A Dynamic Reservation Scheme based on Online Charging System with Family Shared Plan

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***Abstract*—For simplifying the bills and controlling the data usage, *Family Shared Plan* (FSP) is now a popular plan of telecommunications. Based on 3GPP specifications, *Online Charging System* (OCS) has to determine *Granted Unit* (GU) and create reservations per session before the services are delivered by the serving network. However, fixed GUs can not be adapted to dynamic consumer behaviors, such as travel, watching FIFA World Cup all night or taking pleasure in a new online application. Obviously, short of GUs will make redundant signals of reservation, but excessive ones will cause scarcity of resource. Since how to determine GU is an open issue by telecommunications operators, we design a new scheme to periodically assign dynamical GUs for subscribers belong to same FSP, based on their data usage and shared monthly data allowance. Simulation results not only show that our algorithm can substantially reduce redundant signals more than 3 times, no matter what unpredictable behaviors they do, but also observe interrelation between logging time and cooldown timer in our scheme.**

***Index Terms*—LTE, 4G, Reservation, Online Charging System, OCS.**

I. Introduction

Since Verizon launched its first *Family Shared Plans* (FSP) in June 2012 [1], it has become a popular plan of telecommunications. Subscribers belong to same FSP, whether they are family or not, use their own devices to surf the Internet and share the same quota with different consumer behaviors. For example, the aged call Skype to their abroad children, nine to five check their Google Calendar and hold an online meeting, teenager play online game or watch Youtube all day long.

More devices are attached to a FSP means that monthly data allowance is much faster exhausted than individuals. In fact, operators have different policies to deal with subscribers over using their monthly data allowance [2]. China Mobile (Hong Kong) will disconnect subscribers from network to prevent bill shock, Singtel (Singapore) will charge on per GB basic, but NTT docomo (Japan) will limit subscribers to access some services such as video streaming. For simplifying the bills and controlling the data usage, FSP can be set a monthly-capped value with upper bounds to limit the exceeded payment, even be disconnected network automatically.

Based on 3GPP specifications, Fig. 1 is Online Charging System (OCS) architecture for IMS services. When Subscribers enable their applications, such as Youtube, Line or Chrome, IMS Application Servers communicates with Session

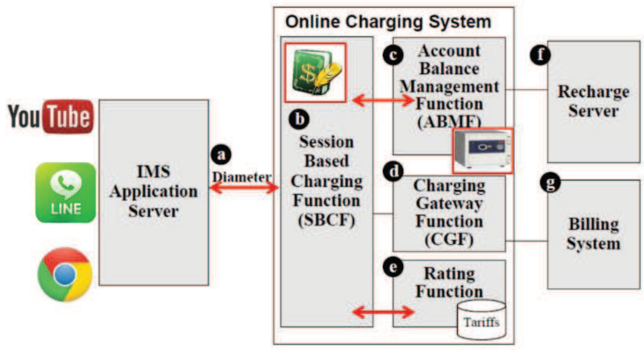

Fig. 1. Online Charging System architecture for IMS services

Based Charging Function (SBCF) using Diameter protocol. The SBCF performs session based charging and credit control. It communicates with the Rating Function (RF) in order to determine the value of the requested bearer resources or the requested session. On the other hand, SBCF communicates with the Account Balance Management Function (ABMF) to query and update the subscribers' account and counters status. When the prepaid user's credit depletes, the ABMF connects the Recharge Server to trigger the recharge account function. The Charging Gateway Function (CGF) is integrated with SBCF and transfer OCS charging data records (CDR) files to the operator's Billing Systems.

In more depth, Fig. 2 describes a Session based Account Reservation with Debit scenario for the case when the SBCF interacts with an ABMF over an Rc reference point [3]. When SBCF receives an online charging request for a certain service, it not only requests account and counter information for the subscriber from ABMF, but also manages the subscriber's context information and determine the tariff for the requested service involving the Rating Function. More important, SBCF has to determine Granted Unit (GU) and create reservations per session before the services are delivered by the serving network. In here, we can image ABMF is a "cash box" and GU as a "wallet" for a certain service, which is used as the service is delivered by the serving network or session parameters changed (e.g. QoS). Note that reservations maybe repeat zero or more times with GU used. Finally, SBCF will request the ABMF to debit the reservations when session ends. Note that the debit value may be equal or lower than reserved value.

