Cost and Policy Implications of AIN-Based Local Number Portability Implementations*

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Abstract

Local Number Portability (LNP) remains one of the challenging technical hurdles toward true competition in the local exchange. While short term solutions, such as NPA overlays and remote call forwarding exist, longer term solutions are still in the developmental and early implementation stages. Sections 251 and 271(c)(2)(B) of the Telecommunications Act of 1996 specifically require number portability, so the need to find and evaluate viable long term solutions is urgent.

Many aspects of LNP are interesting and warrant research. This paper will focus on evaluating LNP from the perspectives of implementation costs and institutional opportunities for anti-competitive behavior. This work will assume an Advanced Intelligent Network (AIN) based approach to implementing LNP.

Recent efforts have resolved many of the technical LNP concerns, however a number of cost and policy issues still exist that have not been resolved. In reviewing the technical aspects of number portability, an examination of the implications on market entry by new LECs and the opportunities for strategic behavior by the market participants is developed. Market behavior will be closely tied to the cost and regulatory developments that ensue. Implementations that promote entry, are low cost, and deter undesirable strategic behavior are clearly the preferred approaches. With this in mind, an analysis of the total cost of implementing an AIN solution is developed. This analysis is based on a solution that provides a completely portable environment, while meeting required criteria. This paper will suggest that the cost of implementing LNP could run into the billions of dollars. This raises the question of whether ensuring competition justifies such cost requirements. However, when other issues such as network evolution and the provision of future service are considered, the cost of LNP might prove more reasonable. Implementing LNP purely on the grounds of competition might turn out to be short-sighted and impractical.

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1 Introduction

Local number portability is a means for a customer to retain their telephone number when changing their location, service provider, or service. In today's telephone environment, the customer must obtain a new number for any of the following conditions; moving to a new location outside of the present switching area, choosing a new service provider (such as a competitive LEC), or choosing a new service, such as integrated digital services network (ISDN). A true solution would provide for portability across all of these areas, and provide for integration into future architectures. In addition to technical feasibility, the solution must properly approach the issues of cost and competitive behavior in the development and implementation of the service. The introduction of LNP is intended to remove a barrier to entry for competitive local exchange carriers (CLECs) and thus promote competition in the local exchange. To ensure this competition, the competitive environment that LNP could produce must be assessed and the implementation must be designed to ensure that certain players are not given strategic advantage. This would include cost concerns that could create barriers to entry for CLECs. Interest in this topic will likely develop as providers and regulators begin the arduous task of implementing number portability.

Regulators, inter-exchange carriers (IXCs), competitive access providers (CAPs), CLECs, and LECs have all taken the position that LNP is an necessary step to competitive local exchange service. There have been a number of surveys (see Gallop95 or INC96)that show many subscribers (particularly business) are unwilling to change providers if this requires changing telephone numbers. A Gallup survey showed that 90% of business customers were unwilling to change their provider if it required a change in their phone number. These customers state that the impact in terms of cost of upgrading to the new number and the potential loss of customers would make this change prohibitive. Considering the surveys, the lack of portability is a potential barrier to competition. A barrier to competition can be thought of as a condition that imposes costs on an entrant that the incumbent do (or did) not have to bear [**?**]; number portability meets this definition in most commonly accepted interpretations.

Interim solutions available today generally require a competitive carrier to accept some cost and/or technical disadvantages. However, some incumbent LECs have maintained that new entrants and existing carriers competing in the local exchange are simply attempting to use number portability as a means of furthering their own goals of keeping the RBOCs out of the inter-LATA business, and maintaining existing regulatory constraints, while they are able to operate free of restraint. If LNP is a critical aspect of local competition, then care must be taken to implement a competitive solution. Accurate analysis must be made in order to ensure that undesirable strategies are not undertaken [5] [13]. It might prove worthwhile to consider other factors beyond the provision of competition when debating the usefulness of LNP.

1.1 Motivation for this Research

Number portability has been discussed for several years, but has never had the momentum and backing required for implementation until a few years ago. Recent interest in LNP broadly spans the industry, including: the incumbent and competitive LECs, the inter-exchange carriers and the FCC and the Public Utilities Commissions (PUC). As can be imagined, each of these groups views the issue of portability in a different light and have thus formed their own guidelines to LNP implementation. At least two industry groups are examining the matter, and a number of PUC

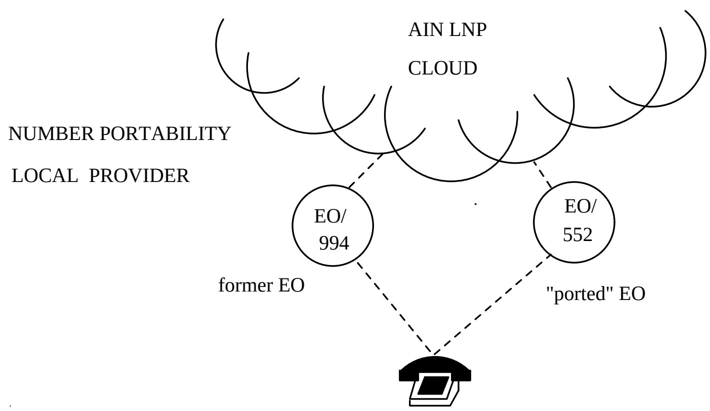

Figure 1: Service Provider Portability

and FCC notices have recently been released. There is now little question as to whether LNP will be implemented. It is only a question of how soon and in what manner the implementation will occur. This has prompted the formation of alliances, with each coalition presenting their own vision of LNP architecture, policy and goals. This can be seen readily in design statements these companies have presented in recent months at the Industry Numbering Committee (INC) workshops (see INC papers 95). [1]

Most of the research on LNP has been undertaken by the providers involved (incumbent and competitors), each presenting an architecture suited to serve their best interests. The issue of LNP is being solved/resolved mostly behind the scenes at industry workshops, without academic or public intervention or participation. There has been little outside evaluation of the models that have been proposed, nor have there been broad evaluations by the players involved. The FCC began to show interest in the area with the release of a Notice of Inquiry late in 1995. The benefits gained from a such service must outweigh the costs of provision, however, assessing these benefits becomes a difficult matter, with terms of measurement being diffuse and abstract. The incumbents have long argued that the gains obtained by number portability do not outweigh the cost of implementation. This issue has long been used by the incumbent carriers as grounds for not considering LNP. Moreover, the LECs have argued that the gains provided by opening competition in the local exchange won't justify the cost of infrastructure changes.

