Abstract

During the past few years, the mobile prepaid service has been growing exponentially all over the world. Four approaches have been proposed to provide mobile prepaid service. We describe these approaches and compare their strengths and weaknesses. Our analysis indicates that the handset based approach is a low-cost, high-risk solution. The wireless intelligent network approach is a high-cost, low-risk solution. The service node approach is a quick solution, which allows fast deployment with limited capacity. The hot billing approach is an average solution that cannot provide real-time rating.

Mobile Prepaid Phone Services

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Prepaid phone is a telecommunication service that requires a customer pays before the calls are made. In the early days, coins played an important role in prepaid phone service. The telephone companies then realized that coins present a range of problems. For example, extra overhead is required to periodically collect the coins. Furthermore, coin payphones are likely to be damaged due to vandalism for coin stealing. To avoid equipment damage and revenue loss, prepaid cards were invented, which have become the fastest growing payment method. The average availability of smart-card-based payphones is more than 95 percent, while the comparable figure for coin phones is less than 70 percent [1]. Prepaid telecommunication services were offered in Europe and Asia in 1982 and became popular in the United States in 1992 [2]. In the United States, more than 30 prepaid solution vendors are competing for carrier business [3].

During the past few years, mobile prepaid service has grown exponentially all over the world. In 1997 there were about 60 million Global System for Mobile Communications (GSM) subscribers across the world, and 8 percent of them subscribed to prepaid service. It is predicted that in 2001, the number of GSM subscribers will increase to 140 million, and 25 percent of the customers will subscribe to the prepaid service [4]. Asian countries such as the Philippines, Australia, Hong Kong, Singapore, and Taiwan have already shown successful examples of prepaid services. It is estimated that the worldwide prepaid revenue will be US$102.8 billion annually by the year 2007 (http://www.baskerville.co.uk).

In *postpaid* service, the customer pays for telecommunication service after a period of time, typically a month. Postpaid may exhibit a high deposit barrier and the risk of bad debt. These disadvantages can be removed or reduced by prepaid service, which allows a smaller prepayment to go immediately toward customer usage. In the beginning, the prepaid cards used in pay phone applications were simply token cards whose main benefit was to address the theft and vandalism issues associated with the use of cash. Later, more advantages were exploited. From the service provider's viewpoint, business operation costs have been significantly reduced for prepaid service. The additional costs of credit checking and collection can be eliminated, because no service is provided if the end user does not deposit enough money in the accounts. In other words, service can be offered to people with bad credit (as high as 40 percent of the prepaid customer population), and revenue is received typically one and a half months earlier than for postpaid service. Since it is not necessary to bill prepaid subscribers, printing of invoices and management of accounts are avoided.

From the customer's viewpoint, prepaid service provides immediate service without the need to sign a long-term contract of commitment, which allows better control of spending. Although new electronic payment procedures are likely to make possible short-term contracts for post-paid services, such solutions are not widely used, and most prepaid customers do not want any contract at all. Particularly, many end users (especially the young) just want to enjoy the service and simply do not want to fill in subscription forms. Their need can be satisfied by prepaid service. Imagine buying a prepaid GSM subscription in the supermarket! Furthermore, prepaid service eliminates the monthly subscription charge and reduces the perceived risk of stolen or lost cards. The above discussion of prepaid telephone services implies that any customer-imposed barrier to entry is relatively low. This conclusion is particularly true for mobile phone service. In Taiwan, FarEastone reported that in May 1999, more than 40 percent of its 1.2 million customers subscribed to prepaid service within one year of the company launching prepaid service in mid-1998.

Although fixed and mobile prepaid services share many characteristics, they have two major differences. First, a fixed telephone service provider knows nothing about the prepaid customers [2]. Second, fixed prepaid service only allows outgoing calls. On the other hand, mobile prepaid service allows both incoming and outgoing calls. Thus, no account management is required in fixed prepaid service. A subscriber simply buys a calling card and starts making calls. As soon as the prepaid balance is used, the card is inactive. On the other hand, to provide mobile prepaid service, a prepaid service center is required to perform account management and other functions, as we elaborate on later. We should also point out that although prepaid service has several advantages over postpaid service, it has its limitations. For example, some mobile operators do not allow roaming to prepaying customers, since roaming costs would quickly consume the prepaid credit. On the contrary, they allow roaming in the post-paid case, provided the customer pays by credit card.

This article describes and compares four mobile prepaid service solutions. We will illustrate these solutions based on GSM. Our descriptions can be generalized for other mobile phone networks such as IS-136 Digital Advanced Mobile Phone Service (AMPS) and IS-95 cdmaOne. We first identify the requirements for mobile prepaid service. Then we describe mobile prepaid

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service approaches based on hot billing, handset, service node, and wireless intelligent network. These approaches are compared to provide guidelines for service providers to select their prepaid service platforms.

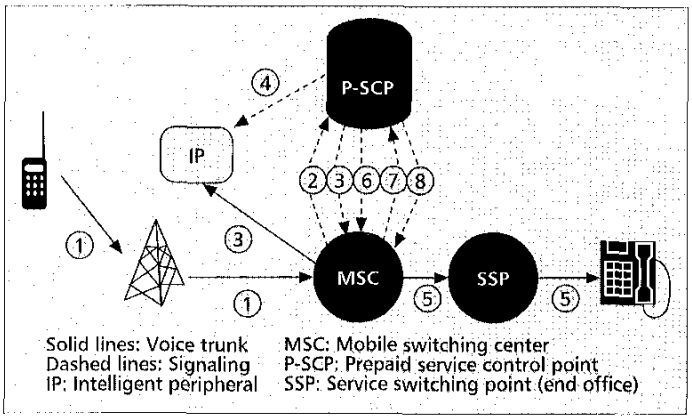
Mobile Prepaid Services

We use GSM as an example to illustrate how prepaid service works. In GSM prepaid service, a customer subscribes to the GSM service with a prepaid credit. This credit is either coded into the *subscriber identity module* (SIM) card or kept in the network [2]. In many service areas, initialization of a prepaid customer must be completed within a certain number of days after subscription. In Taiwan, prepaid service is available immediately after purchasing the service. Whenever the customer originates a prepaid call, the corresponding payment is decremented from the prepaid credit. A status report of the credit balance can be obtained from the SIM card or network.