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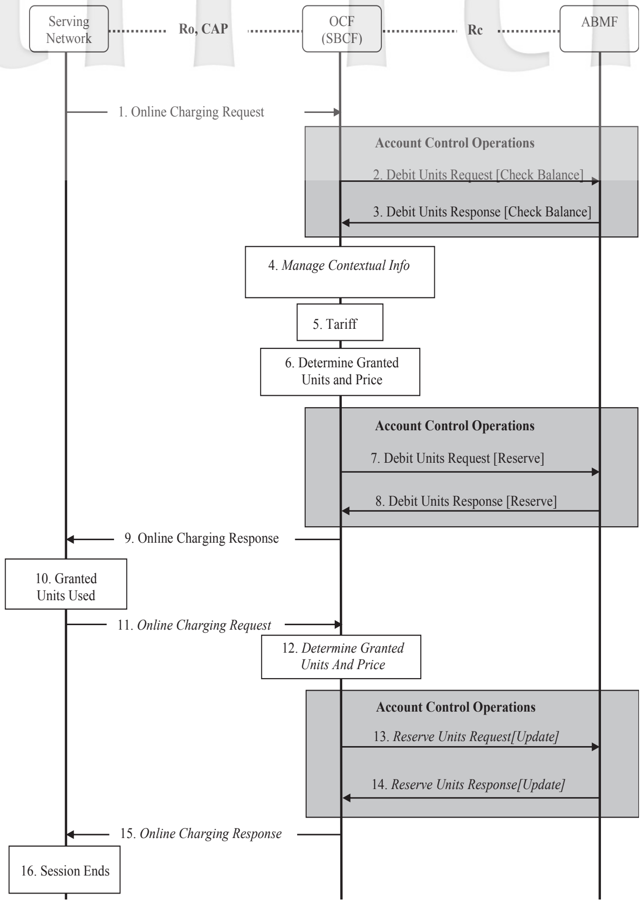


Fig. 2. Session based Account Reservation with Debit

Since how to determine GU is an open issue, fixed or multiple times GU is usually adopted by telecommunications operators. However, both schemes can not be adapted to dynamic consumer behaviors, such as travel, watching FIFA World Cup all night or taking pleasure in a new online application. Sometimes people will change their Internet behaviors in a short time, such as travel, watching FIFA World Cup all night or taking pleasure in a new online application. Obviously, short of GUs will make redundant signals of reservation, but excessive ones will cause scarcity of resource. Whether those reasons have brought about more data usage or not, operators need a new scheme to appropriately assign dynamical GUs for subscribers belong to same FSP, based on their data usages and shared monthly data allowance. The rest of this paper is organized as follows. Section II introduces related works such as specifications and papers. We propose our new scheme in Section III and compare its performance with fixed and multiple-times schemes in Section VI. Section V gives a conclusion of this paper.

II. Related Works

3rd Generation Partnership Project (3GPP) produces several specifications for OCS and diameter. [3] specifies in detail the Diameter based offline and online charging applications for 3GPP networks. It includes all charging parameters, scenarios and message flows. [4] specifies charging functionality and charging management in 3GPP networks. It covers all internal aspects of the OCS and contains the architecture and functions of the OCS logical components and thereby derives the functionality of the OCS interfaces. [5] specifies the Policy and Charging Control functionality for Evolved 3GPP Packet Switched domain, including both 3GPP accesses and Non-3GPP accesses. [6] is a study report for Rc reference point supported by ABMF. The study covers the drive and requirement analysis, existing architectures, key issues analysis, recommendations, etc. [7] specifies a Diameter application that can be used to implement real-time credit-control for a variety of end user services such as network access, Session Initiation Protocol (SIP) services, messaging services, and download services.

Diversified research has been proposed based on 3GPP specifications. [8] proposes three key aspects of online charging with respect to information utilization, signaling aspect, inter-domain aspect, service-based and component-based aspect. It also compares works in the literature based on the proposed criteria.

[9] defines a model and the possible use case scenarios in which the User Charging Context (UCC), such as available budget on subscriber's account or a list of available access networks, may be utilized in online charging and increase value for money. Authors further specify comparable measures for future online charging solutions by identifying the relevant context-related charging events in [10].