1.2 Research Focus

The focus of this research can be presented in two perspectives, one being an evaluation of the technical and cost impact, and the other being an evaluation of the competitive and regulatory impact. It is difficult to separate these issues due to their interrelated nature. Therefore, it is often necessary to address these issues simultaneously, as will be seen in the sections that follow. In terms of technical impact, there exist three issues that are central to service. The first is the method of addressing, which will affect the manner in which the numbering resource is

[1] The Industry Numbering Committee, with its INC LNP workshops and documents, are actively discussing LNP issues. The FCC has released several documents (including 96-286 and 95-284) and has included several statements in the recent Telecommunications Act (section 251 and 271(c)(2)(B)).

used. The second is the network architecture, which will impact traffic and cost of service. The third is operations, which will require modification of billing and operator services. Other impact concerns include: interconnection, modification for future architectures and services, performance and reliability issues, and security (these issues are only briefly addressed in this paper).

Central to LNP implementation is the issue of cost. From a rational investment perspective, the cost must be evaluated with respect to the expected benefits. This evaluation is, at best, difficult, partly because the benefits are largely public and diffuse[2] while the costs are private and identifiable. To motivate incumbents, who will in all likelihood bear at least some of the cost, there must be justification of the service beyond the competitive LEC's desire to gain market share. With this considered, it should be realized that LNP will require architectural revisions that later services will also require.

Under those requirements, any approach to implementing LNP should focus more on the developing aspect of the network, than on the "quick-fix" approach that opens the market to competition, while increasing the risk of network degradation. The cost model that we develop is based on an AIN model, which is consistent with revenue-enhancing investments that most incumbents will undertake regardless of LNP. Thus, one factor that must be considered by regulatory agencies is not just the total cost of implementing LNP, for which we estimate an upper bound, but the *incremental* cost of LNP on an already existing AIN-based network. We do not compute the incremental cost in this paper; we only recommend that it be considered.

In addition to technical implementation issues are institutional implementation issues. That is, what kind of organizational implementation is necessary to ensure successful implementation and operation of LNP? U.S. policy, as embodied generally in the Telecommunications Act of 1996, is focused on developing a market for telecommunications services of all kinds that is fair (in that all competitors operate under the same rules, that market entry and exit is as "frictionless" as possible, and that no operational advantages accrue to incumbents or entrants simply because they are incumbents or entrants). Let us consider the institutional aspects of each of these:

"Fairness" Procedurally, the database dips, updates, *etc.* must be done without regard to origin. This is easiest to enforce if a carrier is not involved in the operation of the LNP database. All users should see the same relative access delays, information, *etc.* It is also important that the privacy of the database contents be maintained, as it could contain competitively useful information.

Entry/exit Barriers A competitive marketplace depends on the ability of firms to enter and exit the market efficiently. With its large sunk capital costs, telecommunications is a costly market to enter or exit, but this sunk cost can be included in rational economic decision making. An institutional barrier to entry (or exit) exists if some factors, economic or otherwise, make it more difficult for one firm to enter (or exit) than another. In the case of LNP, high "buy-in" to a cooperative that operates a database can be an entry barrier; similarly, the inability to sell shares of a cooperative can be an exit barrier.

Operational Considerations The system should operate in such a way that incumbents and entrants alike can expect similar system performance. Furthermore, there should be no

[2]They are public in the sense that the benefits accrue to many private parties, including users. Note that the incumbents may also benefit in the long run from reduced costs of regulation, although those, too, are often difficult to quantify.

incentives that would bias the network toward either type of participant. This means that the databases, *etc.* cannot be operated and maintained by a competitor in the local exchange marketplace, as this control would create incentives and means for opportunistic behavior.

The remainder of this paper is organized into four sections. Section 2 provides background information on telephone numbering and includes a description of the North American Numbering Plan (NANP). 800 number portability is also discussed; this provides a basis for comparison with LNP. Also in section 2, a brief technical overview of the elements required for LNP implementation. Section 3 presents issues relating to competition and regulation in light of LNP. The introduction of LNP is intended to open local telephone markets to competition. Properly opening this market will require the involvement of regulators at both the state and federal level. Interestingly, most regulators have been slow to address this topic. Section 5 presents a cost model of implementing a national LNP scheme. This model is based on a calculation of the additional traffic generated by LNP and the resulting hardware that would be required.

2 Background

2.1 North American Numbering Plan

At the heart of number assignments lies the North American Numbering Plan (NANP), a design which does not allow for portability in geographic number assignments. The NANP provides for the assignment of a geographic telephone number to describe a network address. This address defines a network location through which a call is routed and a customer is provided service. [3] The nature of this assignment is inherently non-portable. The structure of the ten digit number is geographically and service provider limited. That is, the NPA is defined to a geographic area and the NXX is defined to a central office (a provider). A customer choosing to change providers will also be required to change their NXX. The NANP numbers are an integral aspect of routing and rating of a call as the present numbering system is defined. NPA codes are assigned to geographic regions and allow for routing and rating (assigning a charge) based on the known connection between geographic area and NPA. The NXX codes are assigned to LEC central offices (more specifically to a switch), as well as to the other providers (such as CAPs). This assignment allows the network to route calls to the correct switch on the basis of the NXX dialed. The geographic specificity of the number also allows for proper rating of the call. The distance sensitive aspect of rating depends on evaluating this structure of the number. By removing this geographic aspect of a number much of the assumed rating structure is destroyed or at least made inaccurate. One solution would be to base rating on the vestige of the previous physical numbering plan. If a completely non-geographic design was implemented, new approaches to determining distances would need to be implemented in order to provide for distance rating. [5]