If the balance is depleted, the customer cannot originate calls, but may be allowed to receive phone calls for a period (e.g., six months). To recover the prepaid service, the balance needs to be recharged by purchasing a top-up card. The top-up card is like a lottery scratch card. When the seal is scratched off, a secret code appears. The customer dials a toll-free number and follows the instructions of an interactive voice response (IVR) to input the *mobile station ISDN number* (MSISDN, i.e., the GSM phone number) and the secret code. The system will verify and refresh the account if it is a valid code. On the other hand, if the prepaid balance is not depleted at the end of a valid period, the balance is automatically reset to zero. After a certain period of time, the unused prepaid credit may be considered abandoned and becomes the operator's or government's property.

Several mechanisms in mobile prepaid service are not found in fixed prepaid service:

- An extra billing system is required for mobile prepaid service. Various rate plans must be maintained based on destination of call (local, national, international), particular numbers (premium rate or free), partitioning of airtime vs. land network usage, call forwarding charges, and so on. Tariff switching is required when a customer moves around different areas during prepaid calls.
- A real-time usage metering function must be built into the prepaid service system to monitor the amount of remaining credit on the customer account. This function measures the services provided to the customer, and decrements the balance during service or immediately after service is completed.
- Sales taxes are generally collected at the *point of sale* (POS) for prepaid. Other taxes (universal service fees, relay service fees, presubscribed line charges, and federal access charges) are embedded in the cost of the prepaid product and then allocated by the service provider accordingly. Due to the mobility of prepaid customers, mobile service providers must understand usage originating from different tax jurisdictions based on mobility databases such as the home location register (HLR) and visitor location register (VLR) [3].
- A customer care mechanism maintains items including customer activation time, deactivation time, credit value, remaining time period, PIN information, deletion time, reason for subscriber deletion, and so on. An easy credit-refresh mechanism is essential to encourage customers to continue to prepay for service. The mechanism should also generate solicited responses to customer balance inquiries and unsolicited warnings when the customers' remaining balances are below predetermined thresholds.



■ **Figure 1.** *WIN prepaid call origination.*

Four solutions have been proposed to implement prepaid services. The wireless intelligent network approach follows a standard intelligent network protocol to implement the prepaid mechanism. In this approach, the credit-counting mechanism is implemented on the service control point. The service node approach attaches an external node to the MSC. This service node is based on computer telephony integration (CTI) or private branch exchange (PBX) technologies, which implements all prepaid functions without requiring any hardware/software modification to the mobile service center (MSC). The hot billing approach utilizes call detail records in existing billing systems to implement prepaid functions. A prepaid service center is required, which modifies a prepaid user's credit on a per-call basis. The handset-based approach performs credit deduction at the MS. This mechanism is typically implemented at the SIM card in GSM. In the remainder of this article, we elaborate on these service solutions and their implementations.

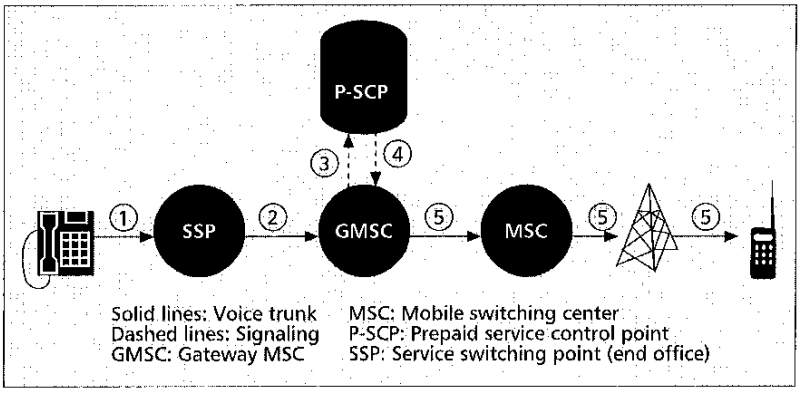
The Wireless Intelligent Network Approach

The *wireless intelligent network* (WIN) approach is considered a complete solution to prepaid service. In this approach a *prepaid service control point* (P-SCP) communicates with the MSC through an SS7 signaling network. Several WIN triggers are defined. At prepaid call setup and during the call holding time, the MSC encounters WIN triggers at different stages, which remotely instruct the P-SCP to carry out decisions about how that call should be processed based on prepaid applications. All billing information for a prepaid customer is stored in the P-SCP. The mobile network may need extra SS7 links to accommodate signaling traffic generated by the WIN prepaid mechanism.

WIN Call Origination

Figure 1 illustrates WIN call origination with the following steps:

- Step 1 — The prepaid customer initiates a call by dialing the called party's telephone number.
- Step 2 — The MSC encounters the WIN call setup trigger. The call setup process is suspended, and a prepaid call request message is sent to the P-SCP. The message includes the MSISDN, location information of the MS, and called party telephone number. The P-SCP determines whether the customer can make the call by querying its database. Based on threshold processing parameters defined in the prepaid billing system, the P-SCP may deny or accept the call. Assume that the call is accepted.



