The Design and Implementation of Policy-based Bandwidth Billing System

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Abstract: This paper presents a billing system for the network with multiple service levels, the Policy-based bandwidth billing system (PBBS), which not only bills users for their consumed services and bandwidth resources but also controls and guarantees the QoS classes required by the users over IP networks. The Policy-based pricing scheme adopted by PBBS can be applied into many kinds of pricing schemes such as flat rate pricing, duration-based pricing, volume-based pricing, service-based pricing, schedule-based pricing, or online-bandwidth-based pricing. The PBBS is based on the Policy-based bandwidth management system and achieves the billing and bandwidth controlling according to the policies made by the network providers and users. The system requires no change in the existing protocols and applications and can be used to bill and manage multiple domains simultaneously. An implementation of PBBS based on the BandKeeper system is described and the result indicates that the proposed system is practical.

Key words: PBBS, Billing system, Policy-based networks.

1. INTRODUCTION

As the Internet population grows up year-by-year in a rapid rate, the problem of sharing the bandwidth and Quality of Service (QoS) provisioning has become the focus of much recent research. Even if there will be much more bandwidth in the future, the control of the network resource utilization remains essential for the prevention of the waste on bandwidth and for more efficient using in the important applications which have special demands. Therefore, solutions aim on the Policy-based Network Management is

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provided, which manages the bandwidth according to the predefined bandwidth policies [4] [8]. Besides, many studies show that pricing on the network services enables the network to be used more efficiently and provides a possibility to control utilization and sharing of network resources [3] [10] [11].

However, the primary pricing schemes currently adopted by both dial-up and broadband Internet Service Providers (ISP) are flat rate pricing and pure duration-based pricing, and each of them is not an ideal pricing scheme. For the flat rate pricing, it causes an inefficient utilization on the bandwidth resource. The reason is that users do not face the true marginal cost of usage and thus resulting in over-usage and potentially higher than socially optimal levels of infrastructure investment to meet the demand. The high levels of usage under flat-rate unlimited-access service planes have the potential to reduce the overall performance under broadband access technologies[5] [4]. For the duration-based pricing, it is not impartial to apply the same charging scheme to the users even when they have the same connection duration. For example, user A transmits large amount of video clips and MP3 files all the time via Ftp or Http and user B is just idle on the BBS reading his favorite articles via Telnet. Although users A and B have the same duration, user A uses much more bandwidth than user B. So it is not fair for user B to apply the same duration-based pricing scheme as user A. The charging schemes on bandwidth should be more precise, make more efficiency on the utilization, reduce the waste of the bandwidth, and follow the principle that how much the user has to pay should depend on how much bandwidth resource the user has consumed.

Early in 1995, a system for billing users for their TCP traffic was proposed[10], which was achieved by delaying the TCP ACK message to postpone the establishment of connections while the user is contacted, verifying in a secure way that they are prepared to pay. It also showed that pricing schemes might be used to control network congestion either by rescheduling time-insensitive traffic to a less expensive time of the day, or by smoothing packet transfers to reduce traffic peaks. Besides, there are many pricing architectures for the DiffServ Network[2] [11], which require a more complex network topology, and are not widely and commercially used now. A congestion-pricing scheme was also proposed[1], which assigns a price for each packet entering a switch. When a packet traverses several switches on its route, each switch adds its price to the price currently carried by the packet. The price reflects the degree of congestion encountered by the packet and end users are informed of how much they are charged when their packets are acknowledged. However, it's not fair to apply this scheme to the end users because they should not be blamed for the congestion. For the multi-domain network, a pricing and accounting architecture has been proposed[7], which requires an additional network access agent (NAgent) to mediate between users and network providers. In this paper, the *Policy-*

based Bandwidth Billing System (PBBS) on a multi-domain network is proposed, which is based on the *Policy-based Bandwidth Management System (PBMS)*[9] . The PBBS requires no change to the existing protocols and applications. It uses the *Policy-based pricing scheme*, which can be molded into not only the pricing schemes currently used by most ISPs (flat rate and duration-based pricing), but also other various pricing schemes. The PBBS provides precisely bandwidth pricing and more efficient bandwidth utilization.