2.2 "800" Number Portability

A number of papers have examined the economic and competitive impact of 800 portability (see Kuehn, 92; Stoffels, 92). There is a general technical and regulatory similarity between 800

[3] The NANP uses the format NPA-NXX-XXXX (N represents a digit from 1 to 9, X represents a digit from 0 to 9) to define a phone number in which the NPA defines a geographic area (often referred to as the area code), the NXX defines a central office in that area, and the XXXX defines the line number within that office.

portability and LNP. However, the 800 analogy does indicate a number of policy and pricing dilemmas that will likely arise during initial and later phases of LNP implementation. In the case of 800 portability, AT&T was the incumbent and the LECs and the other IXCs were the entrants; as can be seen LNP represents an interesting turn of events. An advertising campaign used by AT&T prior to and during the implementation of 800 portability focused on creating a climate of uncertainty. AT&T promoted the idea that the competitors networks were less reliable and that the transition period would be full of problems. It should be pointed out that transition to 800 number portability was not without difficulty. Several service management system (SMS) and service control points (SCP) failures did occur. It will not be surprising if similar propaganda will be used again; this time by the incumbent local providers [6].

Several of the guidelines suggested for LNP were first suggested for 800 portability. These are:

Equal Competition Opening 800 service was intended to provide competition in a long held monopoly, however the inability to port 800 numbers represented a significant competitive disadvantage to the new entrants. The solution had to ensure an equal ability to compete. [1] The next guideline that was that the solution should allow for the customer to be able to freely move between providers. This ensured that competition would continue in the market and that switching to a new player would not represented a terminal move.

Customer Transparency This guideline represented a large number of issues including; connection delays, connection quality, and general functionality of the service. This turned out to be a technically difficult problem that controlled the implementation designs.

Minimize Infrastructure Changes This was a logical guideline that minimized cost, time, and effort.

Much of the same rhetoric used during the development of 800 portability is heard today with regard to LNP. Concerns regarding competition and equal access have been raised on one side, as well as rumors projecting the deterioration of service quality on the other. Much of this might well have been a result of those involved with the technical and policy aspects of implementing 800 portability service. 800 portability database proposals were made by the LECs, in much the same way that IXCs have proposed many of the LNP solutions. The similarities between LNP and 800 portability allow for the provision of a reference after which predictions can be modeled. Development of the association between these models must be undertaken in a prudent manner to avoid assuming aspects of one exist in the other when, in fact, they do not translate [7, 8].

Time delays associated with the architectures are a major concern in implementing LNP. This same concern was expressed during the development of 800 portability. During that time, AT&T argued that the service would result in time delays of up to 20 seconds. Much of this delay was attributable to the lack of SS7 implementation in the local exchanges. Most of these predictions were unfounded; delays tended to increase, but not to the extent predicted. The introduction of 800 NP resulted in the deployment of SS-7 across the network. A similar increase in AIN capabilities can be expected from the introduction of LNP. An additional analogy can be drawn to the pricing requirements of the database queries. During the initial phase of 800 portability, the IXCs accused the LECs of trying to inflate their 800 database access rates by including query costs that were excluded specifically under FCC docket 86-10. The range of rates proposed varied from 0.15 cents to 33 cents per query. The FCC reacted by affixing a 0.15 cents/query rate during the period of initial investigation. At present, much more is understood about the costs associated with database access and this will allow for more ready rate analysis of LNP. This is not to say that the players involved will not battle over the rates. This merely points out that the FCC now has some means of predicting possible cost and pricing schemes with a fair degree of accuracy [12].

The analogy between 800 portability and LNP grows tenuous when considering a number of fundamental issues. First, 800 service calls make up a small fraction of all calls, while future LNP usage is enormous in comparison. [4] Second, 800 numbers do not share the strong geographic aspect of the NANP. The NXX portion of an 800 number previously served to identify the carrier providing service, not an inherently geographical link to a location. With 800 portability, a database query is performed on the whole number and the routing information associated with the carrier and number are provided. With LNP, the same whole number query may be required, however the scale will be much greater. The amount of infrastructure conversion is likewise much larger. By placing the translations into the SS7 network, upgrades will be required. Database size and access speed will need to match the demands of the traffic and performance specifications; estimates of these numbers are presented in the analytical evaluation section of this paper.

2.3 Technical Requirements

In today's numbering environment, a telephone number identifies not only the customer, but also the network address. As such, the routing and rating follow logically with the numbering design. However, to allow for portability this logical connection must be revised. There must be a separation of the dialed number from the network address. By freeing the dialed number, a new provider can be associated with that customer number, thereby providing for service provider portability. This association logically belongs in a database (DB). The exact architecture required has not yet been determined, although, several proposals have been made. The implementation will likely go through several stages of development, culminating with CNP. It appears unlikely that the architecture will be implemented as a single DB, rather it will include a number of partitioned DBs each serving respective areas or providers. In order to provide this DB lookup capability, the use of the advanced intelligent network (AIN) and signaling system 7 (SS7) architectures is the logical approach, with updates and triggers provided by the signaling network. An example of an AIN LNP model is presented in figure 2.

2.4 Signaling System

Intelligence has been provided to the telephone network with the introduction of improved signaling systems and intelligent network architectures. This came in the form of common channel signaling (signaling system 7) with service switching points (SSP), signal transfer points (STP) and service control points (SCP)/databases. The SS-7 allows for the separation of the signaling from the voice channel, providing for a much more efficient use of the network. The SCP provides for the implementation of DB queries and other intelligent provisions to the phone network

[4] There are 4.5 million 800 service database dips daily, with the databases that handle this traffic operating at around 500 queries/second. This represents a reasonable DB requirement. However, when considering general phone traffic, there are over 1 billion calls per day. Even if only those numbers that are ported require additional handling, this still becomes a problem of grand proportion. With this volume and rapidity of calls, it is clear that the 800 portability model only serves as a means for gross comparison and many of the analogies do not hold.