■ **Figure 2.** *Prepaid call termination in IN.*

- Step 3 — The P-SCP instructs the MSC to establish an integrated services digital network (ISDN) (voice) link to the *intelligent peripheral* (IP). The IP is a node that contains functions and resources, such as voice announcements or dual-tone multi-frequency (DTMF) digit collect capabilities, needed to exchange information with an end user.
- Step 4 — The P-SCP instructs the IP to provide the prepaid customer with an *account status notification*, such as account balance and the charging rate of the call to be made.
- Step 5 — The P-SCP asks the MSC to resume the call setup procedure, and the call is eventually connected. The P-SCP starts a countdown timer. The amount of credit decremented (from the current balance) is derived from carrier-defined threshold parameters, the rate plan, destination, and time/date dependency.
- Step 6 — The call terminates when either the balance depletes or the call completes. If the countdown timer ends before the customer terminates the call, the P-SCP instructs the MSC to terminate the call. In normal call completion this step does not exist.
- Step 7 — Once the call is terminated, the MSC encounters a WIN call release trigger, which sends a disconnect message to the P-SCP indicating the time at which the call is completed.
- Step 8 — The P-SCP rates the completed call and updates the customer's prepaid balance accordingly. Then it sends the current balance and cost of the call to the MSC. The MSC releases the call.

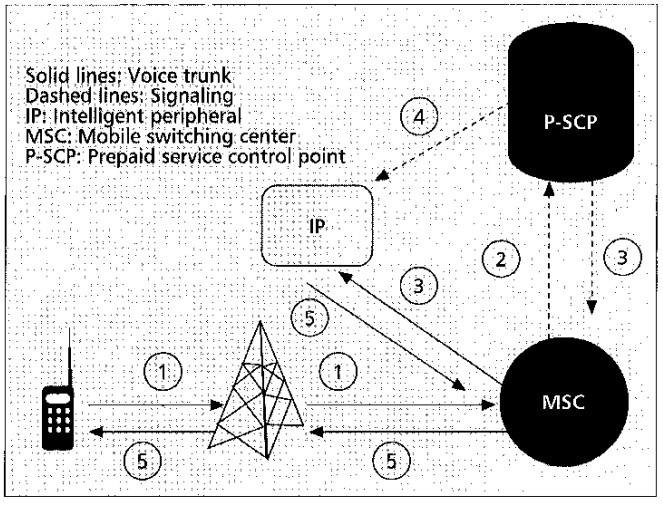
In the above procedure, steps 3 and 4 are optional.

WIN Call Termination

For calling-party-pay billing, which is exercised in Taiwan, call termination to a prepaid customer is exactly the same as that for postpaid call termination. For called-party-pay billing (which is exercised in the US), the message flow of a WIN prepaid call termination is illustrated in Fig. 2.

- Step 1 — The calling party dials the prepaid customer's MSISDN.
- Step 2 — The call is forwarded to the gateway MSC (GMSC) of the prepaid MSISDN.
- Step 3 — The GMSC encounters a WIN call setup trigger. The call setup process is suspended, and a prepaid call request message is sent to the P-SCP. The message includes the MSISDN and related information.
- Step 4 — The P-SCP determines whether the prepaid customer is eligible to receive the call. Assume that the call is accepted. The P-SCP asks the MSC to resume the call setup procedure.
- Step 5 — Following the GSM standard *mobile station roaming number* (MSRN) retrieval and call setup procedures [5, 6], the call is eventually connected. The P-SCP monitors the prepaid customer's balance as described in step 5 of the prepaid call origination procedure.

For called-party-pay billing, the call release procedure for prepaid call termination is exactly the same as that for prepaid call origination.



■ **Figure 3.** *WIN prepaid recharging.*

WIN Prepaid Recharging

The message flow of WIN prepaid recharging is illustrated in Fig. 3.

- Step 1 — A prepaid customer initiates the recharging procedure by dialing a special number.
- Step 2 — The MSC encounters the WIN trigger, and a query message is sent to the P-SCP. The message includes the MSISDN of the prepaid phone and related information.
- Step 3 — The P-SCP instructs the MSC to establish a voice channel to the IP.
- Step 4 — The P-SCP interacts with the IP to play an announcement and ask the prepaid customer to enter a PIN number and related information for recharging. Then the P-SCP checks the validity of the voucher.
- Step 5 — After credit update, the P-SCP asks the IP to play a new balance announcement. Then it instructs the MSC to disconnect the IP. The MSC releases the call, and the recharging procedure is completed.

The Service Node Approach

This approach is the most widely deployed prepaid service solution. Many major switching infrastructure providers have predefined call models within their distinct switching architecture. To deploy prepaid service without interrupting existing call models, most mobile service providers implement service nodes in their network to externally control prepaid billing.

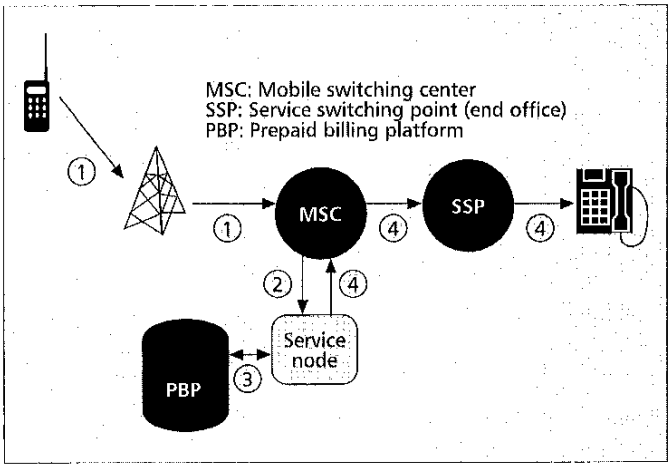
As shown in Fig. 4, a service node is typically collocated with an MSC, and is connected to the MSC using standard T1/E1 trunks assigned to a particular block of prepaid numbers. To make the call setup procedure more efficient, high-speed trunks can be considered for connection. Since the service node is collocated with the MSC, high-speed link deployment cost is acceptable.