The rest of the paper is organized as follows. Section 2 is the overview of the Policy-based Network Bandwidth Management System[9] and the Policy-based accounting architecture[3] , both are the basis of the PBBS. Section 3 describes the system design of the PBBS and the concept of the Policy-based pricing scheme. Section 4 presents the implementations of the charging policy maker and converter in PBBS. Finally, conclusions and future works are drawn in Section 5.

2. THE PRELIMINARY

2.1 Policy-based Network Bandwidth Management System

The Policy-based Network Management becomes a popular issue in recent years since it provides a mechanism for guaranteeing the QoS of each application and managing the bandwidth resource via policies. An implementation based on the architecture of Policy-based Network Management, the PBMS[9] , has been proposed. It manages the bandwidth resource of the IP network by controlling the TCP connections and UDP streams according to the bandwidth policies, and exports the data of traffic. The device first classifies the flows according to the policies (Source IP/Netmask, Destination IP/Netmask, protocol type and service port), and then enforces the QoS settings on these flows.

The billing system should not only do the accounting and pricing jobs by metering and analyzing the connections, but also manage and control the bandwidth resource actively to prevent from the illegal access and to increase the utilization. Consequently, the PBMS is a good platform for the implementation of the billing system.

2.2 Policy Reference Model

The PBBS takes advantages of the reference model of Policy-based Accounting[3] and combines the bandwidth control functions of PBMS to

develop a novel policy reference model for the Policy-based pricing scheme. The model is shown in Figure 1. The blocks at the right side are layered according to the processing of the data from the bottom level bandwidth controlling via metering up to the final billing process. The block on each layer is configured by the policy shown on the left side. The configuration parameters are extracted from the policy and passed to the corresponding block. In PBBS, the billing and charging policies not only control the billing and charging blocks, but also act as an instructor of how to controlling the bandwidth, which is a new function block in this model. In other words, the bandwidth controlling policies of PBBS derive mainly from the billing and charging policies.

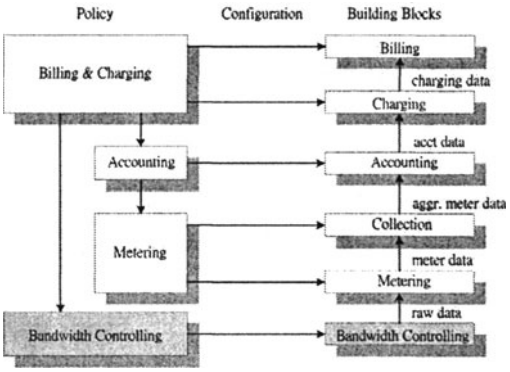

Figure 1 The reference model of PBMS (based on the model of Policy-based Accounting)

3. THE DESIGN OF POLICY-BASED BILLING SYSTEM

3.1 Policy-based Pricing Schemes

Based on the Policy-based Bandwidth Management System, many kinds of controlling and metering on the bandwidth can be achieved. Therefore, there are plenty of parameters can be used for charging: the parameters on duration-based charging and on volume-based charging, the parameters on charging different QoS of the bandwidth, even the parameters on charging different kinds of TCP or UDP services. Since all the parameters are available, the charging scheme becomes more flexible, but on the contrary, more complex than it is used before (which only takes care of the duration-based charging). The users (who pay the money to buy the bandwidth) should not face the complicated parameters and charging schemes, for that should be the bandwidth provider's duty. To look after both the manager's

side (flexible and exact charging) and the user's side (simple and clear choices), the PBBS introduces the *Policy-based pricing scheme*, which provides the users with a set of *Virtual Lines*, the pre-allocated virtual channels with predefined bandwidth classes and pricing schemes. These bandwidth class and pricing schemes are specified in the *charging policies* by the *Charging Formula*, which is composed of several pricing parameters. A Virtual Line can be composed of one or more charging policies depending on the QoS and pricing schemes in each time period.

3.1.1 Making Charging Policies

A charging policy is composed of three elements: *charging formula*, *QoS specification* and *activated hours*, where QoS specifications are inherited from the PBMS.

