Number Portability for Telecommunication Networks

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Abstract

Number portability is a telecommunication network function, which allows subscribers to switch services, service providers, or locations without changing their telephone numbers. Near-term number portability is typically implemented by existing telecommunication services such as remote call forwarding. Long-term number portability can be implemented under the advanced intelligent network platform. In this article we introduce the number portability issues and provide a tutorial on AIN. Then we show the AIN implementation for long-term number portability. Finally, a cache approach is proposed to speed up address transfer, which can effectively reduce the network overhead incurred by AIN query for number portability.

N*umber portability* allows a subscriber to keep a "unique" telephone number [1, 2]. From the viewpoint of service providers, number portability is a network function that helps a service provider to compete with another service provider that is already serving a customer.

There are three types of number portability [3]:

- *Service portability* allows a subscriber to keep the same telephone number after changing services.
- *Service provider portability* allows a subscriber to keep the same telephone number after changing service providers.
- *Location portability* allows a subscriber to keep the same telephone number after changing physical locations.

Before we discuss number portability issues, we first introduce the format of a telephone number by using the North American Numbering Plan (NANP) [4] as an example. NANP follows International Telecommunication Union — Telecommunication Standardization Union (ITU-T) Recommendation E.164 [5], where a telephone number is of 10-digit format NPA-NXX-XXXX. In this format, Number Plan Area (NPA) can be a geometric information code (GIC) or a service access code (SAC). The last seven digits in the NANP telephone format represents a *subscriber number* in the format NXX-XXXX where N is a number between 2 and 9, and X is a number between 0 and 9. In this subscriber number format, the first three digits (i.e., NXX) are typically a central office (CO) code that identifies the CO switch of the telephone number. Based on the NPA code, the NANP numbers can be classified into two categories.

Geographic NPA (G-NPA) — The NPA code is a GIC commonly known as the area code. Any call to a G-NPA telephone number will be directed to a home CO before rerouting (if any). In G-NPA, CO codes may be allocated to a service provider, or G-NPAs within a CO code may be allocated to that service provider. An example of a G-NPA number is 626-457-xxxx, which represents a telephone number for Los Angeles, California.

Nongeographic NPA (NG-NPA) — The NPA codes are assigned to services (i.e., the NPA code is an SAC). In NG-NPA, a subscriber can be assigned an arbitrary NXX-XXXX number within an NPA code. For example, the 800 SAC code is for toll-free service, and the 900 SAC code is for a premium rate service in the United States. In Taiwan, the 090 SAC code is for Advanced Mobile Phone Service (AMPS cellular service. For some services, the NXX codes can be assigned to a specific service provider. For example, the SAC code 093 is for Global System for Mobile Communications (GSM) services in Taiwan, where the NXX codes are assigned to various GSM service providers (e.g., NXX = 2XX for Chunghwa Telecom and NXX = 1XX for three local GSM operators).

Under the above numbering plans, number portability is not supported in many existing systems. For example, if a subscriber in Taiwan wants to change AMPS service to GSM service, his/her cellular number must be changed from 090-NXX-XXXX to 093-NXX-XXXX. Thus, service portability is not supported. Another example is the change of telephone service from plain old telephone service (POTS) to integrated services digital network (ISDN). Since ISDN service is only available through ISDN switches, POTS subscribers should change their telephone numbers to receive ISDN services.

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If a GSM subscriber in Taiwan wants to change from Chunghwa GSM to Far Eastone GSM, then GSM number must be changed from 093-2XX-XXXX to 093-1XX-XXXX. Thus, service provider portability is not supported. From the viewpoint of customers, the need for service provider portability may depend on the billing policy. In the United States, cellular subscribers typically pay for both incoming and outgoing calls. In order not to receive undesirable calls, the customers are unlikely to distribute their numbers widely. Thus, number portability is not an important factor when the customers decide whether to change cellular service providers. In Taiwan, on the other hand, the cellular subscribers only pay for outgoing calls (the incoming calls are paid for by the callers), and are likely to widely distribute their numbers. Consequently, service provider portability is essential for fair competition among cellular companies.