The service node can be implemented by using CTI techniques [7–11] or PC-controlled PBX techniques [12]. The idea behind CTI is to utilize computer intelligence to manage telephone calls. With *application programming interfaces* (APIs) such as Telephony API (TAPI) [13] and Telephone Services API (TSAPI) [9, 14], prepaid applications for the service node can be developed for small installations (e.g., several hundred lines). In a PC-controlled PBX, the software (typically written in high-level languages such as C++) in the call control layer can be modified to implement various telecommunications applications. We have utilized this technique to implement a mobility manager for the wireless local loop [12]. The same platform can be used to implement the prepaid service node effectively. A PC-controlled PBX provides larger and more cost effective solutions (in terms of telephone line capacity) than CTI switching. On the other hand, a CTI platform supports general APIs, which allows faster deployment than in the PC-controlled PBX platform.

The prepaid call origination based on the service node approach is illustrated in Fig. 4:

- Step 1 — The prepaid customer initiates a call by dialing the called party's telephone number.
- Step 2 — The MSC identifies that the caller is a prepaid customer. The MSC sets up the trunk to the service node.
- Step 3 — The service node authorizes the call request by consulting the prepaid billing platform.
- Step 4 — If the call request is granted, the service node sets up a trunk back to the MSC, and the trunk is eventually connected to the called party. The service node starts credit decrementing.

One may argue that at step 4, the service node should set up the call directly to the *public switched telephone network* (PSTN) without passing through the MSC again. By doing so, two ports in the MSC are saved. Typically this alternative is not considered due to the extra overhead incurred for interworking to the PSTN. In general, small switches such as service nodes are not allowed to connect to the PSTN point of interface (POI).



■ **Figure 4.** *Service node prepaid call origination.*

The Hot Billing Approach

Hot billing uses *call detail records* (CDRs) to process prepaid usage. A prepaid CDR is created in the MSC. The information in a CDR includes type of service, date/time of usage, user identification, destination of the call, and location information [15]. These records are generated when the calls are completed, and are transported from the MSC to the prepaid service center. The balance of the customer's account is decremented according to the CDRs. As a customer uses up the prepaid credit, the HLR and authentication center (AuC) are notified to prevent further service access, and the prepaid service center instructs the network to route the next prepaid call attempt to an IVR to play an announcement indicating that the balance has been depleted. The IVR can also communicate with the customer to replenish the prepaid credit by using a top-up card, credit/debit card, or credit transfer from a bank account.

Figure 5 illustrates the interfaces that may be used in the hot billing architecture. In this architecture, a call record is sent from the MSC to the prepaid service center by using protocols such as *Common Management Information Service Element* (CMISE) [16]. The same protocol can be used for communication between the prepaid service center and the HLR. The HLR communicates with the MSC by invoking GSM MAP service primitives [5]. The IVR generates automatic messages that allow the customer accounts to be queried and reloaded. The voice trunks between the IVR and the MSC are set up by SS7 ISDN User Part (ISUP) messages [17].

Hot billing depends on real-time data collectors/routers to transport the CDRs from the MSC to the prepaid service center. The HLR/AuC needs to be updated to allow/prevent prepaid access to the customers.

Hot Billing Prepaid Service Initialization and Call Origination

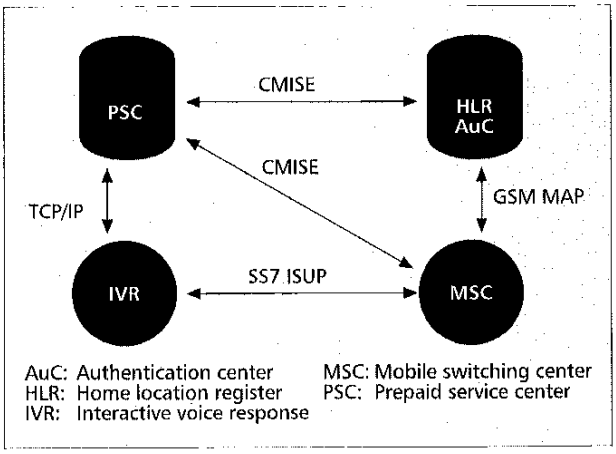
This subsection discusses service initialization and call origination for the hot billing approach. Note that other prepaid service approaches share similar service initialization procedure described in the following steps:

- Step 1 — The customer subscribes to the prepaid service center at the POS or by calling the customer care center.
- Step 2 — The prepaid service center creates a subscriber data record including IMSI, MSISDN, account of credit, period of validity, tariff model, and other authentication-related information.
- Step 3 — The prepaid service center activates the prepaid service by sending the customer data to the HLR, which then creates a record for the customer.

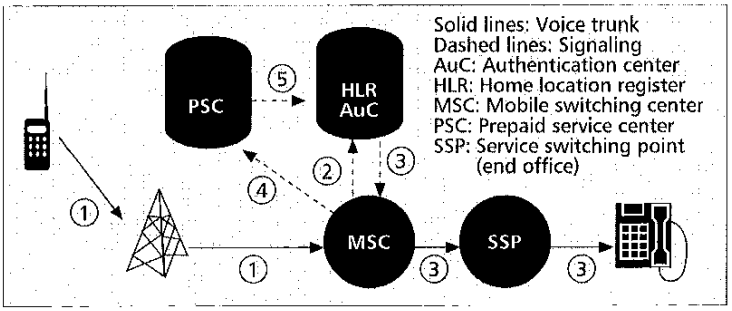
To remove a customer from the prepaid service, the prepaid service center simply sends a request to the HLR to delete the customer's record.

The hot billing prepaid call origination procedure is illustrated in Fig. 6 with the following steps:

- Step 1 — When a customer originates a prepaid call, the IMSI is sent to the MSC.



