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Introduction

Niklas Zennström, a co-founder of Skype, stated: "It's the same thing with Skype. Some users are paying for services, but not everyone." Although services such as Skype have promoted free phone calls, *Charging, Billing and Accounting* (CBA) are still among the most important activities in telecommunications operation today. The charging function collects information related to chargeable events, correlates and processes the charging data, which are sent subsequently to the billing functional entity. The billing function processes the records coming from the charging functional entity according to the respective tariffs in order to calculate the charge for which the user should be billed. For example, it processes the call detail records to create some final output, which can be invoices for customers. The accounting function enables an automatic procedure for sharing of revenues, where the portion that is due to each player is calculated based on the agreement between the involved players [Kou04].

In mature markets, service differentiation is a key driver for telecom operators and service providers. As the convergence of services and networks accelerates, a major challenge will be to offer more services, innovative business models, and enhanced service accessibility. Charging and billing are a key part of the service delivery chain that supports the service differentiation challenge. They must offer the necessary flexibility and universality in order to follow, and sometimes anticipate, the evolution of service offer catalogs.

Various billing policies have been exercised in the *Public Switched Telephone Network* (PSTN). For example, in Taiwan, charges for local calls are on a per-minute basis, while charges for cellular services are on a per-minute basis or a per-second basis. Conversely, in the US, local calls can be provisioned under a monthly flat-rate charge. Flat-rate charging reduces the per-call billing cost, which is a primary motivation in the recent evolution of billing systems.

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Billing World [Mor96] reported that two of the most desirable attributes of telecommunications billing systems are:

- the flexibility of upgrading it; and
- the capability to quickly inform the in-house billing experts about its status.

Telecommunications services are "culture sensitive" and the method of service charging significantly affects customer behavior. For example, since US cellular users are charged for radio access whether they place or receive calls, they tend to share their phone numbers carefully to avoid "junk calls". In Taiwan, however, since called parties are not billed, cellular users tend to distribute their phone numbers as widely as possible to enhance their business opportunities. To maximize profits, a cellular carrier needs to offer a variety of billing plans for the same services, and may need to adapt the plans to the "customer culture". Thus, the ease of upgrading is an important attribute of the billing system.

Another important attribute is the timely provision of billing status reports, which are essential for monitoring and diagnosing the billing system. One way to achieve this attribute is to report the customer billing records in real time. In PSTN, the real-time billing information is delivered through the *Signaling System No.7* (SS7) network. There are three formats for customer billing:

- The *full-detail format* provides all details (including the date, time elapsed prior to connection, calling number, called number, duration of call and charge) for each call.
- The *bulk-bill format* indicates the usage amount, the allowance amount, and the total usage charges over the allowance amount of a call.
- The *summary-bill format* provides the bulk-bill information and a summary showing total calls, overtime minutes, and the associated charge.

The full-detail format is typically used for long-distance calls while the bulk-bill and summary-bill formats are used for local calls. The billing information is produced from the *Automatic Message Accounting* (AMA) record, which is used primarily by local telephone companies to process billing records and exchange records between systems. The AMA record created by Telcordia (formerly Bellcore) is typically delivered in an SS7 message. During the call setup/release process, the monitor system tracks SS7 messages of the call and, once the call is complete, generates a *Call Detail Record* (CDR) in the AMA format. The CDR is then transferred to the rating and billing system.

In the traditional circuit-switched domain, a CDR is the computer record produced by a telephone exchange containing details of a call that passed through it. In the packet-switched domain, a CDR is generated by a network node for a data session. The "CDR" term is referred to as a *Charging Data Record*. In this book, CDR stands for "Call Detail Record" in a typical telephone call, and for "Charging Data Record" in a data session.

The possibility of cellular users roaming from their "home network" to a "visited network" causes difficulty in providing real-time customer billing records. When a cellular user is in a visited network, the billing records for all call activities remain in the visited network. In the 2G cellular roaming management/call control protocol [Lin95], the visited network and the home network do not interact at the end of a call. Instead, the billing information remains in the visited system as a "roam" type data record in *Cellular Intercarrier Billing Exchange Roamer Record* (CIBER) [Cib] or *Internet Protocol Detail Record* (IPDR) [Ipd] formats. These data records are batched and periodically sent to a clearinghouse electronically, and are forwarded by the clearinghouse to the customer's home network later. Alternatively, a roaming user manager may be responsible to forward billing records concerning roaming users to their home operators and support the *Transferred Account Procedure* (TAP), which converts and groups billing records in files under the TAP format in order to be sent to the respective operators.