If a public switched telephone network (PSTN) subscriber in Taiwan wants to change location from Taipei to Tainan, the telephone number must be changed from 02-XXXXXXXX to 06-XXXXXXX. Thus, location portability is not supported. However, we would like to point out that under the G-NPA numbering plan, subscribers may not appreciate location portability for the following reason. Subscribers are likely to associate the GICs (area codes) with geographic areas and assume that the charges for their calls are based on the calling rates to the areas indicated by the GICs. In other words, G-NPA location portability may result in consumer confusion. Thus, a voice announcement to the caller may be required to provide the billing information for a dialed G-NPA ported number. Another alternative for location portability is to use NG-NPA numbers where the format of the numbers does not imply any location information.

Many studies and discussions [6] lead to the conclusion that number portability should be supported in the modern telecommunication services and suggest that any long-term number portability implementation should satisfy the following minimum criteria.

Capabilities and Service Quality — A long-term number portability implementation should support existing network services, features, and capabilities without unreasonable degradation in service quality and network reliability. Otherwise, the implementation will result in a competitive disadvantage to the service providers. Furthermore, emergency services and intercept capabilities are mandated to ensure public safety.

Numbering Resource Allocation — Since new telecommunications services (especially wireless services) have developed rapidly, the consumption rate of numbering resources (e.g., NANP codes) is likely to accelerate. Thus, it is important that a long-term number portability implementation efficiently use numbering resources without requiring subscribers to change their telephone numbers.

Call Setup Routing — A long-term number portability implementation should allow a service provider to route telephone calls to their customers without being affected by the networks of other carriers.

This article will focus on the routing issues for number portability. A number of implementation alternatives for number portability have been explored [6]. They can be classified into two general categories: *onward routing* methods and *database* methods. Onward routing methods are considered interim number portability solutions. On the other hand, long-term implementations are based on database methods.

Several terms must be defined before we describe the routing methods. Originally, a telephone number is assigned to a switch, called the *donor switch* or *release switch*. If the telephone number is moved from a switch to another switch, the new switch is called the *recipient switch*. The moved number is referred to as a *ported number*.

Onward Routing Methods

The onward routing approach first routes a call to a switch based on the dialed number (typically a G-NPA number). The switch then transfers the call to its destination. Examples of this approach include remote call forwarding (RCF) and flexible direct inward dialing (FDID). RCF redirects calls to the recipient switch of the ported numbers by placing a second telephone call (by dialing a new number) to the new network location. FDID routes the second call over a dedicated facility to the switch of the new service provider without placing a new call.

Onward routing methods such as RCF are existing telecommunication services. They are being used only on an interim basis because the exercise of these methods results in network inefficiency: since the dialed numbers are used to route calls to line appearances on the (donor) switch, forwarding many ported numbers will exhaust the switch resources.

Since the onward routing mechanism is already built into most switches, installation is inexpensive. Thus, the costs for supporting onward routing number portability are incremental, consisting of the following parts:

- *Number transfer costs* consist of two parts. The first part is incurred by the donor switch to determine if the number is no longer resident. The second part is incurred in performing the RCF translation to identify the address of the recipient switch.
- *Call transfer costs* are incurred in redirecting the call from the donor switch to the recipient switch of the ported number.

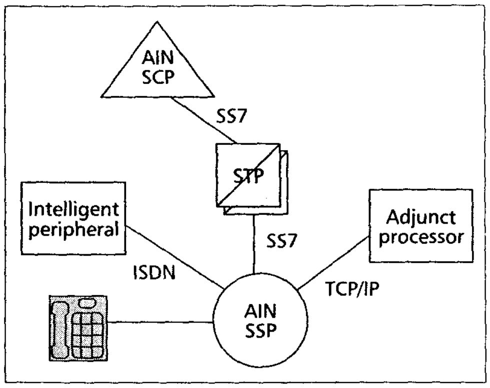
There are several alternatives to charge a service provider who utilizes RCF for number portability. In California and Illinois the state commissions set cost-based fixed monthly rates for RCF, while in New York and Maryland the commissions set cost-based rates for minutes of use.

As we pointed out, onward routing methods are considered as interim number portability solutions. Long-term implementations can be based on the database methods under the advanced intelligent network (AIN) platform. In the remainder of this article, we introduce the AIN architecture and its call model. Then we describe the database methods for number portability and show how these methods can be implemented using AIN.

Advanced Intelligent Network

In traditional signaling systems such as Signaling System No. 7 (SS7) [7–12], call processing intelligence depends heavily on switch-based translations and features. On the other hand, AIN [13] controls the call processing intelligence by software distributed in switches, databases, and other elements throughout the network rather than being confirmed to translations within the originating and terminating switches. In other words, AIN adds service capabilities to the telephone network, which are independent of the involved telephone switches.