■ **Figure 5.** *Hot billing architecture and interfaces.*



■ **Figure 6.** *Hot billing prepaid call origination.*

- Step 2 — Based on the IMSI, the MSC instructs the HLR to check if it is a valid service.
- Step 3 — If the verification is successful, the HLR downloads the customer data and a prepaid tag to the MSC. The call is connected.
- Step 4 — When the call terminates, a CDR is created and sent to the prepaid service center.
- Step 5 — The prepaid service center decrements the prepaid credit based on the received billing record. If the balance is negative, the prepaid service center instructs the HLR to suspend prepaid service or delete the customer's record.

Hot Billing Customer Query and Recharging

A customer can query his/her current balance through the following steps (Fig. 7):

- Step 1 — The customer makes a service query call that is typically free of charge.
- Step 2 — The MSC sends the request together with the MSISDN of the customer to the IVR and sets up a voice path to the IVR.
- Steps 3 and 4 — The IVR queries the prepaid service center for the balance information.
- Steps 5 and 6 — The IVR plays an announcement to answer the customer.

When the prepaid credit has been decremented below a threshold, the prepaid service center automatically calls the customer and plays a warning message to remind the customer of credit recharging. The customer may recharge the prepaid credit using the top-up card mentioned earlier. This recharging procedure is similar to the credit query procedure illustrated in Fig. 7.

If the prepaid credit is depleted during a phone call, the credit becomes negative at the end of the phone call. The negative credit is potential bad debt. If the customer does not recharge the credit, this negative credit becomes a real bad debt of the service provider. Thus, the "one-call exposure" [2] becomes a major concern in the hot billing approach. A prepaid customer may place the last call and stay connected while the account balance becomes negative. This occurs because most wireless switches do not release the CDR until the call has completed. Some service providers argue that one call exposure may not be a problem. If the purchased prepaid credits are large enough, the user has to exhaust the credit before he can overrun the account, which may not be cost effective for fraud usage. However, one call exposure may still be a serious problem, especially when called-party-pay billing is exercised and parallel call forwarding service is available. In this scenario, the MS is used as the call forwarding mechanism, and the defrauder consecutively initiates several calls to the MS in parallel with different forwarding destinations. Some prepaid solution vendors suggest that call forwarding should not be offered by prepaid service providers.

To avoid bad debt, the other three approaches described in this article decrement the prepaid credit by seconds during a phone call. In the hot billing approach, sending these "real-time" CDRs by seconds to the prepaid service center and processing these CDRs at the center may incur heavy overhead for the network. Practically, the CDRs are delivered and processed on a per-call basis and, in some cases, on a multiple-call basis. Thus, in the hot billing approach, it is important to select the CDR sending frequency such that the sum of the CDR sending/processing cost and the bad debt is minimized [18]. Also, service providers may guard against one call exposure by using appropriate call barring classes. Based on the thresholds under consideration, the network determines when to warn and deny service to a customer.

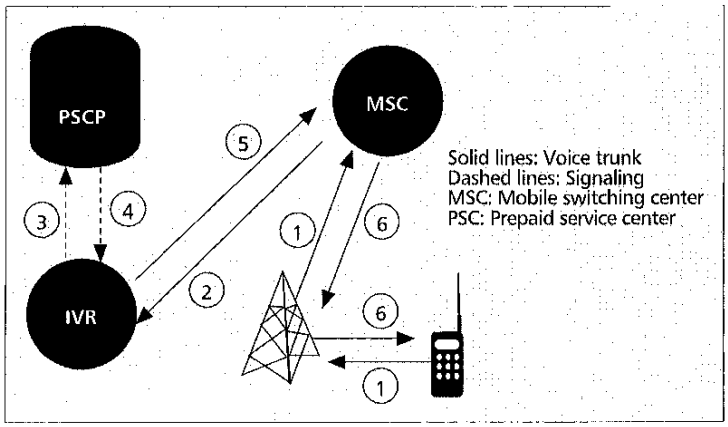
The Handset-Based Approach

In the handset-based approach, the mobile station (MS) performs credit deduction during the call and checks whether the credit limit has been reached. In this approach the prepaid credit is stored in the MS. In the United States, special phones are required; for GSM, the credit is stored in the SIM card. We use GSM as an example to describe how the handset-based approach works.

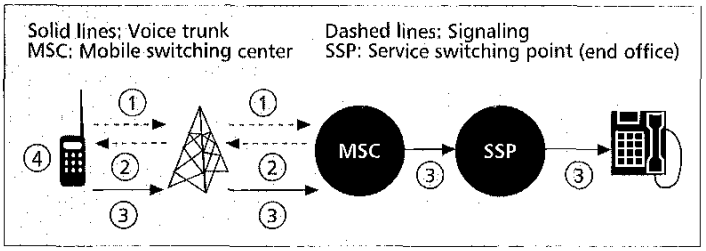
SIM Card Issues

In a typical implementation, the memory size of a SIM card is 8 kbytes; in the later SIM version, it is 16 kbytes [19]. This memory is partitioned into two areas. One stores information such as abbreviated and customized dialing numbers, short messages received, menu of subscribed services, names of preferred networks to provide service, and so on. The other stores programs that can be executed to carry out simple commands.

The handset-based approach utilizes the GSM Phase 2 *advice of charge* (AoC) supplementary message to transfer the prepaid balance information and tariff schemes. AoC provides information for the MS to produce a cost estimate of the services used. AoC consists of two service types: *advice of charge charging* (AoCC) and *advice of charge information* (AoCI). AoCC allows the MS to modify related charging data fields, while AoCI does not. To exercise handset-based prepaid service, the MS must support AoCC. Older MSs that only sup-



■ **Figure 7.** *The hot billing prepaid credit query procedure.*



■ **Figure 8.** *Prepaid call origination in the handset-based approach.*

port AoCI do not work. The supplementary AoCC service is activated for every prepaid customer in the HLR, which will be used in call setup and tariff switching.