3.1.1.1 Charging formula

The charging formula is constructed by several pricing parameters and is an expression like the following:

$$UC = \Pi D * \Sigma (P_{fee} * P_{scale})$$

Where P_{fee}, P_{scale}, and D are pricing parameters and will be described later. The charging formula not only indicates the pricing scheme, but also implicates the reserved QoS. Besides, all the QoS specifications and pricing schemes in this policy will be effective only in the specified activated hours. To construct a charging formula, all the pricing parameters obtainable from the data exported by the PBMS (parameters on fees, parameters on scales) should be considered. Applied to the traditional pricing schemes described before, an example of the duration-based charging formula should look like the following:

$$UC = F_{rcombw} * T_{use}$$

Furthermore, an example of the online-bandwidth-based charging formula (the fee varies with the bandwidth):

$$UC = F_{bwd\_uset} * T_{use\_bwd} + \Sigma (F_{bwx\_uset} * T_{use\_bwx})$$

The charging formula can be the combinations of several kinds of pricing schemes. An example of the duration-based billing on the committed bandwidth with Service-based billing on Ftp service by transmitted octets is as follows:

$$UC = F_{rcombw} * T_{pre} + F_{serv\_ftp} * O_{use\_ftp}$$

3.1.1.2 Activated hours

The activated hours of a policy are the hours in a week in which the QoS settings and pricing schemes are effective. The reason for using a week as the scheduling target time period is that it's a working cycle for most of the people in the world. The charging policy does not care about the time longer

than a week (a month, a year...) and leaves it to the users while making the *User's Policy*. A charging policy can be specified to be effective in the whole week, in a couple of days, in every night, or only in the hours of important conferences, and it's all up to the maker's decision and their commercial considerations. Figure 2 illustrates the activated hours of Policy 1A and Policy 1B, a working-hour policy and a night-time-hour policy.

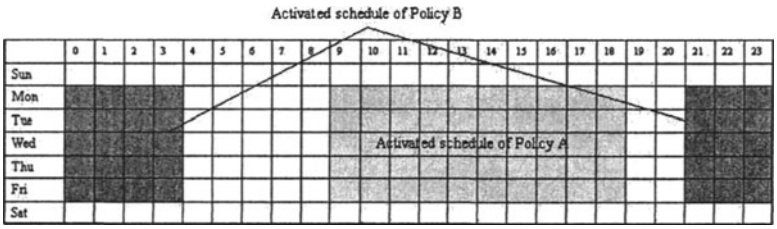

Figure 2 The activated hours of charging policy 1A and 1B.

3.1.2 Setting up the Virtual Lines

Once the charging policies are ready, the Virtual Lines can be set up by grouping the policies to a "larger" policy, which takes care of the bandwidth QoS and pricing schemes of a whole week. For example shown in Figure 3, Line Class 1 is in fact the Charging Policy 1 which is made by grouping Policy 1A, Policy 1B, Policy 1C and Policy 1D. Policy 1A specifies the working day bandwidth and the pricing may focuses on the Service type of business applications such as Http, SMTP, POP3 and NetBIOS and may be charged by consumed octets. Policy 1B specifies the bandwidth for Servers backup time (since the enterprise usually does their backup job in the midnight) and the pricing may focuses on FTP and the charging may be by time. Policy 1C is activated in the non-working hours so that the reserved bandwidth in this period maybe zero or lower than usual and the charging may be free or at a discount. Policy 1D specifies the very important videoconference time with higher bandwidth and more charging on VoIP service. Each policy has its own QoS specification and charging formula, takes care of its own activated hours and specifies a part of the Virtual Line. The Virtual Line can be composed of many policies, or only one policy, which is a policy with the whole week as its activated hours.

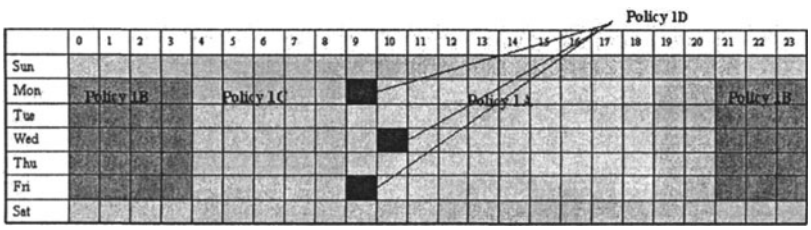

Figure 3 Line Class 1: composed of Policy 1A, Policy 1B, Policy 1C and Policy 1D.