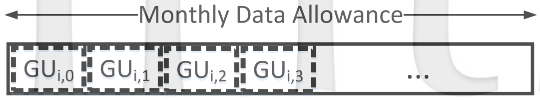
[11] develops an analytic model to investigate the performance of Recharge Threshold-based Credit Reservation (RTCR) mechanism for Universal Mobile Telecommunications System (UMTS). Therefore, network operators can select the appropriate recharge thresholds to reduce the probability of in-progress service sessions being forced-terminated. To avoid session suspension during credit reservation of the OCS prepaid mechanism, [12] proposes a Credit Pre-reservation Mechanism (CPM) before the credits at the gateway GPRS support node (GGSN) are actually depleted.

III. Proposed Schemes

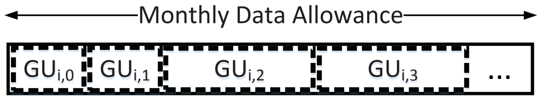
Table I is the notations we use. The most common scheme is *Fixed Scheme* (FS), which always allocate and recharge same default GU for every session. In addition, *Individual Scheme* (IS) also considers subscriber's previous monthly data usage and allocates different GUs personally, such as Fig. 3 (a).

$$GU_{i,j} = \frac{Previous\ Monthly\ Data\ Usage_i}{Days} \tag{1}$$

Despite easy implement, FS and IS are not suitable for variable subscriber's behaviors. Allocating excessive GUs maybe causes resource occupied problem, such as some subscribers can not use their network services even remaining monthly data allowance (RD) is not truly exhausted but AMBF keeps



(a)



(b)

Fig. 3. Basic schemes of (a) FS & IS, (b) MTS (w=2;m=2).

reserved GUs until the sessions end. On the other hand, insufficient GUs can lead to redundant signals of reservation. In practice, some operators adopt *Multiple-Times Scheme* (MTS), which monitor subscriber's reservation times and increase their insufficient GUs by multiple-times, such as Fig. 3 (b).

$$GU_{i,j} = \begin{Bmatrix} GU_{i,j-1} & ; & j\%w \neq 0 \quad \& \quad j \neq 0 \\ m \times GU_{i,j-1} & ; & j\%w = 0 \quad \& \quad j \neq 0 \\ Default\ GU & ; & j = 0 \end{Bmatrix} \quad (2)$$

Since how to allocate appropriate GUs can be reduced to a Subset Sum Problem, which is a NP-Complete Problem, we propose a new efficient scheme to appropriately assign dynamical GUs for subscribers belong to same FSP, based on their data usages and shared monthly data allowance.

TABLE I
NOTATIONS OF SCHEME.

Notation	Definition
N	Number of subscribers
U_i	i-th Subscriber; i $\leq$ n $\leq$ N
j	Counter of reservation times
w	Trigger of increasing GU
m	multiple-times for increasing GU
P	Logging period
Q	Cooldown timer
π	Remaining Time before billing date
RD	Remaining Monthly Data Allowance
S_i	Data Usage of UE_i
R_i	Remaining Granted Unit which S_i have
$GU_{i,j}$	Expected Granted Unit of S_i (if RD is well-to-do)
$GU'_{i,j}$	Expected Granted Unit of S_i (if RD is short of quota)
θ	Minimum unit for $GU'_{i,j}$ (e.g. 1 packet)

Fig. 4 is the idea of proposed scheme. Assuming operator has logged all subscriber's data usage over P period, the proposed scheme will be trigger when a subscriber's current GU is exhausted but his/her sessions have not yet ended. We describe detail steps below:

1) Checking the cooldown timer Q, which is designed to prevent excessive calculations of new GU. If Q is not yet overdue, the scheme will terminate remaining steps.