Several data fields in a SIM card are used to provide charging information for prepaid service: the *accumulated call meter* (ACM), *accumulated call meter maximum* (ACM*) and *price per unit and currency table* (PUCT). The ACM parameter is used to accumulate used prepaid units. The ACM* parameter is used to record the amount of purchased prepaid credit. When the MS receives an AoC message from the MSC, it converts AoC into a sequence of SIM commands which modify the SIM data fields (i.e., ACM), thereby debiting the customer. The PUCT is the value of the home unit in a currency chosen by the subscriber. The value of the PUCT can be set by the subscriber and may exceed the value published by the GSM network. The PUCT value does not have any impact on the charges raised by the network.

A prepaid service center is required in the handset-based prepaid system, which utilizes the short message service to download executable programs to the SIM card. In call setup and tariff switching, the MSC provides the tariff charging parameters to the MS, and the MS executes the programs with these parameters for call debiting.

In the SIM card, an extra software filter is required to distinguish prepaid-related short messages from normal short messages. To enhance security, a prepaid-related short message may be authenticated by the SIM card. The GSM specification allows customers to access ACM and ACM* data fields in the SIM card by using a password PIN2. To support prepaid SIM card, the PIN2 must be disabled by the card manufacturer when the card is personalized. When the prepaid customer becomes a postpaid customer, the PIN2 will be activated with a short message triggered by the subscription switching process.

The SIM Toolkit specification supports proactive commands that enable the SIM card to execute application programs [20]. For GSM Phase 2 SIM cards with larger memory, the cards can run applets downloaded from the SIM toolkit service. These applets can run security checking algorithms and simple rating algorithms. The 16 kbytes of memory (now under deployment) allows the SIM cards to hold tariff table data for various rate plans.

Handset-Based Prepaid Call Origination

The prepaid call origination for handset based approach is described in the following steps (Fig. 8).

- Step 1 — The prepaid customer initiates a call by dialing the called party's telephone number.
- Step 2 — Based on the rate plan and other parameters (e.g., destination and time/date dependence), the MSC sends the AoC e-parameter (including charging information, e.g., ACM and ACM*) to the MS.
- Step 3 — If the MS supports AoCC, it acknowledges the reception of the e-parameters. If this acknowledgment is not received by the MSC, the call is denied. Otherwise, the call is connected.
- Step 4 — During the call, the MS uses the AoC e-parameters as tariff information. It decrements the credit on the SIM card by incrementing the used units in the ACM. If the MS identifies the value of ACM as reaching that of ACM*, the MS disconnects the call and informs the MSC of call release. This AoC disconnection mechanism is working autonomously in the MS without any involvement of the network.

Besides call setup, the AoC e-parameters are transferred to the MS at tariff switching (e.g., billing rate changes because the MS roams to another area).

To reduce the fraud risk, the handset-based approach may be combined with the hot billing approach. In this case, the prepaid service center in the hot billing approach is included in the prepaid architecture. Figure 9 shows the message flow of the prepaid call origination for the combined approach.

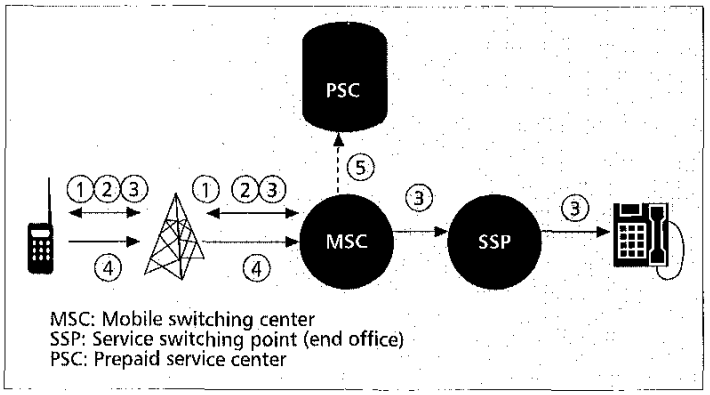
- Steps 1–3 — These steps are the same as the call origination for the handset-based approach. Some of the details (i.e., steps 2 and 3 in Fig. 6) in the hot billing call setup are not shown here.
- Step 4 — The call is released when the call completes normally or the MS notices that the prepaid credit is used up. In either case, the MS sends a message to the MSC for call release.
- Step 5 — The MSC generates a prepaid CDR, which is then transferred to the prepaid service center. Unlike the regular CDR, the prepaid CDR includes the AoC e-parameters. The prepaid service center updates the prepaid credit as in the hot billing approach. When ACM is above a threshold, the prepaid service center may automatically send a warning message to the MS for recharging the prepaid credit.

From the viewpoint of the handset-based approach (Fig. 10), this combination provides better fraud protection. When the credit in the prepaid service center is different from the MS, the service provider may terminate the service for further fraud investigation. From the viewpoint of the hot billing approach, this combination eliminates the possibility of one call exposure. As soon as the credit is used up, the MS terminates the call, and the situation is reported to the prepaid service center.

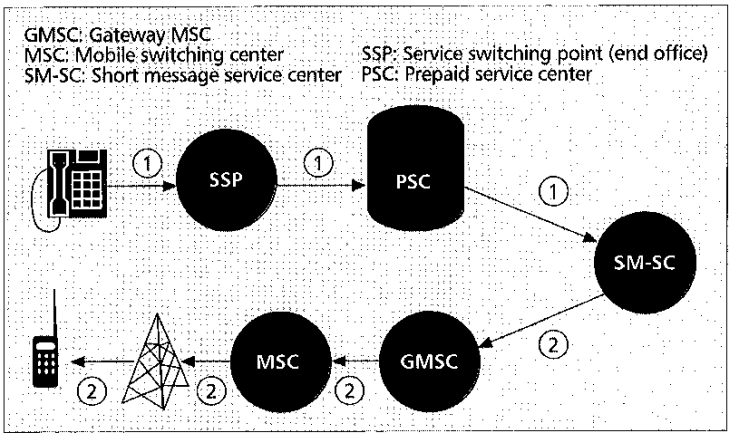
Besides the extra implementation complexity, a potential issue for the combined approach is that the charging information (e.g., ACM and ACM*) may not be consistent for reasons other than fraud usage. Thus, synchronization between the prepaid service center and the MS is important.