With AIN, telephone companies can rapidly and flexibly provision services to customers. What makes AIN so powerful is that services can be deployed on centralized databases and intelligent peripherals. A telephone company saves time and money by avoiding the necessity of loading specific software and feature sets into every CO switch. Using AIN, multiple CO switches can query that single-service database to carry out call processing.



■ Figure 1. *The AIN architecture.*

The AIN Architecture

The AIN architecture is illustrated in Fig. 1 [13]. In this architecture, the service switching point (SSP) is a telephone switch (CO or tandem). The *signal transfer point* routes the control messages (SS7 messages) to their destinations. The service control point (SCP) contains databases to provide enhanced services. The SCP accepts queries from an SSP and returns the requested information to the SSP. The intelligent peripheral (IP) is a node that contains functions and resources (e.g., voice announcements or dialed digit collect capabilities) needed to exchange information with an end subscriber. The IP can be connected to an SSP locally via an ISDN interface or remotely via the SS7 network. IPs may also connect to an SCP via a TCP/IP or ISDN interface. The *adjunct processor* is similar to the AIN SCP. The differences are the following:

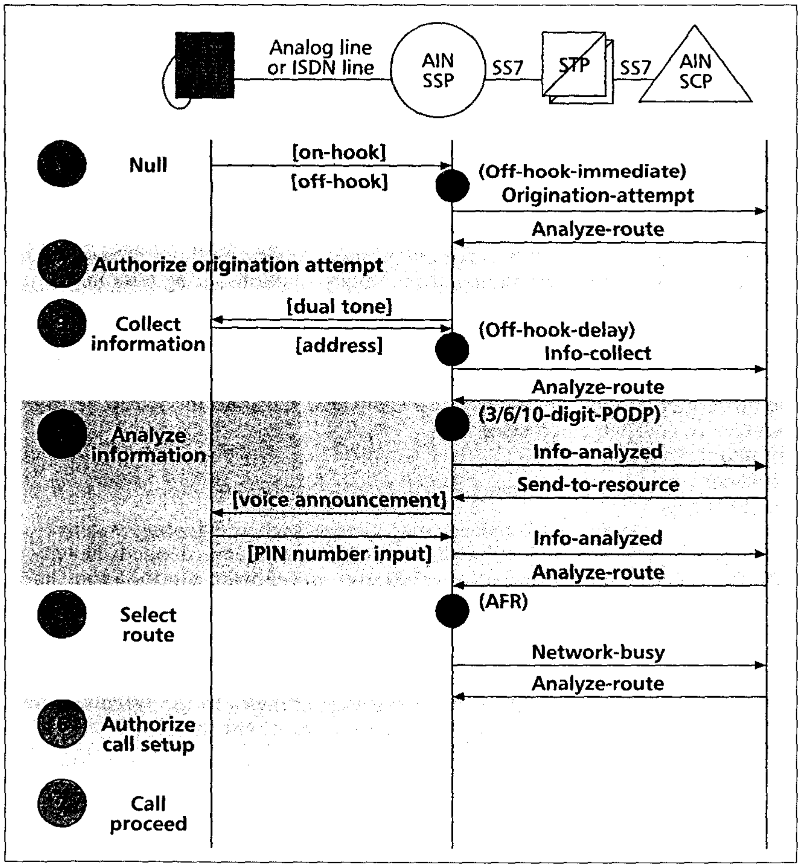
- The adjunct processor uses TCP/IP (although high-speed Ethernet) instead of SS7.
- The processing speed of the adjunct processor is in general faster than the SCP.
- The adjunct processor is appropriate for small service providers (e.g., with one switch that does not need SS7 connections).

In this article we will use the terms *adjunct* and *SCP* interchangeably.

The AIN SSPs and SCPs are like clients and servers in the remote procedure call (RPC) model [14]. During the call processing procedure, the AIN SSP may detect the need for AIN processing (at the so-called *trigger detection points*, TDPs). If so, one or more triggering actions are performed. *Triggering* is similar to invoking an RPC. The *trigger types* are like the RPC procedure names. The trigger action temporarily suspends the SSP call processing, and launches a parameterized query to the AIN SCP. The AIN SCP performs actions based on the trigger type, and returns some results to the AIN SSP. The AIN SSP then resumes the call processing and determines the next action based on the results provided by the AIN SCP.

