Electronic Numbering (ENUM) Management for VoIP Communications

Managing the interoperability complexities between PSTN and IP network infrastructures will require a flexible and intelligent operations management strategy

Innovative ENUM Management solutions such as the Lucent VitalQIP® ENUM Manager, manages the complexities and automates the translation of IP addresses to 10-digit telephone numbers.

This white paper addresses:

- How DNS is used to resolve hostnames to IP Address
- Leveraging existing DNS infrastructure to enable ENUM services
- How a phone number is translated into an ENUM URI to complete a phone call
- Benefits of deploying an effective ENUM Management application

Lucent Technologies
Bell Labs Innovations

Introduction

With today's increased focus on convergent technologies, IP Multimedia Subsystems (IMS) and the acceleration of Voice over IP (VoIP) and other IP-based services like IP Video, Voice Protocol for Internet Mail (VPIM), Instant Messaging and Internet Fax – fast, easy and reliable administering of IP Addresses and Domain Name System (DNS) services is quickly becoming a critical management issue.

One technology beginning to be implemented for administrating various types of records in Domain Name Systems is known as ENUM. ENUM is defined in IETF RFC 3761. Different sources define the ENUM acronym differently, and one definition, as per the IETF, is "tElephone NUmber Mapping." 1

In brief, ENUM specifies a method for storing information in DNS servers to map an E.164 number (a.k.a., telephone number) to associated user contact information. The contact information could be for an Internet phone address, cell phone number, e-mail address, fax number, web page URL, or other contact information. This contact information is stored in Naming Authority Pointer (NAPTR) records, which are associated with E.164 domain names.

One example application of ENUM is to convert a phone number dialed on the Public Switched Telephone Network (PSTN) to a Session Initiation Protocol (SIP) IP address for a Voice over IP (VoIP) phone on the Internet. For example an E.164 domain name for the phone number (222) 333-5555 is "5.5.5.5.3.3.3.2.2.2.1.e164.arpa.". Note that the digits in the E.164 domain name consist of a phone number in reverse order.

Lucent Technology, a pioneer and leader in IP address management, provides a centralized management solution that streamlines and automates the administration of ENUM domains (e.g., .e164.arpa.) and the Naming Authority Pointer (NAPTR) records for the reliable and secure management and translations necessary for VoIP communications. Lucent IP address management solutions are built for the most demanding VoIP environments to speed call routing and ensure call completion reliability with an unparalleled E.164 number resolution proficiency.

Understanding Domain Name System (DNS)

The DDNS/DNS is a system for mapping names to IP addresses and vise versa. On the Internet, DNS is used by virtually all inter-networking software, such as remote terminal programs like telnet, file transfer programs like FTP, and electronic mail like SMTP (Simple Mail Transfer Protocol). Its basic function is to provide name and address resolution on a network.

At the most basic level, DNS maps a host name to an IP address. DNS provides a single naming model throughout the distributed environment, based on the idea of a hierarchical name space, accommodating a large, rapidly expanding set of names. DNS makes its information available throughout the network, regardless of whether the network is departmental, organization-wide, the Internet, or any mixture of the above.

DNS is a distributed database system for resolving host names into IP addresses. The host information is distributed among thousands of name servers organized into a hierarchy. This way, it does not require a central site to administer it. Each Domain Name server is designated responsibility for one or more domains and may refer requests for unknown hosts to another DNS server in the hierarchy, as shown in Figure 1.