Handset-Based Prepaid Recharging

Like the hot billing approach, a customer recharges the prepaid credit by purchasing a scratch card.



■ **Figure 9.** *Prepaid call origination in the combined approach.*



■ **Figure 10.** *Roaming to other networks for prepaid service.*

- Step 1 — The customer makes a toll-free call that will be connected with an IVR. The prepaid service center validates the secret code (obtained from the scratch card) and the MSISDN of the prepaid customer. If validation is successful, the prepaid service center resets ACM to zero, and ACM* is set to the amount of the new credit.
- Step 2 — If the recharging procedure is successful, the prepaid service center generates a reload short message. This message is delivered to the MS through the *short message service center* (SM-SC) [21–23] in a few minutes. If the SM-SC fails to deliver the message (e.g., the MS is turned off), it repeats the message delivery action until it succeeds.

A Comparison of Prepaid Solutions

Based on the descriptions in the previous sections, we compare the four prepaid service approaches in the following aspects: roaming, scalability, fraud risk, service features, and real time rating.

Roaming to Other Networks

Assume that the home and visited systems belong to different service providers. To provide roaming to prepaid customers, an agreement (which can be part of a roaming agreement) must be made between the home and visited systems. This agreement is required so that the visited system can (and is willing to) distinguish prepaid calls from postpaid calls generated by visiting customers. In most existing scenarios, GSM service providers assign special MSISDN number blocks to prepaid customers. The visited system then identifies a prepaid call based on the MSISDN. There are potential disadvantages to using MSISDN for prepaid call identification. First, operator number portability [24] will not be allowed. (With number portability, a customer can switch mobile service providers without changing the MSISDN.) Second, service number portability will not be allowed; that is, for the same GSM system, a prepaid customer cannot switch to postpaid service without changing the MSISDN. Identifying prepaid calls by IMSIs seems to be a better alternative to address these issues. However, the MSC at the visited system may need to be modified so that it can perform call routing based on IMSIs.

Prepaid charging cannot be performed at the visited system due to the restriction that the home and visited systems may exercise different prepaid service solutions that are incompatible.

Thus, most (if not all) networks require the visited MSC to route the prepaid call back to the home network. This operation is achieved by using the standard *alternate* or *optimal* routing that can easily be implemented by setting up routing parameters in the MSC. That is, in the call model of a visited MSC, if the prepaid MSISDN is recognized, the visited MSC routes the call based on the MSISDN instead of the called party number. Figure 11 uses the service node approach as an example to illustrate how prepaid call origination is performed in the visited system. When the visited MSC receives the prepaid call at step 0, the MSC routes the call directly to the GMSC of the prepaid MS. The remaining steps are those described earlier. Extra trunk connection is required in this call setup procedure. Prepaid calls are charged more than postpaid calls partially due to this. It is clear that the above procedure is too expensive for international roaming [25]. The roaming issue is essential to all prepaid solutions investigated in this article.

Scalability

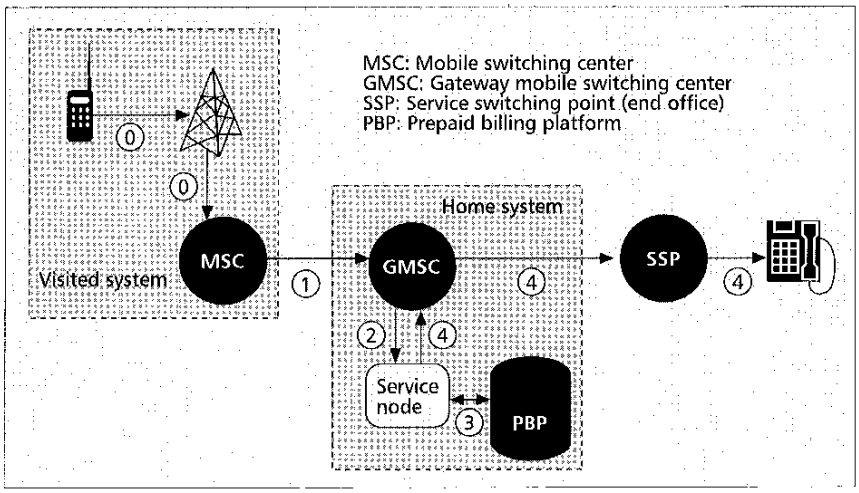
It is apparent that both the handset-based and WIN approaches have good scalability.

In the hot billing approach, the size of the prepaid customer population is limited to the MSC's ability to process and deliver CDR messages.

In the service node approach, the capacity of the trunks between the service node and the MSC limits the prepaid customer population that can be accommodated in the system. Interestingly enough, in Taiwan, statistics from a service provider exercising the service node approach indicated that a GSM network traffic jam is caused by incoming calls to prepaid customers, not outgoing prepaid calls. That is, the traffic jam is not caused by the limited capacity of the service node. Why? (Hint: calling-party-pay billing is exercised in Taiwan.)

Fraud Risk

In the handset-based approach, AoC communication is not encrypted, and it is fairly straightforward to tamper with or



■ **Figure 11.** *Prepaid short message service.*

ignore AoC by intercepting the debit commands. Also, it is possible to modify the credit illegally in the MS. Thus, it turns out that the handset-based approach has poor fraud protection. Several manufacturers have worked on SIM encryption with the SIM toolkit.