The AIN Call Model

The AIN call origination flow is illustrated in Fig. 2. In this figure, the circles in the AIN SSP timeline represent the TDPs. Depending on the services provided, the triggers at the TDPs may or may not be detected, and the message exchanges between the SSP and the SCP may or may not exist in the call process.



■ Figure 2. *The AIN call origination flow.*

Step 1 — Initially, the SSP is in the *Null* state or *Null* PIC (*point in call*) when the telephone is on-hook. If the SSP receives the off-hook indication, the `Off-hook-Immediate` trigger may be detected for services such as *hotline* (the hotline service allows the caller to automatically access a given telephone each time the caller lifts the handset). In the hotline service, the `Off-hook-Immediate` trigger is detected, and an `Origination-Attempt` AIN Transmission Capability Application Part (TCAP) message is sent from the SSP to the SCP. The SCP identifies the destination routing number, and sends it to the SSP by the `Analyze-Route` message. This message requests the SSP to resume the call originating process and provides information relative to that process. Note that in the hotline service, steps 3 and 4 of the call flow are skipped.

Step 2 — The SSP enters the *Authorize-Origination-Attempt* state. The SSP verifies the authority of a subscriber to place a call based on line restrictions. For an analog line, a call request may be rejected if no dual-tone multifrequency (DTMF) receiver is available in the switch. (DTMF is a technique used by the telephone set to generate address signals to the switch. The switch utilizes DTMF receivers to interpret the dialed digits.) For a trunk, the call request may be rejected when the glare condition is detected. (In a two-way trunk, both switches may seize the trunk at the same time. This situation is called the *glare* condition.)

Step 3 — The SSP enters the *Collect-Information* state. It sends the dial tone to the subscriber and then collects dialed digits from the line. The call may be rejected if the dialed digits are not received before a normal *inter-dialed-digit* timer expires (typically 5 s). After the SSP has collected enough information from the telephone, it may proceed to step 4, or an `Off-hook-Delay` trigger may be encountered. The `Off-hook-Delay` trigger can be used to implement the restricted calling service that allows customers to restrict certain types of calls. For example, the `Off-hook-Delay` trigger may be hit when a subscriber dials a 900 number. In this case, the SSP sends the `Info-Collect` query message to the SCP. If the query passed the screening process, the SCP returns the `Analyze-Route` message to the SSP, and the SSP proceeds to step 4. If the query fails the screen process, the SCP returns a `Send-To-Resource` message to the SSP. The SSP will instruct the IP to play a denial announcement and disconnect the subscriber.

Step 4 — The SSP enters the *Analyze-Information* state. It interprets and then translates the collected information according to the specified numbering plan. The information may be invalid (i.e., the dialed number violates the numbering plan in force), and the call is rejected.

Several triggers may be encountered at this state. An example is the 3/6/10-Digit-PODP trigger. This trigger is used for a call with access to the public office dialing plan (PODP), which is used by customers (e.g., businesses) to block certain outgoing calls such as international or toll numbers. This security screening service performs some kind of security process in the network before an end user gains access to the subscriber's network, systems, or applications. The trigger can also be used to implement number portability, to be described in the next section.

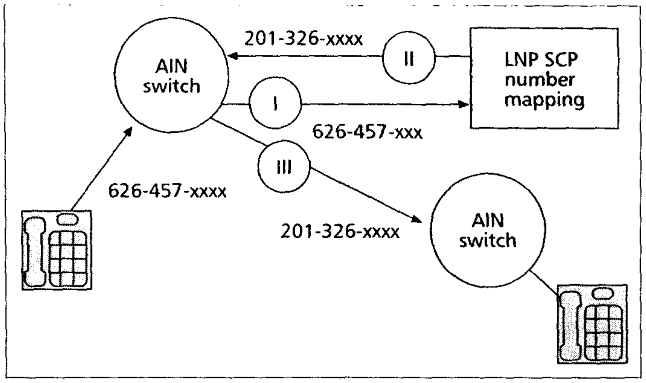
When the trigger is detected, the SSP sends the `Info-Analyze` message to the SCP. The SCP replies the `Send-To-Response` message to the SSP, which may or may not include an instruction to play an announcement to the caller. Two examples of voice announcement are given below:

PIN information Collection — The voice announcement instructs the caller to enter a personal identification number (PIN). This identification number is forwarded from the SSP to the SCP through the `Info-Analyzed` message. If the PIN is valid, the SCP returns the `Analyze-Route` message containing routing and billing instructions, and step 5 is executed.