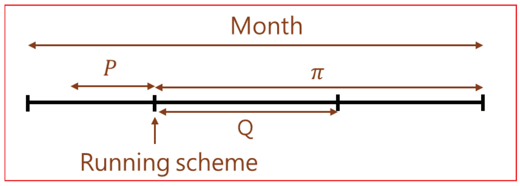
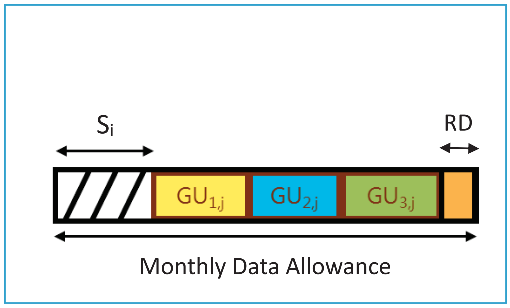
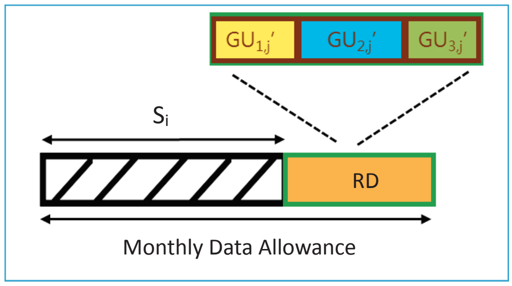


Fig. 4. Idea of proposed scheme



(a)



(b)

Fig. 5. Comparison of Remaining Data is (a) well-to-do, (b) short of quota.

2) Since we already know UE_i's data usage (S_i) in P period and (*RD*), we can predict how many quota of $GU_{i,j}$ should be reserved in remaining time before billing date (π). Note that we should subtract current Remaining Granted Unit (R_i) which UE_i already have.

$$GU_{i,j} = \left(\frac{\pi}{p} * S_i\right) - R_i \quad (3)$$

3) Check the sum of $GU_{i,j}$ whether exhaust RD or not.

$$check\ if\left(\sum_{i=1}^{N} GU_{i,j} \geq RD\right) \quad (4)$$

- If *RD* is well-to-do, we can reserve each $GU_{i,j}$ same as we predict by (3) such as Fig. 5 (a).
- If *RD* is short of quota, we should normalize and reserve each $GU_{i,j}$ fairly such as Fig. 5 (b). Note that we should use floor function to keep minimum unit, such as one packet.

$$GU'_{i,j} = \left\lfloor \frac{GU_{i,j}}{\sum GU_{i,j}} * RD \right\rfloor \quad (5)$$

4) *RD* finally remain a small quota when GUs keep be reserved. Therefore, we adopt *First-Come-First-Reserve* (*FCFR*) to reserve whole *RD* to a subscriber and then terminate our scheme.

$$check\ if\ (RD < n \times \theta) \Rightarrow FCFR \qquad (6)$$

Note that *FSP* has exhausted all monthly data allowance in this moment and all subscribers should be terminated their network service or decrease their transmission rates based on policies.

IV. Simulation Analysis

Using C++ language, we develop a simulator to count reservation times. Table II describes notations used in Table III, which shows different behaviors of three occupations: geek, worker and student. We set three subscribers, one geek, one worker and one student, belong to a same FSP, and observe the influence of logging period (P) and cooldown timer (Q) in our proposed scheme, respectively. Besides, we compare our scheme with two kinds of fixed schemes. Note that all simulated results are average of 10000 times.

TABLE II
NOTATIONS OF BEHAVIOR

Notation	Definition
H	High usage ; 70 - 110 KB per minute
M	Middle usage ; 40 - 60 KB per minute
L	Low usage ; 10 - 30 KB per minute
X	None usage

TABLE III
BEHAVIORS OF OCCUPATIONS

Time	Geek	Worker	Student
00:00 - 01:00	H	X	X
01:00 - 02:00	H	X	X
02:00 - 03:00	H	X	X
03:00 - 04:00	H	X	X
04:00 - 05:00	X	X	X
05:00 - 06:00	X	X	X
06:00 - 07:00	X	X	X
07:00 - 08:00	X	H	M
08:00 - 09:00	X	M	L
09:00 - 10:00	X	M	L
10:00 - 11:00	X	M	L
11:00 - 12:00	X	M	L
12:00 - 13:00	L	L	L
13:00 - 14:00	L	M	L
14:00 - 15:00	L	M	L
15:00 - 16:00	L	M	L
16:00 - 17:00	L	M	L
17:00 - 18:00	L	H	M
18:00 - 19:00	L	L	M
19:00 - 20:00	H	L	M
20:00 - 21:00	H	L	H
21:00 - 22:00	M	H	H
22:00 - 23:00	H	H	L
23:00 - 24:00	H	L	X