The performance of the transmission of billing information depends on the frequency of information exchange. In an ideal case, records would be transmitted for every phone call to achieve real-time operation. However, real-time transmission would significantly increase cellular signaling traffic and seriously overload the PSTN signaling network. In order to achieve billing status reports quickly, a tradeoff should be made to balance the frequency of the billing transmission with the signaling traffic [Fan99].

In the *Universal Mobile Telecommunications System* (UMTS), a *Charging Gateway* (CG) can generate CDRs and transfer them to the billing system using the *File Transfer Protocol* (FTP) [IET85]. The CDRs are transferred in either push or pull modes [3GP06b]. In the push mode, the CG pushes the charging records to the billing system. CDRs generated from the charging node are transferred to the billing system at a frequency controlled by the CG. In the pull mode, the billing system pulls the charging records from the CG. The time and frequency of the file transfer is controlled by the billing system.

1.1 Charging for Mobile All-IP Networks

By providing ubiquitous connectivity for data communications, the Internet has become the most important vehicle for global information delivery. Furthermore, introduction of the 3G mobile system has driven the Internet into new markets to support mobile users. Specifically, the *Internet Protocol* (IP) has played a major role in UMTS in providing a wide range of connectionless services to mobile users [Lin05a].

The Internet environment encourages global usage with flat-rate tariffs and low entry costs. A major problem of the "flat-rate" tariffs is that such a business model cannot justify the expensive equipment/operation investments of mobile services [Das00, Fal00, Rei06]. Mobile telecom operators have to move from a bit-pipe model to a revenue-generating services model. To integrate IP with wireless technologies with the “right” business model, the *3rd Generation Partnership Project* (3GPP) proposed UMTS all-IP architecture to enable web-like services and new billing paradigm in the telephony world. This architecture has evolved from *Global System for Mobile Communications* (GSM), *General Packet Radio Service* (GPRS), and UMTS Release 1999 to Releases 4–8. UMTS Release 4 introduces the *Next Generation Network* (NGN) architecture for the *Circuit Switched* (CS) and the *Packet Switched* (PS) service domains. UMTS Release 5 introduces the *IP Multimedia core network Subsystem* (IMS) on top of the PS service domain. This evolution requires new mechanisms to collect information about chargeable events and to impose flexible mobile billing schemes (such as time-based, volume-based, or content-based).

A telecom operator typically provides *offline charging* (referred to as postpaid charging) where the charging records are collected and then sent to the billing system once the service has been delivered. On the other hand, prepaid telecommunications service requires a user to make an advanced payment before the service is delivered. Usage of prepaid service does not require deposit and monthly bill. Instead, the usage fee is directly deducted from the user’s prepaid account. (Figure 1.1 shows an example of prepaid recharge webpage. The users can refill the prepaid accounts through this

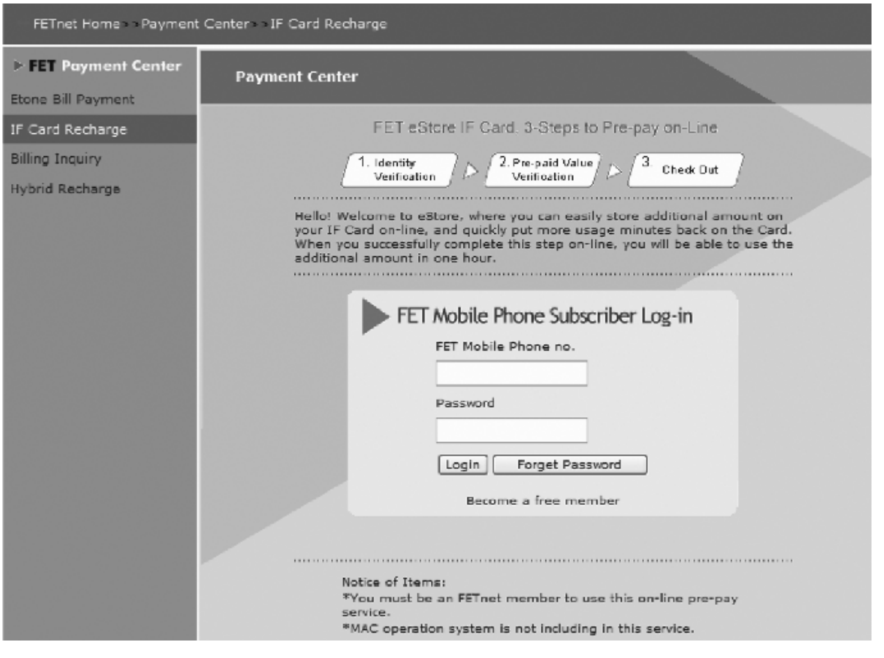

Figure 1.1 A recharge webpage for prepaid card (reproduced by permission of Far EasTone Telecommunications Co., Ltd)