Billing Information Provision — The voice announcement provides the billing rate to the caller. The caller may determine to terminate the call by hanging up the handset or to continue the call (by inserting coins or pressing a special key on the phone set). In the latter case, the call setup procedure proceeds to step 5.

Step 5 — The SSP enters the *Select-Route* state to select the outgoing route (e.g., the output line for an intraswitch call or a trunk group for an interswitch call). If the route is busy, the call may be rejected or the `Automated-Flexible-Routing` (AFR) trigger detected. In the latter case, the SSP sends the `Network-Busy` message to the SCP. The SCP may instruct the SSP to route the call to the destination SSP indirectly through a tandem.

Step 6 — The SSP enters the Authorize-Call-Setup state to verify the authority of the calling party to place this particular call. The call is denied if the continuity check fails. (During call setup, if the originating switch specifies a continuity check, the selected trunk from the terminating switch to the originating switch is checked to ensure a satisfactory transmission path.) In the normal case, step 7 is executed.



■ Figure 3. *The LRN database method.*

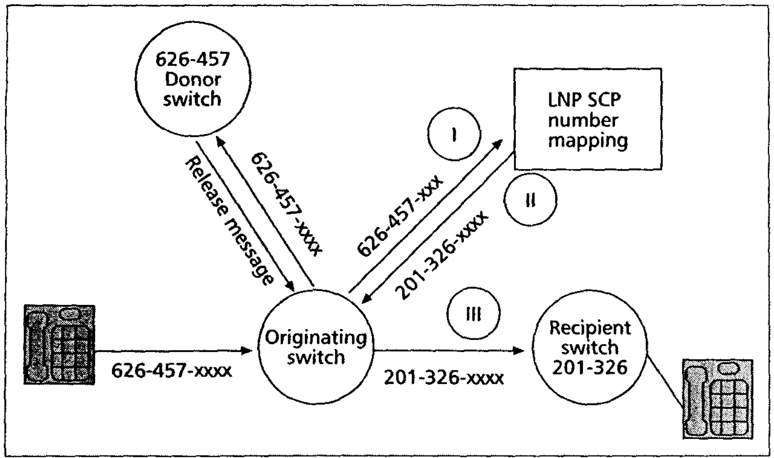
Step 7 — The SSP enters the *Call-Proceed* state, sends an indication of the desire to set up a call to the called party, and waits for the response from the called party. After the called party answers, the call is established.

Note that triggers described in the above call model correspond to specific services (and typically do not occur in every call setup). In the next section, we show that the `3/6/10 PODP` trigger in AIN can be used to implement the database methods for number portability. Other triggers mentioned in this section will appear in the call flow that supports number portability if the corresponding services are offered.

Database Methods

Database methods for number portability utilize local number portability (LNP) databases to route calls to their destinations. An example of this approach is the location routing number (LRN) method proposed by AT&T [15]. In this method, 10-digit LRNs are provisioned to uniquely identify every switch in the network. The first six digits of the LRN will be one of the assigned NPA-NXX of the switching element. The purpose and functionality of the last four LRN digits have not yet been defined, but are passed across the network to the terminating switch [16]. All telephone numbers in one NPA-NXX are assigned to a donor switch. If the number is moved or *ported* to a new (recipient) switch, the LNP database maps the telephone number to the LRN number of the recipient switch. When a ported number is disconnected (the customer no longer pays for the line), the number is released back to the original service provider (*snap-back*). After appropriate aging, the original service provider can reassign the number to a new customer. The LRN proposed by AT&T is for G-NPA. A similar approach for NG-NPA has been proposed by GTE. In the database method, a triggering mechanism is required to fire the query to the database. The mechanism is typically implemented under the AIN platform described earlier. Following the AIN concept, call delivery to a ported number consists of the following steps [3, 17] (Fig. 3).

Step 1 — The calling party dials the number 626-457-xxxx. When the number is received by the originating switch, digit analysis is performed (see AIN steps 1–3), and interactions between the switch and the SCP may occur. Then the switch identifies that the dialed number is a ported number, and an AIN trigger (e.g., the 3/6/10-Digit-PODP trigger in AIN step 4) is detected. A query (i.e., the Info-Analyzed message in an earlier section) is launched to the corresponding LNP database in the SCP.