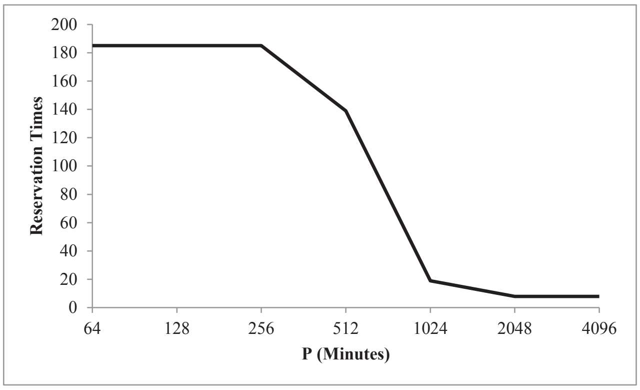


Fig. 6. Observing logging period

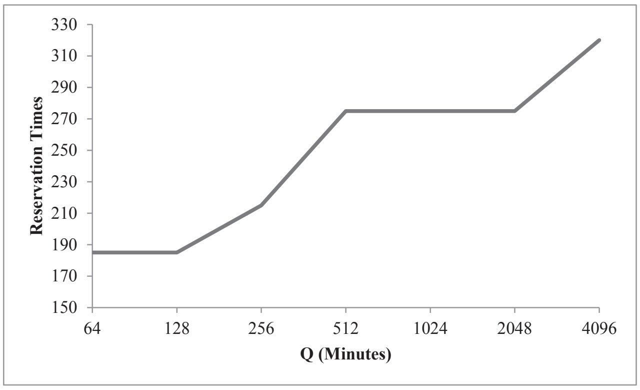


Fig. 7. Observing cooldown timer

A. Logging Period

In Fig. 6, *P* is gradually increased with multiple times and *Q* is set for 10 minutes. We can observe that reservations times are obviously decreased since we log enough time. This phenomenon is reasonable because sufficient logging period can predict expected GUs precisely. Note that reservation times are fixed before 256 minutes and after 2048 minutes, it reflects short P can't improve our scheme and appropriate one is 2048.

B. Cooldown Timer

In Fig. 7, *P* is set for 10 minutes and *Q* is gradually increased with multiple times. We can observe that reservations times are gradually increased since we relax the cooldown timer. This phenomenon reflects that expected GUs are unprecise since Q is not yet overdue to calculate the new ones. Note that appropriate Q is 128 minutes because reservation times are fixed before 128 minutes.

C. Comparison

Since P and Q are variables which operators can tune by their policy strategies, we set P to 2048 minutes and Q to 128 minutes in Fig. 8, based on the appropriate ones from Fig. 6 and Fig. 7. Two kinds of fixed GU schemes, FS and IS, are compared with our proposed scheme. Note that each

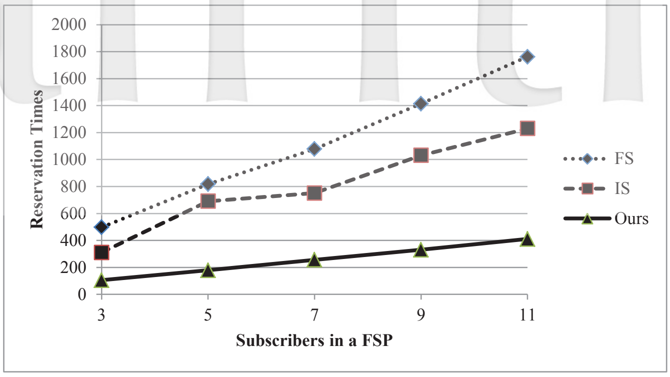


Fig. 8. Comparison

subscriber's behaviors is set randomly based on Table III. We can observe that our scheme can substantially reduce redundant signals more than 3 times, no matter how many members in a FSP or how unpredictable behavior they have. This phenomenon shows that our scheme can appropriately assign dynamical GUs for subscribers, based on their data usages and shared monthly data allowance.

V. Future Works

For simulations, we will further compare our scheme with practicable scheme working on really OCS system, which GUs are same at initial but gradually increasing with multiple-times, such as MTS. Besides, we will consider that subscribers are willing to buy more data entitlements (e.g. RD will be recharged) and calculate the appropriate GUs for all subscribers. We believe our research is a pioneer in Smart Data Pricing (SDP).

Acknowledgments

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