An Application Server Approach for Number Portability in IMS networks

Rafael Gava de Oliveira, Paulo Sigrist, Wilson A. Higashino, Cassiano O. Becker, Carlos E. Pagani
Venturus Centro de Inovação Tecnológica
Campinas, Brazil
{rafael.oliveira, paulo.sigrist, wilson.higashino, cassiano.becker, carlos.pagani}@venturus.org.br

Joaquim Silva
Ericsson Telecomunicações Brasil
Indaiatuba, Brazil
joaquim.silva@ericsson.com

Abstract— **Number portability (NP) is an important requirement present in most telephony networks. Typically, NP is regulated by local legislation and is inherently against the very nature of routing in circuit-switched networks, which can complicate its deployment. The technological move towards IP-based networks demands treatment of legacy numbers portability, so as to enable interoperability among technologies and allowing progressive substitution of old networks. This paper aims at presenting an application server-based approach for NP aimed at NGN networks, especially IMS. A test implementation is presented, along with a discussion of currently used approaches, as well as of the one here proposed. Test results validate the approach and show good overall performance.**

Keywords - Number Portability, Telecommunication, NGN, IMS, Application Server.

I. INTRODUCTION

Number Portability (NP) refers to the ability of changing subscribers' carrier, physical location or type of service, without changing his telephone number. This requirement is present in most telecommunications networks today and helps developing competition among carriers.

Typically, NP is regulated by local legislation and varies according to a country's dial plan and network. This variety complicates the deployment of a standardized NP scheme, what is usually very disturbing and requires careful consideration and analysis.

In this paper, we present an Application Server (AS) approach for NP aimed at NGN networks, especially those IMS-based. NP for these networks is very important, as it enables a gradual substitution of legacy networks.

We start in Section II with a brief overview of NP concepts and how it is commonly implemented in today's networks. In Section III, the rationale and architecture of an application server based approach are presented, followed by a description of its test implementation in Section IV. Section V presents the validation tests performed, and in section VI we discuss different aspects of NP in IMS networks. Finally, in section VII we point out some future work and draw conclusions about the applicability of the AS-based method.

II. CONCEPTS

A. Number Portability

Historically, phone numbers have been used both as subscriber´s identification and routing address. Its hierarchical structure is especially suited to digit-by-digit analysis, with routing decisions being sequentially made as the call connection is gradually established from caller to callee. NP disturbs this hierarchy and introduces a separation of dialed number and routing address. Therefore, telephony networks must be enhanced in order to comply with NP, adapting its signaling and routing mechanisms. Furthermore, NP also requires changes in phone numbers administration, billing and service management [1].

There are several types of NP currently available. Non-geographic NP (NGNP) refers to the ability of changing the provider of service-specific applications, such as freephone (800 or 0800). Geographic NP (GNP) refers to geographic numbers and is further divided into Service Provider NP (SPNP), Location NP and Service NP. The first case allows the subscriber to change his service provider without changing his phone number. Because of its importance from enabling the competition among providers, SPNP is the most frequently deployed NP worldwide. Location NP allows the changing of fixed phone subscriber's location, and Service NP enables subscribers to modify their service (e.g., from POTS to ISDN). Mobile phone NP (MNP) is mostly viewed as a special case of SPNP.

Generally speaking, NP is implemented as a translation mechanism that maps the dialed number into a routing address. This mapping and the subsequent routing can be done in a variety of schemes, namely All Calls Query (ACQ), Query on Release (QoR), Call Drop Back (CDB) and Onward Routing (OR). Reference [1] details and compares these methods.

Furthermore, on a second level, local regulations usually enforce one of the NP schemes, along with other requirements related to signaling and NP database management. As a result, a number of different solutions have been proposed, which are summarized in the next sections.

B. Number Portability in legacy networks

According to [1], various standards have been defined in order to provide NP to legacy networks. In general, an NP database query is an operation that contains the dialed directory number, with its response containing the routing number. Additional information may also be sent in the query response.