■ **Figure 4.** *The query on release method.*

Step II — The SCP maps the ported number (626-457-xxxx) to the actual network node address (201-326-xxxx, the LRN number of the recipient switch). The recipient's LRN is sent back to the originating switch (through the Analyze-Route AIN message).

Step III — The originating switch routes the call to the recipient switch based on the LRN number 201-326-xxxx. Since the GIC (area code) for a ported number does not provide the actual location information of the called party, the caller may want to know the billing rate before the call is actually placed. In this case, the AIN IP may play a billing-rate announcement to the caller through the originating switch (see step 4 in Fig. 2) and ask the caller's permission before call setup.

A modification to this approach is called query on release (QOR) or *lookahead*. In QOR, the originating switch first routes the call to the donor (release) switch before the final routing is determined. In Fig. 4, when the number 626-457-xxxx is dialed, the originating switch first routes the call to the donor switch (626-457). The donor switch determines that the called number is ported out. The switch invokes the QOR procedure, and sends a release message to the originating switch. When the originating switch receives the release message with the QOR cause value, the trunk between the originating switch and the donor switch is released, and the originating switch initiates the same call setup procedure (steps I–III in Fig. 4) illustrated in Fig. 3. Pacific Bell and Bell Atlantic suggested that carriers should be permitted to implement QOR because this mechanism would eliminate unnecessary database queries (if the dialed number is nonported), which results in cost savings. However, QOR routing to a ported number will be affected by the original carrier (specifically, the donor switch) of the number. That is, the method reduces the new service provider's ability to control the routing of telephone calls (and thus the routing costs) to its customers.

If a call involves several local exchange carriers (local telephone companies) and interexchange carriers (long-distance telephone companies), there are several alternatives to trigger the database query, including:

- The originating service provider scenario, where the originating carrier performs the database query
- The terminating "access" provider scenario, where the terminating carrier performs the database query
- The "$N-1$" scenario, where the carrier immediately prior to the terminating carrier performs the database query
- The first-switch-that-can scenario, where the first switch (in the call path) that has the database access capability performs the query

The switch to perform the database query may affect the call routing and billing mechanisms. Thus, discussions have been conducted to select the triggering scenario [6]. Most parties prefer the N-1 scenario. On the other hand, BellSouth contends that there is no need to select a particular scenario because the above scenarios can coexist through engineering and business arrangements.

A nationwide database architecture (e.g., the 800 database) can be utilized to support database-oriented number portability. However, this centralized approach may have a serious scalability problem when number portability is deployed nationwide. A more appropriate solution is to use regionally deployed databases. Currently, most service providers agree that equipment and databases in this distributed architecture should be administrated by one or more neutral third parties so that numbering resources are efficiently made available to new service providers. It is suggested that the databases contain only ported numbers and the associated routing and service provider information [16]. The new service provider has the responsibility to populate the appropriate line information database and custom local access signaling service information associated with the ported number. The SS7 ISDN User Part (ISUP) enhancements to support database methods can be found in [18]. The portable number call control for service provider portability is given in [19].

Implementation and Operation Costs

The costs of onward routing-oriented number portability is incurred solely by the carrier providing the forwarding service. On the other hand, the database approach will require all carriers to incur costs associated with the installation of number-portability-specific software, and the construction, operation, maintenance, and administration of the number portability databases. In Taiwan, for example, many new local telephone companies will be in service in 1999. These new entrants may effectively be precluded from entering the local exchange market if they are required to bear all the costs of number portability. Two principles for number portability cost recovery have been identified to guarantee fair competition (as quoted from [6]):