webpage when the prepaid credits are completely or nearly depleted.) The prepaid viewpoint for telecommunications services has been deployed and studied for more than a decade (see Chapter 17 in [Lin01]). This service was offered in Europe and Asia in 1982 and became popular in the US in 1992 [Art98]. In Europe and quite a few Asian markets, more than 50% of new mobile subscribers are prepaid users [HP02]. Four billing technologies have been used in traditional (circuit-switched) mobile prepaid service: hot billing approach [Lin00]; service node approach [Cha02a, Cha02b]; handset-based approach; and *Intelligent Network* (IN) approach [Lin06]. Details of these approaches will be given in Appendix G. The first three approaches are already outdated due to significant operation and maintenance costs. The fourth approach still exists and has been evolved from early IN versions to the *Customized Application for the Mobile Network Enhanced Logic* (CAMEL) approach to be described in Chapter 5.

A traditional prepaid approach is typically used to handle only one voice call session at a time. In this case, all prepaid credits are allocated to the in-progress circuit-switched voice session. In advanced mobile data services, the data sessions are packet switched, and multiple prepaid sessions must be accommodated simultaneously. To address the above issues, the telecom networks have evolved from the SS7-based architecture into the all-IP based architecture [3GP, DIA, Kur06a, Kur06b]. The main focus of this book is on pure IP-based mobile charging techniques.

Advanced mobile telecom incorporates data applications with real-time control and management, which requires a convergent and flexible online charging system. Such convergence is essential to mitigate fraud and credit risks and provide more personalized advice to users about charges and credit limit controls. *Online charging* allows simultaneous prepaid and postpaid sessions to be charged in real time. This feature is important for telecom operators to support multiple service deliveries simultaneously. The subscribers cannot make purchases that either exhaust the prepaid balance or exceed the credit limit. Through online charging, the operator can ensure that credit limits are enforced and resources are authorized on a per-transaction basis. From a subscriber's perspective, knowing the charges in advance and having self-imposed credit limits can make the cost of services more transparent. Real-time rating/charging functions help subscribers to control their budgets, and telecom operators to reduce bad debts.

By merging the prepaid and postpaid methods, the *Online Charging System* (OCS) [3GP06a] proposed in UMTS Releases 5 and 6 eliminates duplicate processes such as service development, production support, pricing, and general management activities. In other words, online charging only requires a single set of management processes, which reduces operational costs and enhances flexibility on billing and product diversification. The OCS approach is estimated to reduce 25% of the product launch costs [Con05]. This real-time solution provides two-way communications between network nodes and the charging/billing system, which transfer information about rating, billing and accounting. When the OCS receives a service request from an application server (or a network node), it queries other relevant components, then determines and returns a response to the application server. In contrast, in an offline environment, all usage records typically flow through the billing system in one direction after the service has been delivered.

The IMS architecture supports both online and offline charging methods. In online charging, IMS nodes dynamically interact with the OCS. The OCS in turn processes the user's account in real time and controls the service charges. In the IMS offline method, the IMS network nodes collect the charging information and then send to the billing system after the service is delivered. The charging/billing system does not control the service usage in real time. In this model a user typically receives the bill on a monthly basis.

1.2 Online Charging

The OCS is flexible enough to support multiple charging/billing models. For example, a mobile user might be charged by connection time or by the amount of data transferred. The user may also be given free access to certain websites. Some subscribers may use prepaid billing and others may use postpaid billing. The OCS can support all these requirements for a service provider. Consider a bundle mixing triple play and mobile services for a family, which requires highly flexible rating and community charging capabilities offered by the OCS [Alc07]. The package consists of the following items:

- A 60-euro monthly fee, including triple play services covering unlimited national calls (VoIP), Internet access, and access to selected TV channels (IPTV); a mobile bundle with two hours of mobile communications to national mobile numbers, 30 national short messages, and 10 national multimedia messages.
- The children have their own mobile prepaid account limited to 30 minutes of national voice and 10 short messages debited from the family bundle. They can top up their prepaid account with scratch cards when the balance is exhausted.
- All other calls (outside the monthly fee) are charged by time and destination.
- All services are charged on a single monthly bill.