3.1.3 Making User Policies

One of the features of the PBBS is *Customer-based Bandwidth Scheduling*, which means the customer (the bandwidth consumer) can allocate and schedule the bandwidth to meet his requirement. However, this is a trade off between the flexibility and complexity. To avoid the complexity of scheduling the bandwidth and keep the flexibility and convenience for the user, PBBS leaves only the User Policy to the user and let the manager take care of the complex part (making charging policies, set up Virtual Lines for users). The elements composed of a User Policy are just the factors the user has to consider: *the user's hosts*, *reserved period of date*, and *reserved Line Classes*.

The user's hosts are the target IPs to be achieved the bandwidth controls and billings. The target can be a single host, a group of hosts (a subnet) or a group of subnets. The user has to make choices from the required Lines for his hosts and schedules these Lines to meet his requirement. Figure 4 illustrates the Line schedule of an example User Policy. In this policy the user reserves the bandwidth from May 7 2001 to July 20 2001 with three classes of Lines. The days marked by indigo color are reserved with Line Class 1, which is set with the bandwidth for the use of working days (described in section 3.1.2). The days marked by green color are reserved with Line Class 2, which is set for the use of holidays.

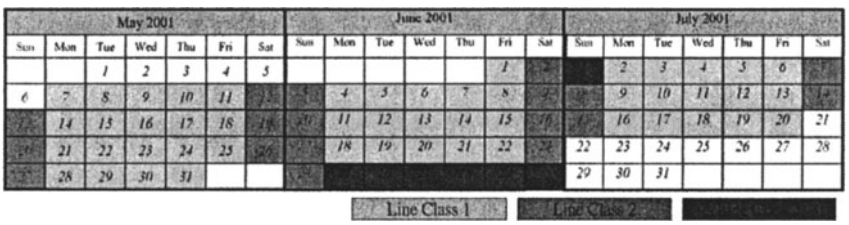

Figure 4 The scheduling of Virtual Lines in a User Policy.

Since there is always more than one customer, the set of Lines predefined by the manager may not be able to fit the demands of all customers. Besides, user may sometimes have an emergency using, for example, more bandwidth for a show in the World Trade Center from June 25 to July 1. The class of Line marked by red color in Figure 4 is provided to solve this problem. The user can specified his requirement to the manager and customize his own Line. At this time, the user has to learn and consider more details of charging and pricing, and how many decisions the user can make is left to the contract between the managers.

3.2 Policy-based Bandwidth Billing System

The *Policy-based bandwidth billing System (PBBS)* is designed as an add-on module of the PBMS. It aims at accounting, billing, and controls the bandwidth according to the user's requirement and payment via PBMS. The manager does not set the bandwidth policies directly, instead, he sets the *charging policies*, which, together with the *User Policies* decided by the bandwidth consumers, are converted to the Bandwidth Policies and are pushed to the PBMS to enforce the QoS settings. The PBBS communicates with the Policy Server, pushes bandwidth policies, and gets required logs of connections for pricing and billing. The billing related policies and logs are stored in the database of the PBBS module. The features of PBBS are as follows:

- *Supports all kinds of pricing scheme*: PBBS uses the Policy-based pricing scheme, which can be molded into flat rate pricing, duration-based pricing, volume-based pricing, service-based pricing, time-period-based pricing, or online-bandwidth-based pricing by changing the charging formula.
- *Customer-based Bandwidth Scheduling*: The users can schedule the bandwidth of his own free will. Describes in Section 3.1.3.
- *Billing following with controlling*: PBBS not only bills the users by metering their bandwidth usages but also can control the usage to avoid the illegal or exceeded using and reduce the waste on bandwidth.
- *Requires no change to existing protocols or applications*: The PBBS is an add-on module on the PBMS and requires no change in existing protocols or applications.

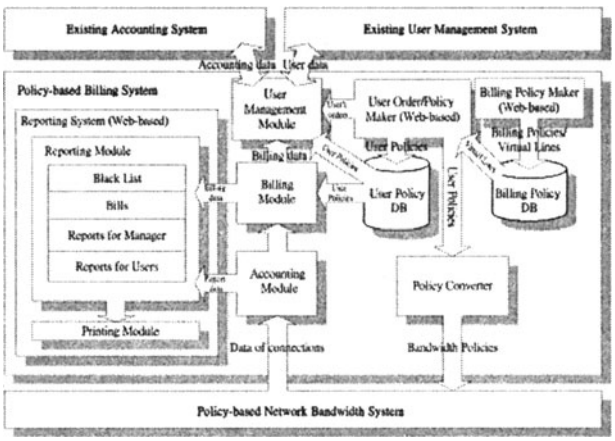

Figure 5 The architecture of the Policy-based Billing System.