Some countries have defined a mechanism based on signaling number 7 (SS7) [26] to carry number portability information. For example, in the Spanish market, the NP service is based on Intelligent Network [27]; on the other hand, the Brazilian market defines a specific numbering prefix together with the SS7 routing mechanisms [19]. A typical example of protocol used in these mechanisms is the Capability Set 2 (CS2) of the ITU INAP [3][4].

C. Number Portability in IMS networks

IMS (IP Multimedia Subsystem) [5] is an architectural framework standardized by 3GPP aimed at delivering voice and multimedia services to the users. This architecture is based on and built according to IETF Internet Standards having SIP [6] as the protocol for signaling. This helps ensuring access independence and integration with legacy wireline networks [5], creating a form of fixed-mobile access convergence and facilitating the migration towards all-IP next-generation networks.

NP for IMS terminals is natively treated and does not require additional effort. However, the migration of old legacy networks towards IMS is a non-trivial process, which requires the coexistence and interoperability of these differing networks. Therefore, IMS should provide a way for treating number portability for plain telephone numbers.

Telephone numbers are represented in IMS networks through the “tel” URI scheme [7]. Furthermore, reference [8] specifies a set of parameters for these URIs in order to carry NP-related information. The idea is, with the results obtained from an NP query, to append these parameters to the URI in order to provide routing information to the subsequent nodes participating in call establishment. The main parameters are:

- *npdi* (NP Database Dip Indicator): indicates that a NP query has already been performed;
- *cic* (Carrier Identification Code): identifies the current service provider for a freephone number;
- *rn* (Routing Number): identifies the route that should be used for call treatment.

In summary, when an NP query is performed, an *npdi* parameter is added to the tel URI, along with a *cic* or *rn* indicating the new route. The format of carrier identification codes and routing numbers is typically specific to each country´s regulation and it is outside the scope of this work.

NP in IMS networks is normally based on these parameters.

The IMS specification describes two methods: ENUM/DNS and BGCF.

1) ENUM-based NP: ENUM is an IETF standard [9] that defines a DNS-based architecture used to translate phone numbers to internet domain names, which can be used to locate and contact an associated resource. ENUM queries are an integral part of the IMS routing process, which uses this database to map phone numbers to SIP URIs [5][10].

NP based on ENUM is quite straightforward and consists of adding or modifying the mapping of ported phones in the ENUM infrastructure. This new mapping could use the NP parameters described above to define the new route or even use a network-specific mechanism. Reference [11] details how ENUM can be used for NP in NGN networks.

2) BGCF-based NP: BGCF stands for Breakout Gateway Control Function and is the IMS node that processes requests for the case where the session cannot be routed using ENUM/DNS [5]. It is located on the border between distinct domains, and is mainly responsible for routing and adapting parameters of the call being forwarded to the outgoing networks.

As an NP alternative, BGCF could retrieve portability information as part of this process. The procedure for doing so is not standardized, it is implementation dependent and it is often subjected to regional requirements. All of these factors tend to require the deployment of customized BGCF NP solutions, or the modification of existing ones.

III. An Application Server Approach of Number Portability

According to [16] the AS is a SIP entity that hosts and executes services. Depending on the service, the AS can operate as a SIP proxy, a SIP UA (User Agent), or a SIP B2BUA (Back-to-Back User Agent), which comprehends a concatenation of two SIP User Agents [6].

As its name suggests, the goal of an AS is to introduce additional services without compromising the signaling call flow of IMS networks. This capability is possible because IMS standards specify an interface (ISC) [5] which allows AS’ to be deployed and triggered based on configuration policies associated to the user’s profile.

AS´s can be employed to perform NP in different ways. In this paper, two approaches are presented: the first and simplest is to consider the AS performing NP as a stateless service. The second approach considers it as a B2BUA.