From the OCS rating viewpoint, the following functions are required:

- Management of the monthly fee (60 euros) with several balances in units (short messages, minutes, multimedia messages, and so on).
- Community management, with routing of charges to the family account, and a limit on the children's usage.
- Out-of-bundle call charging according to the appropriate tariff plan.
- CDR generation and aggregation for the monthly bill.

When a subscriber is first authorized and starts to access the service, the network nodes may send periodic credit control messages to the OCS. For example, the IMS application server might send a credit control request for every megabyte of data downloaded. When the OCS receives these credit control message requests, it updates the subscriber's account accordingly.

The OCS supports *prepaid service* that requires a user to make a payment in advance before enjoying the service. Prepaid service does not require a monthly bill. Instead, the user's prepaid account directly deducts the fee. Depending on the type of requested prepaid service, the OCS reserves an amount of prepaid quota in the subscriber's account before authorizing the service. The OCS deducts the prepaid credit in real time when the prepaid service is delivered.

An example of a prepaid service is described as follows: Suppose that a prepaid subscriber wants to download an MP3 music file that costs $5.00. The IMS application server first sends the reservation request to the OCS. The OCS then determines the price and reserves $5.00 in the subscriber's account. The OCS authorizes the transaction by sending a message to the application server. When the subscriber completes downloading the music file, the application server sends an accounting message to the OCS to indicate that the service has been delivered. The OCS then deducts the reserved $5.00 from the subscriber's account. If the downloading fails (because, for instance, the subscriber cancels the request), the application server sends an accounting message to indicate that the service was not delivered. The OCS then reclaims the reserved $5.00 for the subscriber's account. If the subscriber attempts to download the MP3 file again, the service must be re-authorized.

Another example for online charging is described as follows: Suppose that a subscriber pays for access based on the duration of the connection; for instance, the fee for playing 10 minutes of an online mobile game might be $1.00. Assume that a subscriber has $10.00 in her prepaid account. When she attempts to play the online mobile game, the OCS authorizes and reserves $1.00 for the first 10 minutes of connected time. The subscriber starts playing the mobile game; after 10 minutes, the IMS application server informs the OCS that the subscriber has been playing for 10 minutes. The OCS then deducts $1.00 from the subscriber's account. If the subscriber continues to play the game, the OCS reserves another $1.00 for every additional 10 minutes of connected time.

After the subscriber has played for 100 minutes, her account will be depleted. The next reservation request will be denied. In this situation, the application server might inform the subscriber that she needs to replenish her account before continuing to play the game. The subscriber might purchase a refill card or replenish the account by using her credit card.

The OCS can be configured to determine the status of each subscriber based on the account type (prepaid or postpaid), the duration of service (long-time or new subscribers), or amount of money spent in the last month (high-usage or low-usage subscribers). Different types of subscribers could be handled differently. For example, long-time subscribers could be given preferential treatment. New or high-usage subscribers could be given free access time for promoted services.

The OCS also supports price enquiry; e.g., through *Advice of Charge* (AoC). If a subscriber wants to know the estimated price of the IMS service before purchasing it, the IMS application server issues a price enquiry to the OCS, which checks the fee and returns the estimated price to the application server. The application server then shows the estimated price to the subscriber.

1.3 Concluding Remarks

In this chapter, we introduced telecom charging and billing, which are two of the most important activities in telecommunications networks. We described various billing methods exercised in the PSTN. We elaborated on the offline and online charging mechanisms for mobile all-IP networks and described examples for online charging. Throughout this book, we will introduce advanced charging techniques and mechanisms. Here we emphasize that service providers need to use these charging models wisely so as not to infringe on their ethical responsibility to their customers. As Judge Harold H. Greene said, "The emphasis on getting business and billing goes far beyond the professionalism of law and does the profession injustice." Such injustice is what we must avoid.

Review Questions

1. Describe two of the most desirable attributes for telecommunications billing systems.
2. Which protocol can be used for real-time billing transmission in the PSTN?
3. Describe three formats for customer billing. How are these formats used?
4. What is the difficulty of providing real-time billing records in a cellular system?
5. Which protocol is used for CDR transmission to a billing system in UMTS?
6. Describe two billing record formats used for roaming in a cellular system.
7. Briefly describe the evolution of the UMTS all-IP network.
8. Describe how the traditional prepaid mechanisms (such as hot billing approach, service node approach, and handset-based approach) work. Why are they outdated? (Hint: see Appendix G.)
9. Describe online charging and offline charging. Why is online charging important?
10. Show two online charging services and briefly describe how they work.

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