The modules compose the PBBS shown in Figure 5. The charging policies are made by the PBBS and are converted and pushed to the PBMS. The job of the PBMS here is to reserve or control the bandwidth to meet the

required QoS according to the converted charging policies. The PBMS also takes care the metering and data collecting of all the connections going through it and exports all the raw data to the PBBS. PBBS then does accounting and billing and exports the reports and bills. Besides, the interface is available for PBBS to communicate with the existing financial system and the user management system that are used before the billing system is applied. This is to reduce the add-on efforts of transferring the users' data from the old system to the new one.

3.3 Converting User Policies to Bandwidth Policies

Because the PBBS is designed as an add-on module working on the Policy-based Bandwidth Management System, all the policies of PBBS have to be converted to the bandwidth policies that are acceptable by the PBMS. The jobs of the Policy Converter Module in PBBS are to pick out the QoS part of the User's Policies and to recombine them with the bandwidth policies, leaving the pricing part to the Billing Module.

A User Policy in PBBS is in fact a combination of a set of IPs, a set of charging policies (the Virtual Line) and the schedule times. Since the IPs can be converted directly to the condition of a Bandwidth Policy, most of the efforts of the Converter Module are on charging policies and schedule times. To describe how the policies are converted, let's take the policies illustrated by *Figure 4* as an example. In this example, the QoS settings are described in the user reserved Lines, which are specified by sets of charging policies. As a result, the converting should be started from extracting the QoS settings from these charging policies. The User Policy now can be extends according to its schedules.

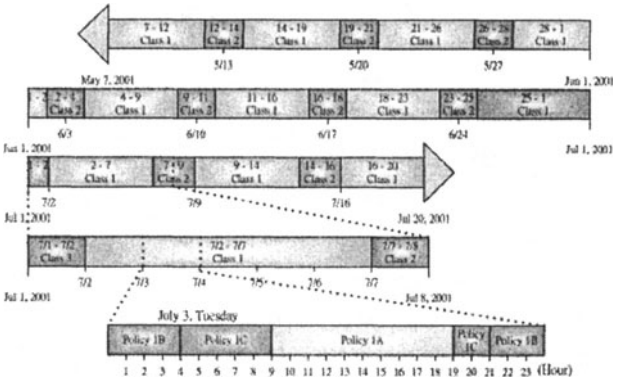

Figure 6 The User Policy extended by the schedule.

Figure 6 illustrates that the User Policy is in fact the combination of a sequence of charging policies arranged by their schedules in Line and in the User Policy. Each charging policy presents a set of Bandwidth Policies. The

QoS settings of the Bandwidth Policy can be obtained from the charging policy, and its schedule is the intersection of the schedule in virtual line and in charging policy as is shown in *Figure 7*.

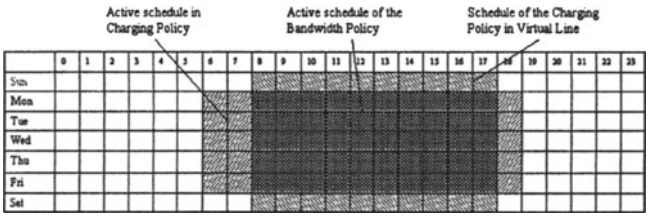

Figure 7 The schedule of the Bandwidth Policy is the intersection of the active schedule in Charging Policy and the schedule of the Charging Policy in Virtual Line.

4. IMPLEMENTATION

To demostrate the practicality of PBBS, an implementation is presented in this chapter. It takes BandKeeper system[9] as its bandwidth management and metering system. In order to have no modification on the BandKeeper system, the implementatoin of the PBBS are designed as an add-on module of the BandKeeper and use the PBBS Policy Maker instead of the BandKeeper Policy Maker. And the implementation demostrates making policies (charging policies, virtual lines and the user policies), and the bills.