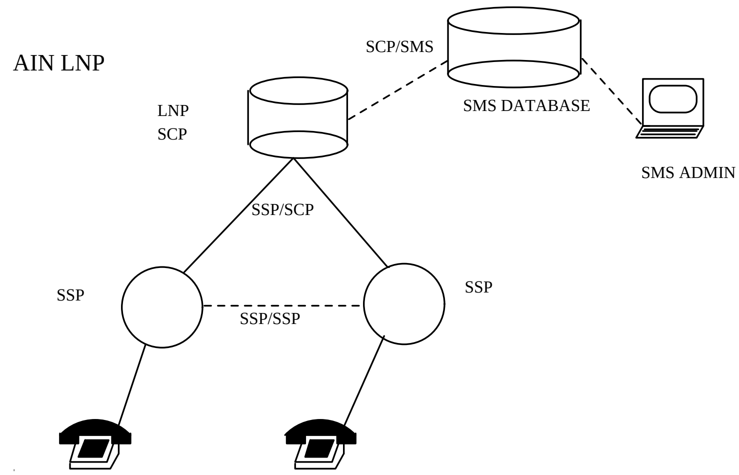

Figure 2: Advance Intelligent Network Local Number Portability

(refer to figure 3). These implementations have allowed for a great increase in routing flexibility. Moreover, these changes have made it possible to sever the long standing relationship between the telephone number (the customer address) and the physical location (the network address) of the telephone, allowing the dialed number to be routed to any physical telephone line based on instructions stored in the SCP.[5] With the introduction of the Intelligent Network came the implementation of the SMS (service management system), an update DB residing outside of the network, that allows for the rapid updating and management of information on the network. This has fostered new service opportunities such as portable 800 service. Even though the exact architectural approach has still not been resolved, it is certain that an IN model will be implemented[6]. With an IN design, the DB queries will be routed from the SSP to the SCP, where translation will occur. The SMS will serve as an administrative update center for the SCPs. A more detailed explanation of the operation of intelligent networks follows in the next subsection.[10]

2.5 The AIN

The basic elements of an intelligent network include the items represented in figure 2. The SSPs are integrated into or associated with stored-program control switches that are able to interface with the SS-7 signaling network. These devices contain limited service logic required to alter the handling of the call. The SSP differs from the ordinary switch in that it allows for the special handling conditions that IN services might require. This service differs from traditional service in that the SSP response can be controlled by a Service Control Point (SCP), not only by the local switch. This routing to the SCP is facilitated by the SS-7 network, a connection generally routed through Signal Transfer Points (STPs). STPs are highly reliable, high speed packet switches that transport signaling messages between the network nodes. This is done through the use of large routing tables that provide routing to the proper SCP. A STP may also perform a Global Title

[5] This capability is also a result of stored program control switches.

[6] This certainty is attributed to the lack of other viable solutions and the heavy installed base of SS-7 and IN components and software.

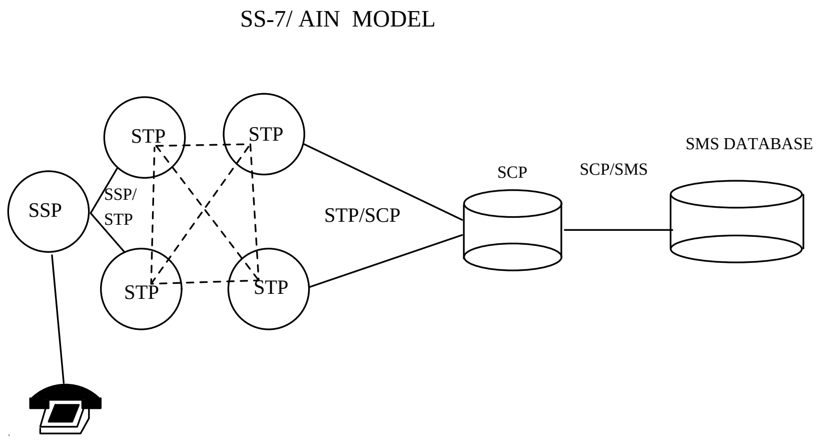

Figure 3: Service Control Point

Translation (GTT), a translation of an unroutable number to a routable address (such as an 800 number). An STP may terminate up to 1024 signaling links and process over 1000 messages a second. These devices are highly reliable with less than 10 minutes of downtime a year and introduce no more than 0.1 seconds of delay. The SCP is a real-time, fault tolerant database transaction processor. These devices can handle 500 to 1500 transactions per second, with a response time of less than 0.2 seconds and downtime of less than 10 minutes per year. [7] SCPs are designed to be upgraded, both SW and HW, without service interruption through the use of mated pairs. In order to manage the AIN platform, Service Management Systems (SMSs) contain the reference database for the SCPs. The SMS can supervise, perform remote maintenance, evaluate performance, and download software to the SCPs. This happens in a non-realtime environment, usually every few minutes. Service creation platforms interface with the SMS to allow network operators and customers to communicate with the SMS.[8]

When a customer places a call to a number which has been ported, a trigger allows for a query to be sent to an LNP DB to provide call routing and other information. The LNP DB could also allow for the rating of customer and network numbers. This DB will likely exist as a distributed system across the nation. The data contained in these distributed DBs will be regional in content. These DBs will not need to be associated with a provider. One such solution envisions the DB being managed by a third party provider, through the use of a service management system (SMS). It appears likely that the DB will exist in more than one setting; in the LECs, the IXCs, and third party providers. Because new entrants may have to purchase their DB provision, the impact of DB location is relevant, as is the pricing associated with access.

The use of the IN has allowed for the implementation of 800 number portability. In 1991, the Federal Communications Commission decided that in order to promote interexchange competition, 800 service number portability needed to be implemented.[3] To accomplish this goal, they

[7] The response times are from Bellcore standards. The transactions capabilities and line termination are industry specifications.

