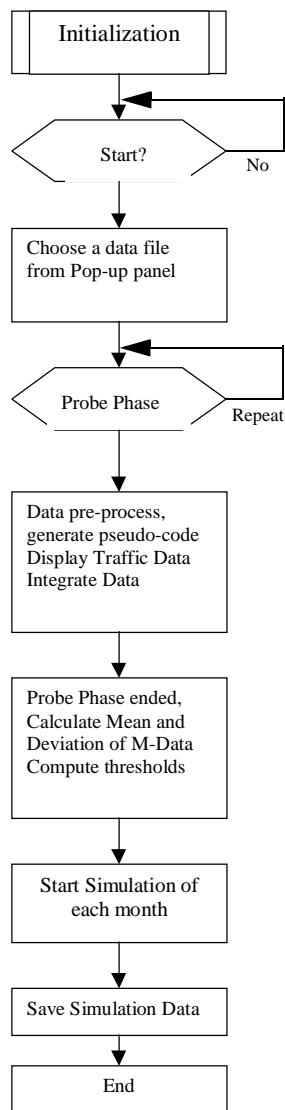


Figure 3: Stepwise Simulation Flow Chart

The flow chart of simulation model is depicted in Figure 3. After the program has been started, the Probe Phase will be conducted first. As already stated above, CPS requires an initial contract between Internet Service Provider (ISP) and customer that contains the customer’s expected traffic characteristics. The Probe Phase is to simulate that the customer is allowed to use the network for a month, where she pays a rather low flat rate or even free. During this period the ISP performs detailed measurements, which afterwards are confirmed by customer and then are used to determine the parameters on which the initial contract is based.

At the end of Probe Phase, the program pops up a menu informing the user that the characteristics of customer have been computed and whether they are to be put into the simulation or manually configured ones shall be utilized. If the user confirms to use these parameters, the program will ask to define the number of thresholds that user wishes. Afterwards, the simulation will ask the user to decide manually or automatically on calculating CP thresholds.

2.3 CPS Simulation

A simulation is conducted in two steps. The first step is to test linear and non-linear thresholds and find out which one are more reasonable to be implemented. The second step adopts thresholds decided by the first step, changes the granularity of the traffic data and checks, whether thresholds are independent from measurement methods:

- The tests of linear and non-linear thresholds are all based on the same traffic data. Using the nonlinear thresholds can tune the number of red and green CPs on purpose. It might be more useful if the data of customer were not described by a stochastic process, which is in equilibrium, fluctuating around (unknown) mean ξ with a standard deviation δ .
- Testing results of different granularities of traffic data. In this step of test the linear thresholds with the integer coefficients are employed. The mean and deviation of the traffic data are calculated in the Probe Phase, which are the same as the values in the first step. The granularity of data is adjusted after the Probe Phase.

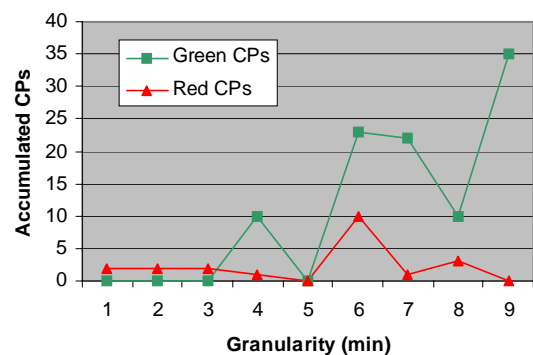


Figure 4: Sample Result for Aggregated CPs

The simulation of results of different granularities of traffic data has been performed. In this step of test the linear thresholds with the integer coefficients is employed. The mean and deviation of the traffic data are calculated in the Probe Phase. The granularity of data is adjusted after the Probe Phase. One set of results are shown in Figure 4. A change of the number of red CPs per year appears when the granularity is greater than six minutes. In this case some characteristics of the original data are missed to be sampled,

because of the unsuitable granularity. There is a difference compared to the characteristics of the Probe Phase. Therefore, purely linear thresholds are not independent of the measurement method applied.

3 SUMMARY AND CONCLUSIONS

The simulation model has been implemented in C and performs on PCs, while taking real-world data as input. The results show that the characteristics of customer determining the values of normal consumption of customer and the corresponding thresholds are reasonable. Such linear thresholds are simple and practicable for the implementation of CPS. But there may occur a problem to charge the customer mistakenly when she changes her behavior during the normal measurement period. This is due to the fact that thresholds are only decided by the behavior of customer during the Probe Phase. In order to solve this issue, major characteristics of the customer (mean and deviation values) must be traced periodically, e.g., monthly. Assuming once again that the actual resource consumption may be viewed as a steady-state stochastic process, the main aim of awarding CPs consists of indicating whether the statement about expected resource consumption (still) is valid.

A simple heuristic could work as follows: If ξ and σ are reasonable estimations for mean and standard deviation, and if the mentioned stochastic process is reasonably close to normal distribution (which is a standard assumption for the case considered), then according to standard probability theory approximately 68.3% of the samples should be contained within the interval $[\xi - \sigma, \xi + \sigma]$, approximately 95.4% within $[\xi - 2\sigma, \xi + 2\sigma]$, approximately 99.7% within $[\xi - 3\sigma, \xi + 3\sigma]$. Hence, if the sample measurement is “too often” outside $[\xi - \sigma, \xi + \sigma]$, this is an indication that maybe stating mean ξ is no longer valid. If the samples are outside $[\xi - 2\sigma, \xi + 2\sigma]$ or even $[\xi - 3\sigma, \xi + 3\sigma]$, this indication is even stronger. This suggests in a straightforward manner to use relative thresholds of the form $\theta_{\pm n} = 1 \pm n \cdot \frac{\sigma}{\xi}$ i.e. one CP is awarded as soon as the measurement differs from ξ by more than σ ,

two CPs are awarded, if the deviation is larger than 2σ . As an additional nice feature, this approach limits inherently the number of thresholds to be about three or four in each direction. The evaluation of this proposal is left to simulation and with respect to an implementation, the customer must be alerted (e.g., by e-mail) and a new measurement should be conducted, as well as the contract between the consumer and ISP has to be modified.

ACKNOWLEDGEMENTS

The main author performed this work under his responsibility as a visiting scholar being at TIK, ETH Zürich. He likes to acknowledge many discussions with his co-authors and their colleagues Jan Gerke, Pascal Kurtansky, and Hasan.

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