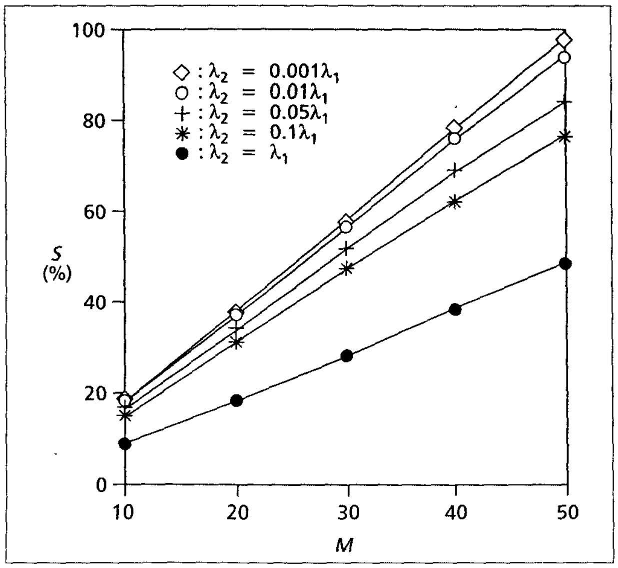
- Cost recovery should not give one service provider an appreciable, incremental cost advantage over another service provider when competing for a specific subscriber. In other words, the recovery mechanism should not have a disparate effect on the incremental costs of competing carriers seeking to serve the same customer.
- Cost recovery should not have a disparate effect on the ability of competing service providers to earn normal returns on their investment.

For example [6], we should recover the costs of currently available number portability from all carriers based on each local exchange carrier's relative number of active telephone numbers so that the amount to be recovered from each carrier would increase with the carrier's size (in terms of active telephone numbers). Accessing costs on a per-telephone number basis should give no carrier an advantage over its competitors. In Rochester, New York, the mechanism allocates the incremental costs of currently available number portability measures through an annual surcharge accessed by the incumbent local exchange carrier from which the number is transferred. This surcharge is based on each carrier's number of ported telephone numbers relative to the total number of active telephone numbers in the local service area. In Taiwan, the new cellular service providers want the AIN operation costs for number portability to be shared by the customers. On the other hand, subscriber demand for number portability will decide whether they should cover the costs; donor service providers are not expected to charge customers for porting their numbers.

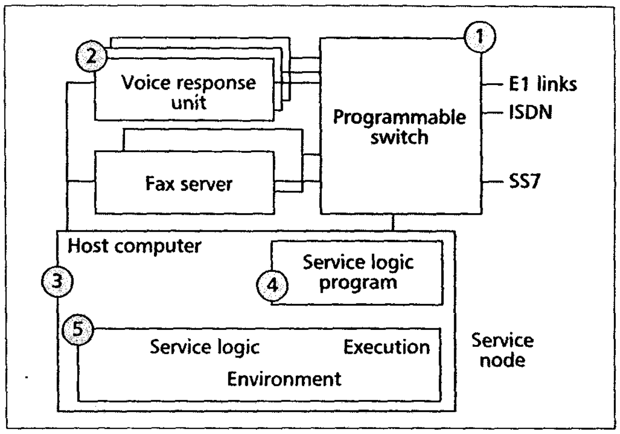
Another cost issue relates to AIN implementation. Although AIN offers flexibility and speed, it also changes the complexity of the network rapidly (when provisioning number portability in the SCP, the modifications can affect millions of customers simultaneously). The implementation complexity (powerful centralized intelligence) of AIN can be very expensive; to reduce this complexity, the service node (SN) approach has been proposed as an early solution for AIN [20]. The SN can be implemented at a much cheaper cost than the complete AIN solution. An SN is similar to an IP in the AIN. Figure 5 illustrates the SN architecture. The SN provides the number portability service through the host computer (3 in Fig. 5). By executing the service logic program (SLP, 4 in Fig. 5) under the service logic execution environment (SLEE, 5 in Fig. 5), the SN controls the *voice response units* (2 in Fig. 5), and the programmable switch (1 in Fig. 5) to carry out the number portability service. The SLP and SLEE in the host computer are basically the same as those in an AIN SCP. The SN can be evolved into a real AIN architecture by moving SLP/SLEE into the AIN SCP, and the SN becomes an IP in the new architecture.

A Cache Approach to Address Transfer

In database-based number portability, it is likely that some of the ported numbers are frequently accessed from an originating switch. In that originating switch, we may keep a cache to map the frequently ported numbers to the LRNs of their recipient switches. Thus, the routing information of the frequently ported numbers can be obtained from the cache instead of the expensive AIN query to the LNP database. A similar approach was considered to support the universal personal telecommunication (UPT) number for personal communications services (PCS) [21]. The cache approach works as follows.