[8] Much of this SCE is still under development. However, when realized this environment will drastically alter communications within the PSTN. The ability to access and configure numerous services in a realtime environment will represent a major change in how communication networks are utilized.

systematically involved all players concerned and began a well organized effort toward this end. The process that went into providing this service took several years of work, with a great deal of disagreement between providers. However, 800 number portability was implemented and has been considered to be a great success, both in terms of technical and competitive implementation. As stated earlier, 800 number portability provides for an analogous model to which LNP might be related. Several of the differences have already been discussed, however, many of the concerns regarding the technical provision and competitive impact are adequately similar. More importantly, it should be realized that 800 number portability required the installation of physical infrastructure, mostly in terms of the development of the AIN architecture in many LECs. In this respect, LNP may be viewed as a means of enhancing the network infrastructure. This installation was required for 800 portability provision, but also was part of the general modernization of the network. This architectural change has allowed for a more logical transition into LNP; much as the changes that LNP requires will allow for future service implementation. This concept of piggy-backed infrastructure change should be viewed in terms of its short-term and long-term significance. Models evaluating the cost associated with infrastructure change must attribute part of the cost to future services that will require this infrastructure. In other words, there must be a separation of the cost for LNP from the general cost of the evolving network.

2.6 Database

NP will require that a signaling point in the network has the ability to dip a LNP SCP in order to determine the true address of a number which has been ported. The customer's address in this sense becomes a virtual address, no longer directly associated with the physical address. During call setup, the call proceeds until it encounters a switch that has the ability to determine that the call requires alternative routing (this would be a switch with SSP abilities that could dip a SCP). In terms of minimized traffic, the best case scenario is the original local switch. The issue of dipping the database also arises with the calling customer. When a call from a ported number is placed, a dip will be required to translate the calling party's address to a virtual address in order to provide CLASS type features of the called party (caller ID). With the goal of performing these dips in the most efficient manner, they should occur as early in the call process as can be managed, so as to reduce signaling traffic overhead. Therefore, the first portable switch, preferably the originating exchange, should perform the dip. If the originating switch is unable to do this, it falls on the access tandem or IXC switch. This design must also address the need when not to dip due to redundancy or absence of porting. [9] Recent DB focus has been to ensure that calls are not dropped during congested periods. This is an condition that Ameritech has pursued in the form of a DB offering that would complete translation of such calls. Ameritech is offering this service at a rate of 3 cents per call, a rate seen as high by much of the industry.

3 Competition and Regulation

3.1 Competitive Motivation for Portability

The principal goal of number portability is to remove a barrier that might inhibit competition in the local phone market. For this reason, the primary concern in terms of portability is that of service provider portability. It is thought that NP will fuel competition among carriers at the local level. The competitive advantage that the incumbents maintain with number ownership could prevent the entry of other players into the market. By removing this technical barrier, the likelihood of the consumer switching providers increases and thereby, in theory, enabling a more open competitive market. This same basic premise was applied to 800 portability. A subset of the earlier deregulated long distance market, 800 service portability was the first to provide equal access to competitive players through the use of portable numbering schemes. One reason that number portability was first seen in the 800 arena was because of the relative ease of implementation as compared to local service portability; the difficulty of porting one NPA as compared to all NPAs. Another, more compelling reason was that regulations did not clearly allow for local competition when 800 portability was being discussed and developed. 800 portability was one of the important elements of a competitive IXC market, which was an explicit outcome of divestiture. [11] The technical difficulties that have been encountered in the local provision of number portability have only been compounded by the lack of regulatory involvement to address the issues of creating a open market. A valid concern can be raised regarding whether end users will move onto competitive providers./footnoteRecently introduced LNP service in Gaitherburg, MD has failed to attract any customers. This raises numerous questions regarding the motivation for implementing LNP. As was the concern in early private lines markets, the provision of LNP may create an environment in which the end user has the opportunity to switch to other providers, but this does not necessitate their move. The question remains as to whether the existence of a competitive opportunity will provide the momentum to create competitors and whether the competitors can create an incentive for the consumer to change providers.

As described above, telephone numbers are assigned to service providers in the form of office codes indicating the physical switch to which they are attached. With the exception of inefficient solutions, such as call forwarding, the customer must change phone numbers in order to change service providers. This, of course, presumes the existence of a competitive provider to whom that customer might switch. For a business, this number change could result in a substantial financial impact. Revenues could decrease as a result of customers being unable to reach the business. Also, the costs involved in updating materials with the previous number could be quite costly. This could include such items as advertisements, business cards, and business agreements. This would provide a significant advantage for the incumbent provider by producing a prohibitive economic barrier against change.

As will be highlighted later in this paper, the introduction of number portability will require substantial monetary outlays. Questions remain as to how the cost of implementing LNP will be distributed among the players. There are several possible answers. In England, the incumbent is being forced to incur much of the cost. This appears unlikely in the US, where the FCC has stipulated that the cost should be a shared problem. In an alternative approach initially suggested by an incumbent, the customer choosing to switch would pay for the transition. This is easily realized as a barrier to those unable (or unwilling) to pay the transition charges, and therefore not in line with a competitive solution. Likewise, requiring the competitive provider to pay could be seen as a barrier to entry. The FCC's recommended approach would require the cost to be split among all involved, with these costs eventually trickling down to the consumer. Assuming the latter, efforts should be taken to evaluate the costs directly associated with LNP and distinguish them from costs incurred for the modernization of the network. This separation is not a trivial issue and may not be readily feasible. Changes that LNP require are consistent with changes that other service provisions will require in the future (such as PCS). These grand architectural changes can not be attributed to a single service when in reality they will be required for future needs. In the case of 800 portability, estimates were well under actual costs, possibly attributable to the lack of well performed analysis. High estimates place the total cost of LNP in the area of US 100 billion dollars and low estimates place it in the area of US 100 million dollars. Keep in mind that local access represents a $90 billion/year industry, an amount that might balance the heavy cost of LNP. At this time it appears that LNP will be implemented regardless of the cost. Other issues of network cost and implementation are discussed in a later section. [5]