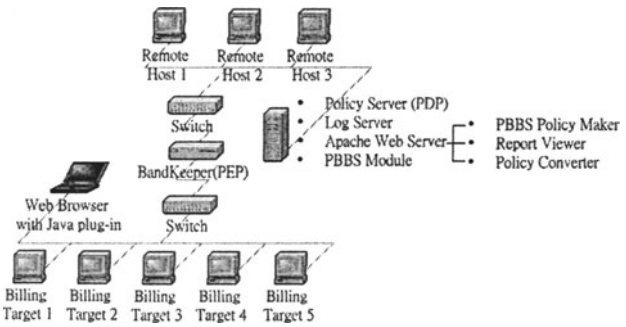

Figure 8 The environment of the implementation of PBBSv

Figure 8 shows the the simulation environment. The simulation presents a contrast between five different pricing schemes: flat rate pricing, duration-based pricing, volume-based pricing, service-based pricing and online-bandwidth-based pricing. Each scheme is applied to a single billing target. All the targets reserved the same bandwidth, and are controlled as possible as we can to have the same transmission time and octets.

The pricing scheme and charging formula for each billing target is shown in *Table 1*. Targets 1 and 2 are applied with the pricing schemes mostly used now by the ISPs (flat rate pricing and duration-based pricing). Target 3 is

applied with the volume-based pricing and the host quota is limitted to 1 Gbytes at most. Target 4 is applied with service-based pricing and the Ftp service is charged with higher price than other services. Target 5 is applied with online-bandwidth pricing. The fee for consumed bandwidth lower than or equal to 256 kbps is 0.5 dollars per minute (the default fee), and for bandwidth higher than 256 is 1.5 dollars per minute.

The bandwidth of all the targets is committed 512 kbps, which is specified in the charging policies. To generate identical and stable traffics for each billing target, a traffic generation tool called *Catapult* is used, which can build the required connections between two hosts according to the specified protocol type (TCP or UDP), service port and data size.

The simulation shows that the total cost varies greatly between different pricing schemes. In this case, the cost produced by the volume-based pricing is much higher than all other pricing schemes. To decide a reasonable charging method, many comercial issues and trade off between users and service providers have to be taken care of, and is beyond the scope of this paper.

Table 1 Pricing scheme for each billing target

Billing Targets	Pricing Scheme	Charging Formula ($: NT)
Target 1	Flat rate	*UC = Frcombw, Frcombw = 500*
Target 2	Duration-based	*UC = Frcombw * Tuse, Frcombw =0 5/min*
Target 3	Volume-based	*UC = (Fbwd_useo * Ouse)+ (Fhq_useo * Oexceed), Fbwd_useo=1.0/MB, Fhq_useo=2.0/MB*
Target 4	Service-based	*UC = (Fserv_ftp * Tuse_ftp) + (Fserv_other * Tuse_other), Fserv_ftp=1.5/min, Fserv_other=0.5/min*
Target 5	Online-bandwidth based	*UC = Fbwd_uset * Tuse_bwd + FbwOver256_uset * Tuse_bwOver256, Fbwd_uset=0.5/min, FbwOver256_uset=1.5/min*

5. CONCLUSION

Since the network provider's trend is providing levelled services and guaranteed QoS to users, a mechanism to charge for the services and to bill the users becomes an important issue from both the commercial and the management point of view. This paper proposes the Policy-based Bandwidth Billing System and the Policy-based pricing scheme that can handle all kinds of pricing situations and can meet most network providers' requirements. They can be applied to campuses, high buildings, the intranet of an enterprise, ISPs, or other IP based networks to construct a service-guaranteed network environment. The users can decide whether they would like to have better QoS and more bandwidth with higher payment, or the normal QoS and bandwidth with less cost.

The PBBS is currently based on the BandKeeper. However, lots of solutions of policy-based network management systems with similar functions are available. A billing system should not be restricted to a specific bandwidth management system. Instead, it should be designed as an independent module. A common interface and secure communications between the billing system and the bandwidth management system are further issues to be studied. Furthermore, when the Service Level Agreements (SLAs) is applied, the decision and the making of the charging policies and bandwidth policies should have some adjustments according to the contracts between providers and consumers. It remains an interesting open issue about the integration of the Policy-based Billing and the SLA.

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