Basically, the idea of NP as a stateless service consists of routing all originating IMS calls to an AS, or those based on a phone number context, through the use of Initial Filter Criteria (IFC) [5]. The AS queries an NP database, and in case of finding a match, additional routing parameters (section II) might be added to the Request URI, giving “hints” to CSCF of how to route the call. IMS standards recommend that the only change performed be parameters added or deleted, without changing the URI initial form.

The method of routing all calls to an NP server is known as ACQ (All Calls Query). The advantage of this method is application simplicity, once it does not involve keeping any call state: only the initial transaction messages flow through the AS, leaving it apart from the remaining SIP messages in a SIP dialog [6].

Another approach to NP via AS is to use it as a B2BUA. The idea behind this method is that on the termination leg of a call addressed to a ported user, an IFC is configured to forward this call to an AS, which acts on behalf of the ported user and generates a new call (SIP Request) to the right destination (the new service provider).

The advantage of this method over the previous one is that only calls addressed to ported users are effectively triggered and forwarded to an AS, minimizing the number of hops and the call setup delay. However, a drawback is the fact that the application must maintain call states and stay in the middle of the entire SIP dialog.

These are only two of conceivable methods for solving the NP problem via an Application Server on IMS networks. Due to the AS position in the IMS signaling flow, various approaches could be developed and applied. Different types of services could be added through a programmable interface, which abstracts the network and signaling, and leaves carriers and developers untied from network vendors.

In the next section, we introduce and describe the NPAS, our NP implementation based on AS.

IV. NPAS

NPAS is an application based on SIP Servlet technology [12] developed by the authors, which provides an NP solution to IMS networks in different modes. The application was developed according to the recommendations of Brazilian Telecommunication Regulator Agency [19].

Initially, NPAS was designed to act as an AS stateless service (Figure 1 – (a) AS Mode), as described in the previous section. In a second moment, the authors extended the functionality of the application allowing it to act as a BGCF (Figure 1 – (b) BGCF Mode) or a DNS backend NP database (Figure 1 – (c) DNS Driver Mode), making NPAS a solution with good coverage and applicability to IMS and NGN networks.

In the BGCF mode, the application acts as the breakout of an IMS network, receiving telephone calls that could not be routed using ENUM/DNS. In addition to the normal BGCF functionalities, an NP query stage was added, allowing the correct routing of calls. Notice that the application can differentiate between AS and BGCF modes because of differences in the Route SIP Header of the INVITE request.

In the DNS Driver mode, the application works as a BIND9 [17] DNS backend, giving it support for ENUM queries. A minimal set of information is compiled and exchanged between DNS Server and the NPAS Application. The DNS Server receives the ENUM query from its clients and instead of consulting its own database, forwards the query to NPAS through a driver. Then, the application executes the URI translation based on its NP database and sends the result back to the DNS Server.

V. VALIDATION TESTS

Several tests were executed aiming at validating the Application Server approach. Initially, a diversified environment composed of software simulators and vendor equipment including Dialogic [20], Telles [21] and Asterisk [22] gateways as well as Ericsson's softswitch [23] and IMS cores like Ericsson Core Networks [24] and OpenIMS [25] was set up in order to perform functional and compatibility tests. After that, we scaled the test bed to a more complex scenario, simulating the integration of three carriers, involving all equipment and software previously described and certifying the functionality and the interoperability of the solution with different types of equipment.

The next step focused exclusively on performance at the application server, regardless of the others network elements, such as the IMS core, MGCF, etc.

A laboratory with four hosts (described in TABLE I.) was used for this purpose.

In order to obtain a more precise result, a traffic generator, SIPp [13], was used instead of the IMS core, stimulating the application in the AS and BGCF modes. With this approach, it was possible to determine the extent to which the application server could handle calls without the need of configuring a full-blown environment with a fast enough IMS core. The NP database was populated with one million entries.