3.2 Regulation of LECs

The communications industry anxiously awaits the full impact of the Communications Act of 1996. The months since its passage have left more questions (and numerous legal challenges) than answers as to the future of the telecommunications marketplace. In general, the Act is intended to usher competition into the communications market. The impact of opening markets that have so long been held in check by regulation and/or monopoly control is difficult to predict. However, it is certain that changes will occur in a number of areas, including: the price for services, the providers of those services, and the manner in which they are provided. One concern expressed by segments of the industry is the possibility of the LECs entering into the long distance market prior to the introduction of any real competition in the local market. This concern stems from the mergers, acquisitions, and positioning that are occurring throughout the industry (including all segments of communications). With the Modification of Final Judgment (MFJ), the LECs were prohibited from entering the long distance market as long as they had monopoly control that could be used in an anti-competitive manner. Fears of pre-divestiture control of the market by a single player have been expressed by long distance carriers and state regulators. Provisions such as LNP must be made to foster a measurable amount of competition in the local market before allowing the LECs to enter into long distance service. The slow pace displayed by regulators would suggest that competition in the local market is a long way off. Proposals regarding the permanent implementation of LNP project a one year start-up period, with additional years necessary to establish competitive levels. Prematurely opening segments of a market with players that possess monopoly control could well create an environment that stifles competition and exasperates the hold that the incumbents have on the market. The likely outcome of this scenario is implementation of further regulatory measures to control this supposed open environment.

Assuming that deregulation at a national level does occur, there are still many tariff issues that reside at the state commission level. This could be a cause of overload for many of these commissions, particularly less regulation-savvy states. Many of these states will likely be more concerned with maintaining universal service than with LNP implementation and the introduction of competition. With implementation of LNP, those RBOCS still under rate of return regulations will be aggressive in effecting the removal of such regulation. If LNP is successful at opening competition and universal service measures are provided, then regulations may be reduced. At a more micro-level, municipal regulations may well impact the implementation of LNP. Municipalities could block rights of way to the competition, which would mean reliance on the incumbent for connection. By blocking competition, the municipality is free to provide the service themselves, although this is unlikely to occur in the US. Accompanying the intended competition of LNP is the restructuring of the tariffs regulating the incumbent's pricing. These tariffs direct pricing and conditions for interconnecting the network with those of its competitors and for unbundling the segments of its network that competitors might use. The issue of separating the cost and pricing in an area such as the local loop is likely to cause a great deal of conflict between the players. Competitors will demand volume discounts so they can profit by reselling services. An accurate assessment of the incumbent's costs associated with provision will be necessary.

The delay in implementing LNP may well be a result of the incumbents' purposeful delay of this process. Many of the incumbents are still reluctant to give up the monopoly control they possess. Ameritech has taken legal steps to delay LNP, based on their claims that LNP will have detrimental impact on the telephone network. However, it appears that this is more likely an attempt to delay competition than concern for the performance of the telephone network. With the modest initial porting of subscribers, even the most inefficient portability scheme can provide the required service without adversely impacting the network. [9] Adding to this delay is the apparent reluctance of the FCC and the PUCs to take action with this matter. This wait-and-see attitude is evident when considering how long it took the FCC to release the first Notice of Inquiry (late 1995). PUCs have recently begun to address this issue by ordering all carriers to work together in implementing LNP (a task that would appear easier said than done). Ameritech is attempting to implement solutions in their market without consensus from other players, going directly against INC and FCC recommended actions. It is likely that the FCC proceedings will move too slowly for some state commissions that intend rapid LNP implementation. For example, the Illinois' state PUC planned to implement LNP in Chicago by the end of 1996; this failed to transpire. The likely outcome of such unilateral implementations is the development of disparate initial solutions serving only the larger metropolitan areas of the nation. Differing regional approaches could well create an environment in which these various architectures will have difficulty merging. Seamless evolution should be considered a requirement. However, disparate interim solutions do not necessarily indicate a problem for evolution into future networks. Interim solutions could allow for a more rapid introduction of competition into the local loop. States that do decide to implement well designed solutions early could well become creators of de- facto standards, which could then serve as a format for other states. The more interesting implications of this competitive pressure by the incumbent, are the possible strategic outcomes. By creating an environment which forces the competition off the incumbents networks, the competitors could turn to other providers (cable loops) or possibly create new networks. In either case the long run implications for the incumbent are problematic. Furthermore, should the disparate interim solutions run contrary to the evolution toward CNP, the lack of action on the part of the state and federal government to unify efforts could profoundly impact the system. [4]

In September of 1995, US West, among the most active Baby-Bells in number portability, asked the Iowa PUC to realign their tariff rates in an attempt to more closely represent cost. The company claims that by altering these tariffs competition will be encouraged in both local and long distance service. Specifically, US West asked to raise their local residential service rates. This would mean the reduction of the traditional subsidies for local service. Also they requested to lower their price on toll service to direct customers and attached providers. US West has also actively sought out resolution of issues critical to number portability and competition with other states. They have requested evidentiary hearings be held and testimony be presented in hopes of clarifying the impact that portability might create in terms of competition and pricing. This concern could be the company's attempt through the use of hearing to delay the inevitable com-

[9] Adverse is defined as representing demands that could result in service degradation. This could include long delays to connect, misrouted called, or lost calls.

petition that LNP will allow. With the introduction of competition to the local loop, incumbent providers will need to concern themselves with policies for the portability of telephone numbers, the unbundling of basic services, and the compensation for call termination. Additionally, regulatory concerns regarding universal service and subsidies provisions need to be addressed.

3.3 International LNP Regulatory Action

In foreign markets, levels of activity vary greatly in regard to number portability. Oftel, England's telecommunication regulator, recently made major revisions to the license agreement with the country's monopoly service provider. Most notably, a financial accounting separation has been devised to prevent unfair cross-subsidy for the incumbent. The more surprising regulatory decision involved Oftel's plan to require the incumbent to pay the costs of re-directing ported calls. In Australia, the Australian Communications Authority (ACA) has created a new national number plan. This plan is designed to allow for the opening of additional numbering resources, while ensuring that customers can freely move onto new carriers. Prior to the release of this revised number plan, ACA imposed an interim license condition on Telstra (the national carrier), which required it to provide LNP to Optus by May of 1998. Under this agreement, Optus will pay the one-off administrative costs incurred by Telstra to transfer a customer to Optus. This one-off amount will decided either by an agreement between the carriers, or by government intervention. Additionally, Optus will pay one cent per call to Telstra for ported calls. ACA is seen as being very aggressive in opening the market to competition, while allowing the industry to reach agreement without regulator oversight.