Fraud risk can be high for the hot billing approach due to the one call exposure concern. As pointed out before, this occurs because most wireless switches do not release the CDRs until the calls have completed. Fraud risk can be reduced if mid-call CDR sending is exercised.

Both the service node and WIN approaches exhibit low fraud risk.

Initial System Setup

The initial system setup cost and time for the handset-based approach is average. This approach does not require changes to the mobile network infrastructure except that the MSC must support AoC. On the other hand, the prepaid MSs must be GSM Phase 2 to receive the AoC messages. Furthermore, special SIM software is required to execute rate plans in the MS. The GSM service providers may be locked to a single-source SIM supplier. This situation is undesirable, especially when the SIM card market is unpredictable.

The initial system setup cost and time for the hot billing approach is average. This approach needs integration of prepaid service center, IVR recharging mechanism and MSC/HLR.

The system setup for the service node approach can be done quickly. The mobile network infrastructure is not modified. The only system setup cost is the establishment of the service node. For this reason, up to the end of 1998, service node was the only working prepaid service solution in Taiwan.

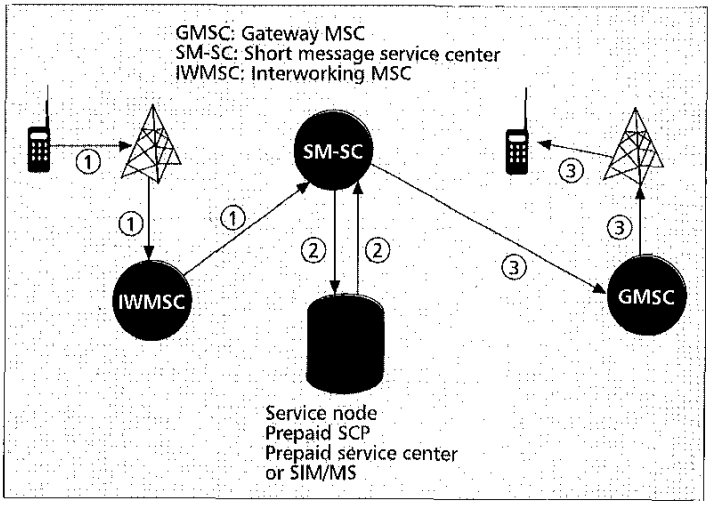
The initial system setup time for the WIN approach is long, and the cost very expensive. Furthermore, this approach is not a fully developed route for many mobile networks to follow. The design of services and switch software development for intelligent network is complex. For small and medium-sized service providers, a full implementation of an IN architecture may not be a realistic option.

Service Features — The handset based approach supports limited service features because the number of rate plans that can be stored in the SIM card is limited and may not be conveniently updated. The SIM card also relies on the MSC to provide the tariff charging model.

The service feature provisioning for the hot billing approach is better than average, which is typically limited by the per post-call charging mechanism.

Both the service node and WIN approaches support flexible service features. For WIN, many service features can be integrated with prepaid service under the intelligent network platform.

None of the four approaches can support prepaid short message service. The reason is that the short message is delivered by the SS7 TCAP, which cannot not be identified by the MSC for the charging purpose. Instead, charging of the short message is done at the SM-SC. One solution is to modify SM-SC such that before delivering a prepaid short message, the SM-SC sends a charging message to MS, PSC, or P-SCP (depending on the approach exercised) for decrementing the prepaid credit of the customer (1, Fig. 12). If the SM-SC receives a positive response (2, Fig. 12), the short message is actually sent (3, Fig. 12).



■ **Figure 12.** *Prepaid short message service.*

Real-Time Rating

In the handset-based approach, real-time rating is performed at the MS. In the service node approach, real-time rating is performed at the service node. In the WIN approach, real-time rating is performed at the P-SCP. The hot billing approach cannot support real-time rating. Credit information update depends on the MSC capability to send CDRs.

Conclusions

This article describes four mobile prepaid service approaches, and compares their weaknesses and strengths. Among the approaches, the handset-based approach is a low-cost, high-risk solution. The wireless intelligent network approach is a high-cost, low-risk solution. The service node approach is a quick solution. It allows fast deployment with limited capacity. The hot billing approach is an average solution that cannot provide real-time rating. An interesting issue not covered in this article is the *aging* problem. When a mobile user unsubscribes to mobile service, the mobile identification number assigned to the user is reclaimed. This reclaimed number must be kept unused for a period. This process is called *number aging*. Number aging is a more serious issue for prepaid service than for postpaid service because prepaid customers change service providers more often than postpaid customers. Furthermore, the aging period is expected to be longer in the United States than in Taiwan because in the United States called-party-pay billing is exercised, while Taiwan uses calling-party-pay billing. The length of the number aging period is for further study.

Besides the technical discussion of prepaid service approaches, we would like to point out that packaging prepaid service for business is very important. Recently, prepaid service was overpromoted in Mexico. Postpaid revenues were seriously lost because prepaid service was introduced with more favorable rates [3]. Thus, it is important that service providers balance their prepaid and postpaid marketing and distribution strategies through segmentation (e.g., targeting prepaid service for high risk customers or packaging the service as a gift). As we mentioned earlier, service providers may know why customers purchase prepaid services. However, our experience indicates that service providers may not know why the customers quit using prepaid service, nor when customers switch to another service provider.

In Taiwan, prepaid service is considered a niche market, and the strategy is to promote a loyalty program that transfers

prepaid customers into postpaid customers. As a final remark, credit transfer for mobile prepaid service is clearly an application for electronic commerce, which transfers electronic cash over digital networks in real time. The prepaid billing systems are influencing existing billing systems, where the payment processing components will need to be tailored for the online nature of the new medium.

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