The methodology used in the performance tests was based on the SIPstone benchmarking [14] and SPEC SIP [15], both of which providing measurements of request handling capacity of a SIP server. The main goal was to determine the Transactions per Second (TPS) rate for the server. For this purpose, the transaction rate was increased until the Average Transaction Response Time (TRT) exceeded 20ms. The Average TRT measures the time spent from the initiation of the INVITE until the receiving of a message ending the transaction. Each measure was made during an interval of 10 minutes. Notice in Figure 2 that the

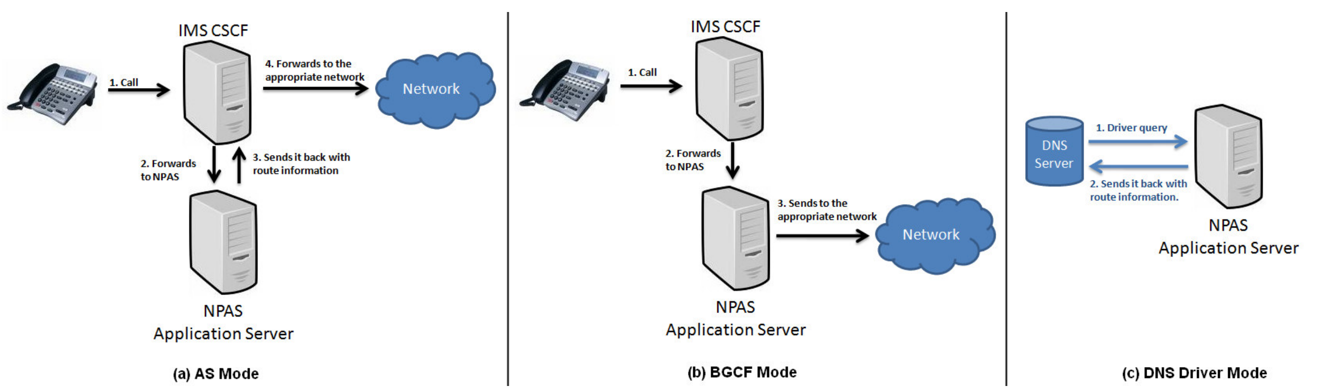

Figure 1. NPAS working modes

Average TRT exceeds 20ms at around 650TPS.

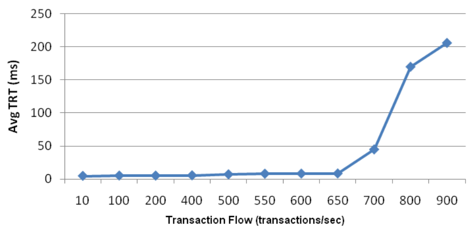

Figure 2. Average Transaction Response Time

Figure 3 depicts the plotting of the Transaction Failure Percentage (TFP) as a function of the transaction rate (call establishment). TFP measures the percentage of transaction that has failed.

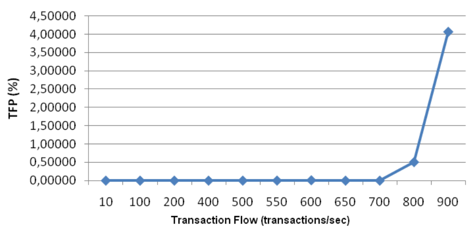

Figure 3. Transaction Failure Percentage

Figure 4 plots the Retransmission Rate (RR) as a function of the generated transaction flow. The RR measures the number of retransmitted messages as a percentage of the total number of generated transactions.

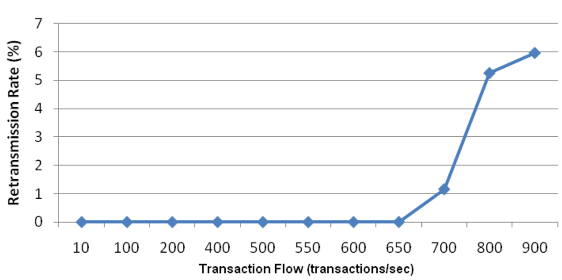

Figure 4. Retransmission Rate

TABLE I. TEST MACHINES SPECIFICATION

CPU	Core 2 Quad 2.83Ghz
Memory	4GB DDR2 – 800Mhz
OS	Linux Ubuntu 9.04
Softwares	Sailfin 2.0 Sun JVM 6 – Update XX