3.4 Provision of LNP Service

It seems reasonable to assume that the LNP support databases and systems will be operated by independent firms. These firms can be profit-making firms, cooperatives, consortia, *etc.* If the price of database dips is allows for sufficient profit, then one could expect private firms to enter into a competitive market for the provision of LNP databases. While this may make the synchronization of the databases of the competitive LNP service providers more technically challenging, it provides an environment that would allow for the least regulation possible. If the database dips are just remunerative, then it might be more reasonable for cooperatives or consortia of the affected carriers to emerge. As long as the "owners" did not have an operational influence, this would be a reasonable approach, although the efficiency and innovation incentives that would be found under competition would be absent.

4 Network Costs and Requirements

4.1 Assumptions

To present a more coherent paper it has been necessary to postpone issues of network cost until a presentation of the architectural, regulatory and competitive concerns has been made. Having now addressed these concerns, this section presents a generic cost model of AIN LNP. This model has been developed by estimating the total necessary enhancement of the present network required to provide LNP. Much of these data are projected as estimates; others have been obtained from industry sources and INC projections. In order to predict the impact in terms of cost and technical feasibility, several assumptions must be made. An AIN LNP solution will result in greater traffic loads. With this, we can determine the equipment that will be required. Traffic will depend on the type of implementation chosen and the number of customers that choose to port their numbers. To handle this traffic, switches, DBs, and additional link capacity will be required. Also, changes to the present switching and signaling software will be required. As described in a previous section, the SCPs will be queried by the STPs for porting information. The SCP will be updated by the SMSs. The implementation modeled is one in which all originating calls result in a dip.

It is demonstrated below that the present SS-7 circuit infrastructure is adequate to accommodate LNP needs. The STPs presently installed are well beyond the required needs of LNP. The additional load generated by LNP messages suggests up to a 100 percent increase in SS-7 load on aspects of the network. SS-7 is far under utilized, the present load is well below 20 percent, therefore the addition of LNP to the SS-7 should not be a problem.[10] This should be evident; on average a call requires 7 SS-7 ISUP messages to complete and LNP (as generally envisioned) will add an additional 2 messages per call (TCAP messages) , thereby adding 100 percent (realize that TCAP messages are typically 4 times larger than ISUP). The SSPs will require SW upgrades, but no significant additional SSP facilities should be required.[11] The infrastructure changes come down to SCP and SMS needs, along with SW. The SCPs that are used for LNP will be exclusively for LNP. So any presently available SCP can not be considered as part of the LNP resource pool.

4.2 Database Requirements

DATABASE SIZE Below are some estimates of the percentage of NALs (network access lines) that will port during each of the following years. These numbers are presented in Table 1 as a basis for estimating the likely database requirements for an NPA.

An issue that must be considered with a DB of this size and realtime nature is the response times. The DB would be required to meet the guidelines of Bellcore's GR-1280-CORE response times. They include a response rate of no more than 120 ms for a 95% load. Additionally, this equipment would be required to conform to Bellcore's SCP reliability specifications of 99.98% availability. SMS size requirements will need to be in the area of 5 GBytes for an NPA. This size is derived from the need for a much larger record size (500Bytes) and the need for each SMS to serve a number of SCPs. This size does not reflect the size of the actual SMS, just the size needs per NPA. The non-time-critical aspect of the SMSs would allow for a much less costly memory configuration (disk storage as opposed to random access memory). [2]

[10] A point to consider is that the increase in signaling load is factored into network evolution. The LNP increase does represent a larger than usual increase, but can be viewed as part of the evolution of the network in that other services will make use of this increase capability in the signaling infrastructure.

[11] This assumes the initial need for SSP capable switches is satisfied; SSP penetration is approaching 100 percent nationally.

SCP Assumptions	
Each SCP record contains 30 bytes (information for translation), assuming one NPA	
10,000 lines/NXX	
800 NXX/NPA	
8,000,000 NALS/NPA	
Growth of NALs	
Year	*Number of NALs*
1996	8,000,000 NALs
1997	8,400,000 NALs (+5%)
1998	8,820,000 NALs (+6%)
1999	9,350,000 NALs (+6%)
2000	9,910,000 NALs (+6%)
Porting Percentage	
Year	*Number of NALs Ported*
1997	420,000 (5%)
1998	880,000 (10%)
1999	1,870,000 (20%)
2000	2,477,000 (25%)
SCP Size	
Percent Ported	*Database Size*
25%	60 Mbytes
50%	120 Mbytes
100%	240 Mbytes

Table 1: Assumptions for Cost Computation

4.3 Traffic Estimates

The following model assumes a steady (stable) network condition, not one in a congestion state or failure. [12] The design is engineered well beyond the typical needs of the network (with links at .4 Erlangs); the results are summarized in Table 2[13]. This is accomplished by designing above the needs of BHCC numbers. In order to determine traffic generation of LNP on the local switch, the following data is used. [14]

Assumption	*Variable Name*
100,000 BHCC (busy hour call completion)	
80% trunk traffic	trnktrf
60% line traffic (will cause LNP transactions)	linetrf
3.5	SS7 messages/call/direction
100 byte avg/TCAP	tcapsiz
25 byte avg/ISUP	isupsiz
1 dip/LNP call	
SS7 2.8 Kbytes/sec/direction (at .4 Erlangs)	
bidirectional links (5,600 O/s)	
100 switches/LATA	sw/lata

Table 2: Traffic Estimates

Switch Message Generation Most of the previous measures come from AT&T data measures. The equations were adapted from an unpublished paper released by AT&T. The SS-7 information can be found in Signaling System 7, by Russell. Some equations were derived from materials founded in IEEE Traffic System Design Handbook, 92. The remaining equations and assumptions are the authors'. In order to estimate the message generation it is necessary to sum the ISUP and the TCAP octets per second that are generated. Assuming 100,000 busy hour call completions, along with the above stated traffic flows and measures, it is possible to predict the message generated at a typical switch. The ISUP traffic is determined to be the ISUP product of the bhcc, the message size, and the number of messages. The TCAP traffic is determined to be the product of the TCAP BHCC, the message size and the number of messages (in this case, one). The TCAP traffic can be thought of as representing the query messages to the databases (the SCPs). The ISUP messages can be thought of as representing the signaling messages used to coordinate the connections. Both of the previous two statements are gross simplifications, but serve to give the reader an idea of the general role that the message serves.