■ **Figure 6.** *The effect of call arrival rate λ_2/λ_1 ($N_1 = 50$, $N_2 = 50$)*



■ **Figure 5.** *The service node architecture.*

Step 1 — When a number is dialed, the originating switch first checks whether the number can be found in the cache. If so, a *cache hit* occurs, the LRN of the recipient switch is obtained from the cache, and the call is routed directly to the recipient switch following step III in Fig. 3. Otherwise, a *cache miss* occurs, and the next step is executed.

Step 2 — The originating switch queries the LNP SCP following steps I and II in Fig. 3. After the switch receives the LRN of the recipient switch from the SCP, an entry in the cache is created to store the dialed number and the corresponding LRN.

Step 3 — The call is routed to the recipient switch following step III in Fig. 3.

The typical size of a cache is smaller than the total ported numbers accessed through the switch. At step 2 of the above procedure, if the cache is full when the switch tries to add a new entry, a policy is required to determine which entry in the cache is replaced. Several replacement policies have been described, and simulation experiments were conducted to evaluate the performance of these policies in [21]. In this article we consider the *least recently used* (LRU) policy. The LRU policy uses the recent past as an approximation of the near future, and replaces the cache entry which has not been used for the longest period of time. The LRU policy associates with each cache entry the time of its last use. When a cache entry must be replaced, LRU chooses the entry which has not been used for the longest period of time.

The cache approach is evaluated based on the cache hit probability p_h. The higher the probability p_h, the better the performance of the cache scheme. A performance model [21] is proposed to evaluate the cache scheme based on the LRU policy. Consider the ported numbers that will be accessed by the originating switch for call delivery. Without loss of generality, assume that the ported numbers are classified into two categories: class 1 (frequently accessed ported numbers) and class 2 (infrequently accessed ported numbers). Note that this assumption can easily be relaxed to accommodate more classes of ported numbers. The net call arrivals (from all lines connected to the switch) to a ported number of class 1 (class 2) form a Poisson process with rate λ_1 (λ_2). Let N_1 and N_2 be the numbers of classes 1 and 2 ported numbers, respectively. Let $M < N_1 + N_2$ be the size of the cache. The percentage S of saved LNP database queries in the LRU cache approach is

$$S = \frac{p_{h1}\lambda_1 N_1 + p_{h2}\lambda_2 N_2}{\lambda_1 N_1 + \lambda_2 N_2}$$

Based on Eq. 1, Fig. 6 plots the percentage S of saved LNP database queries as a function of λ_1, λ_2, N_1,N_2, and M. The figure shows that S increases linearly with M, indicating that the database method benefits from the cache approach. Besides this intuitive result, the figure provides quantitative information. For example, if the cache size is 20 percent of the number of the frequently accessed ported numbers, 10–20 percent of the LNP database queries are saved. As the cache size increases, the benefit of the cache becomes very significant.

Figure 6 indicates that S increases as λ_1/λ_2 (the ratio of the access frequency of class numbers to the access frequency of class 2 numbers) increases. However, this phenomenon becomes insignificant when $\lambda_1/\lambda_2 > 100$. Thus, if the λ_1/λ_2 ratio is small, a large cache is required to efficiently support number portability. On the other hand, if the λ_1/λ_2 ratio is sufficiently large, the ratio is not a major factor in determining the size of the cache.

Conclusions

This article describes the number portability issues and shows how AIN can be utilized to implement long-term number portability. Since AIN offers flexibility and speed, number portability can be conveniently built under the AIN platform. However, AIN may rapidly increase network complexity, particularly when service providers or third parties start provisioning number portability services. It is difficult for carriers to plan their network management in advance. One solution typically followed by network managers is to overestimate the need for trunks and signaling capabilities. They plan for something in excess and then hope it covers the variability. Another solution is the cache approach described in this article, which reduces network overhead by eliminating expensive AIN queries for call routing of frequently accessed ported numbers.

Many implementation issues for number portability are still open, and a lot of work is ongoing. For example, LNP database synchronization in a distributed environment may represent a challenge between administrations and jurisdiction regions. It is important to maintain data in synchronization and to identify costs incurred with the affected components. Furthermore, a standard signaling protocol [18] among the databases and switches must be developed. Another important issue concerns the impact of LNP on billing. Discussions of these issues can be found in [22, 23].

Finally, to implement number portability, regulators should maintain close involvement to encourage consensus throughout the process. Regulators must be firm and clear about the commercial terms for number portability. As atated in the Ovum report [24], "Without a clear legal requirement, number portability will have a stormy passage through the commercial negotiation."

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