TABLE II. SCALABILITY TESTS

Nodes	TPS Rate
2	1400
3	2000
4	2400

TABLE III. STRESS TESTS

Rate	Total Calls	Failed Calls	Failed %	RR
500	360,000	13	0,00%	0,00%
600	360,000	3	0,00%	0,00%
700	420,000	1	0,00%	0,01%
800	480,000	40,038	8,34%	0,01%
900	540,000	74,242	13,75%	2,53%
1000	600,000	114,902	19,15%	5,15%
1500	900,000	348,360	38,71%	19,82%

VI. DISCUSSION

When discussing NP approaches, differences can be grouped in four main aspects: flexibility, network overhead, performance and deployment costs. Each aspect will be addressed in what follows.

A. *Flexibility*

AS resides in the service layer, what enables developers to add extra functionality to the network and services without being tied to vendor equipment releases. NP solutions based on AS can take advantage of such a characteristic, as it is possible to easily customize them in order to fulfill specific requirements for synchronizing with the central Portability Database, especially on those countries that do not use a standard distribution method such as ENUM. Examples of other functionalities are counters and reports of NP queries, which are not present in open DNS/ENUM solutions. Additionally, AS services can be enabled and disabled by changing the IFC configuration.

B. *Network Overhead*

The simple fact of adding an AS to an IMS network automatically increases the overhead on the network in two aspects: the time that CSCF spends evaluating and triggering an IFC, and the extra delay of an additional hop in signaling.

With ENUM, the network overhead can be minimized because such a node is already present in the IMS routing process, simplifying the NP query process. However, a drawback exists on the difficulty of maintaining the NPDB up to date, as is the case in countries that do not use ENUM as their default NP data distribution method.

C. *Performance*

ENUM is a lighter, stateless, simpler and faster protocol than SIP, which can motivate its use in an initial analysis.

Using BIND [17] as an example of ENUM/DNS implementation, its performance in executing ENUM queries was around 49000 QPS (queries per second) for an NP database with around 10.000.000 records [18]. In a rough analogy, considering TPS (Transaction per Second) and QPS as comparable units and analyzing the results from section IV, we can see that BIND demonstrated a much higher rate than NPAS. However, BIND has some drawbacks too, as it does not perform well during update operations and is not able to handle high volume of data, achieving 23 updates per second in a 10 million entries database [18]. It should be made clear that these numbers are specific to the BIND implementation; other DNS/ENUM solutions could have different performance.

Some preliminary tests of BIND using NPAS in DNS driver mode as a backend showed that a query rate of 11000 QPS and an update rate superior to 1000 updates per second was achievable. These results show a good potential of NPAS to deal with frequent updates scenarios in that mode.

D. Deployment costs

Deploying an application server in an IMS network is a straightforward task with a relative small cost due to its low impact. Most of the effort, though, reduces to the configuration of the IFCs.

ENUM servers are already deployed in IMS networks. However, if a country regulation does not use ENUM as its source of NP data distribution, adaptation and customization costs must be considered in order to enable the ENUM database to be kept up to date.

VII. Conclusion

NP is a very important requirement in telephony networks and has been deployed in many countries recently. Although there are already many solutions, portability of telephone numbers in IMS networks are not yet completed addressed, as it was mentioned in this paper.

In this work, an application server based approach for NP was presented, along with its corresponding test implementation. We demonstrated the feasibility and flexibility of this approach, and also a comparison with other solutions. A number of tests were executed, indicating good performance and successful interoperability. In summary, it can be argued that NP based on AS exhibits many possibilities for configuration and control of numbering plan and call routing, offering NP services to SIP and ENUM devices with a relative good performance and low cost of development.

As future work, we plan to enhance our tests by deploying our implementation in an IMS core and measuring its performance with respect to other indicators. We also plan to add B2BUA support to the solution and validate that approach. Finally, the DNS driver mode shall be further explored, as it has showed good potential in its preliminary results.

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