W=(ISUP OCTETS) + (LNP TCAP OCTETS)

W= 3612 O/s

[12] Refer to Willman 94 for more on modeling stable systems.

[13] This model ignores non-LNP TCAP generating sources.

[14] This implementation follows the FCC recommendations for LNP.

Link Throughput The number of SSP-STP link pairs can be determined by the total traffic divided by the link rate (5,600 octets per seconds). The number of STP-SCP links can be determined by taking the product of the TCAP traffic per switch and the number of switches, and dividing this by the link rate.

number of SSP-STP link pairs (lp):

lp = 30 pairs

Transactions per Second (TPS) The Transactions per second can be found by taking the line traffic rate and multiplying it by the number of switches.

TPS = (bhcc * linetrf)/3600) * numsw

TPS = 1667

4.4 Requirements

In determining the number of SCPs required, the decision must take into consideration the transaction rate and the link capacity. An SCP may support a number of link pairs, depending on design. It is not unrealistic to expect an SCP to handle all 30 of the links as determined above. Let us assume that the switches are each handling 8 links. This would require 4 SCPs to serve the LATA. However, this equipment is all installed redundantly, so actually 8 SCPs will be required. Assuming that the SCP can process 1000 transactions per second, 2 SCPs would cover the 1667 TPS (again, this must be doubled). Since the number of SCPs is dependent on the maximum of either transaction number or link requirement, it will need to be based on the link requirements. As mentioned, the SCPs will be dedicated in nature and therefore the SCPs already installed cannot be used for LNP provisioning. An additional consideration when determining the number of SCP, centers around the number of competitors in an area. Each competitor would likely have their own facility. This would create a condition in which traffic might not be the primary concern in designing the network. STP numbers can be seen to be adequate in size as the present network provides. This is based on the relatively minor traffic increases that LNP will add to an already under utilized STPs. Present day STP switches can handle 2M O/s. The present load is at 15 percent and the additional traffic from LNP will only amount to an additional 15 percent, while maintaining Bellcore minimum delay requirements. Assuming 250 LATAs, there will need to be as many as 2000 additional SCPs and some fraction of that in additional SMSs. The total number of SMSs will likely be in the area of 50 nationally (this figure could be argued in either direction).

At a cost of up to one million US dollars per SCP and 500,000 US dollars per SMS, this translates to an estimate of over 2 billion US dollars in equipment. The software costs within the Signaling Points (SP) are likely to be in the area of 100,000 per SP, which amounts to an additional 2.5 billion US dollars. [15] The maintenance and operations costs are outside the focus of this paper, but are considered to represent costs equal to HW and SW. In terms of equipment,

[15] The equipment price estimates were provided by Mr. Frank Reese of North Pittsburgh Telephone Company.

SW, and operation costs for full number portability at a national level, this model suggest that the initial estimates of 10 billion US dollars for LNP implementation is not so unrealistic. [16]

5 Conclusions

In this paper, the development and implications of local number portability (LNP) have been examined. In evaluating proposed LNP architectures, the focus has been on three factors; cost, technical feasibility, and competitive behavior. In terms of cost, an estimate of the potential infrastructure costs as well as the potential pricing problems has been presented. In terms of competitive behavior, the concepts development in this paper emphasize that competition must be introduced into these markets with regulatory prudence. Most of the concerns regarding competition in LNP closely mirror the more general concerns of opening the local service market to competition. In this regard, LNP (through its federal mandate) may serve to force regulators to address these larger issues.

The cost model suggests that it is not too unrealistic to expect such an implementation to run well into the billions of dollars. However, it is important to realize that much of this represents investment that would be required for general upgrades of the network and for the provisioning of other services. This point should not be ignored when considering the cost of LNP. To understand the impact that LNP could create in terms of economic and technical outcomes is of great importance to the future of the telephone market, for both the providers and the customers. The implementation that is chosen may well have significant bearing on future telecommunication services.

This paper really just scratches the surface of issues that can and must be addressed with respect to LNP. Further research is needed to address the following important questions:

- How is the cost of LNP to be borne by the industry participants?
- What safeguards are needed to ensure the privacy of information contained in the LNP databases?
- What is the *incremental* cost of LNP, assuming that much of the $10 billion implementation cost estimated here is an investment that will have to be made *anyway* to provide high margin advanced services to customers?
- How should distributed databases of this kind be developed and deployed?
- What are the consequences of database failures (*eg.* synchronization failures, deadlock, *etc.*), and SS7-based LNP failures?
- What are the implications of competitive, for-profit LNP service providers?

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6 Appendix

The following are the equations that were used in determining the traffic generation.

Additional traffic load:

Load=(ISUP OCTETS) + (LNP TCAP OCTETS)

=(bhcc*trktrf*isupsz*isupnum) + (bhcc*linetrf*tcapsz)

=(((100,000*.8)*25)*3.5) + (100,000*.6)*100)

=13,000,000 O/BHCC

Load= 3612 O/s

Number of SSP-STP link pairs (lp):

lp = W / 5,600

lp = .65 pairs

number of STP-SCP link pairs (lp):

lp = (bhcc*linetrf*tcapsz)/3600 * (sw/lata) / 5600

lp = 30 pairs

Transactions per second:

TPS = (bhcc * linetrf)/3600) * numsw

TPS = 1667