[1] IEFT RFC 3761

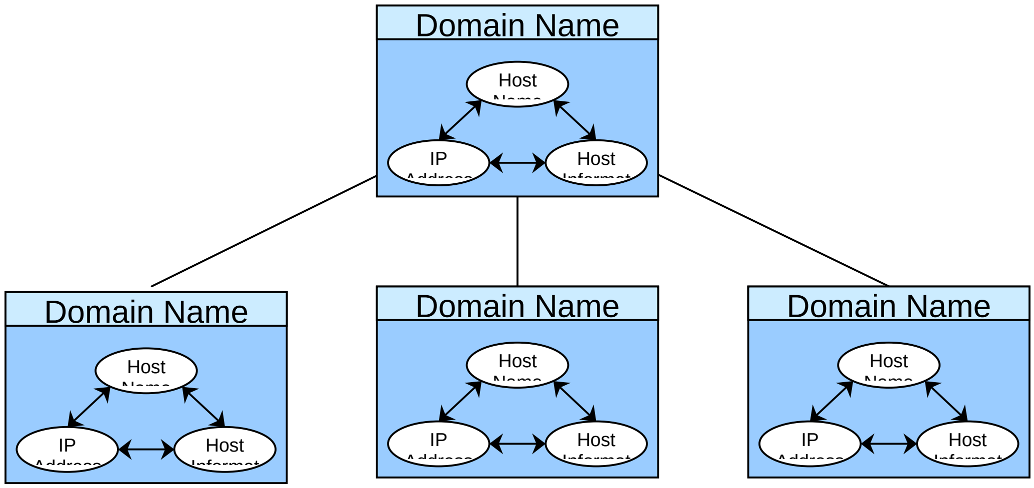

Figure 1 - DNS Hierarchy

The three bottom Domain Name servers have been assigned responsibility for a domain. The top Domain Name server passes requests for unknown hosts to the bottom Domain Name servers. A bottom Domain Name server returns information about the unknown host if it has been assigned to a domain the Domain Name server administers.

The Berkeley Internet Name Domain (BIND) server implements DARPA Internet Domain Name specifications and protocol. BIND is based upon a client/server architecture where the client and the server are comprised of “resolver” and “named”.

The DNS primary function is to resolve a network object’s logical name to its network address(es) and vice versa. The client sends a query to the name server that the client has been configured to use. If the query can be resolved by that server, a response containing the resolution is sent back to the client. If the query cannot be resolved, a reason is sent back to the client.

DNS is inherently hierarchical and distributed in nature. DNS name space has a hierarchical organization, consisting of domains nested within each other. This hierarchical naming scheme is known as domain names.

Hierarchical name space provides autonomous control of domains and subdomains, flexibility for change control, minimum requirements on both the server and network resources, which follow an administrative or an organizational structure.

The top of the domain hierarchy is the “root” (.), which is served by a group of name servers called “root” servers. Directly under the root domain are the toplevel domains. Conceptually, there are two types of top-level domains: geographical and organizational. The geographic scheme divides top-level domains by country, and it is identified by a two-letter code (for instance, CA for Canada, JP for Japan). In addition to the two main types of top-level domains there is one other top-level domain catageory used for infrastructure. This special domain is known as arpa. In the United States, the most commonly used top-level domains are organizational, including:

- com - commercial organizations
- edu - educational organizations
- gov - government organizations
- mil - military organizations
- net - major network centers
- org - organizations other than those above
- arpa – address and routing parameter area (ENUM records)

No servers, including the root servers, have complete information about all domains, but most servers have pointers to other servers in the DNS hierarchy.

Domain names are written left to right from most significant (host name) to least significant (top level domain) with each domain level separated by a period (“.”). For example, the domain name, cs.mit.edu, contains three levels: cs, mit, and edu. In the above example, the lowest level domain is cs.mit.edu, the second level domain is mit.edu, and the top-level domain is edu.

The root of this hierarchy is maintained by the Network Information Center (NIC) and other organizations, as shown in Figure 2.

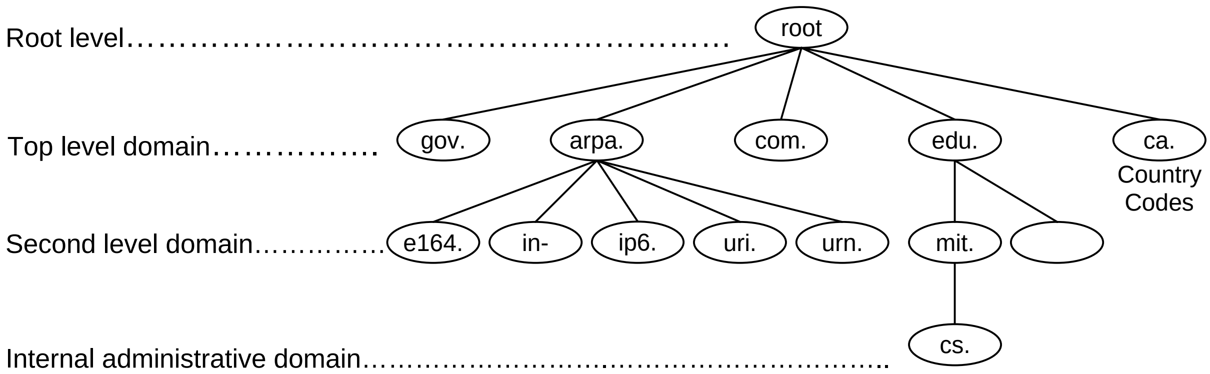

Figure 2 - DNS Domain Structure

In Figure 2, these different domain levels are shown:

1. Root level domain: The root of the tree is maintained on several servers across the world. The root domain name servers maintain information about name servers at the next lower level.
2. Top level domain: Every domain must be registered in one of the top level domains, such as COM, EDU, GOV, ARPA and so on. These top level domains, and their DNS, are maintained by the registrars.
3. Second level domain: These are the corporate domains. Each organization has the responsibility to maintain and administer its own domain.
4. Internal administrative domain: These are autonomous sub-domains within an organization. These sub-domains can be further nested into smaller subdomains. The maintenance and administration of each sub-domain can be a centralized function or the responsibility of sub-organizations.

Each DNS server contains resource records (RRs), which provide the data that make the DNS system work. Several different types of resource records are supported in DNS, some of which include A, AAAA, CNAME, MX, NS, PTR and SOA records. With the development of ENUM a special resource record type is used, know as NAPTR. Naming Authority Pointer Records (NAPTR) are used by ENUM to associate an E.164 number with other services or contact methods. In the following section E.164 numbers and NAPTR records are illuminated.

What happens to the dialed digits in ENUM Calls

In short, ENUM extends the existing and proven infrastrucure used today to access internet addresses. ENUM utilizes the dialed phone number in proper format and merges the phone number with service specific NAPTR records. In order to build a complete ENUM record the E.164 number is used as input to query the DNS for corresponding available services. However for ENUM to be able to use the dialed phone number, the number must be translated into a format DNS understands. Below is the step-by-step process to convert a phone number in common format to the required DNS format.

1. Phone number is entered in normal format: 1-222-333-5555
2. Phone number is translated into a fully qualified E.164 address by adding the area/city and country codes. This becomes +1-222-333-5555
3. All non-number characters are removed. The number now becomes 12223335555
4. The order of the digits is reversed. The example now becomes 55553332221
5. Dots are placed between each digit. We now are looking at 5.5.5.5.3.3.3.2.2.2.1
6. The domain "e164.arpa" is appended to the end of the string, which becomes 5.5.5.5.3.3.3.2.2.2.1.e164.arpa.

The next step required to build an ENUM record is to create the NAPTR record. A NAPTR record consists of 7 fields which together define the service and how the record is to be processed. The NAPTR record fields are Order, Preference, Flag, Service, RegExp or Regular Expression and Replacement fields.
An example NAPTR record is as follows:

IN NAPTR 100 10 "u" "sip+E2U" "!^.*$!sip:info@tele2.se!"

- Order Field = 10
- Preference = 100
- Flag = u
- Service = sip+E2U
- RegExp = !^.*$!sip:info@tele2.se!
- Replacement = not used in example

Next, the resulting string created in step 6 of the E.164 number above is used as the input and merged with the NAPTR record. The result is an entry similar to the following example records.

5.5.5.5.3.3.3.2.2.2.1.e164.arpa. IN NAPTR 100 10 "u" "sip+E2U" "!^.*$!sip:info@tele2.se!"
5.5.5.5.3.3.3.2.2.2.1.e164.arpa. IN NAPTR 101 10 "u" "mailto+E2U" "!^.*$!mailto:info@tele2.se!"
5.5.5.5.3.3.3.2.2.2.1.e164.arpa. IN NAPTR 102 10 "u" "h323+E2U" "!^.*$!h323:info@tele2.se!"

Starting from the left, the dialed phone number in reverse order with e.164.arpa appended makes up the E.164 number. Associated with the E.164 number are 3 NAPTR records, each containing the order, preference, flag, service, regexp and replacement fields. As you can see, all contact methods for the individual are stored as NAPTR records, each NAPTR record is mapped to the primary the E.164 number. By using the preference field, the user will be contacted first by SIP, followed by mail server and finally by h323.

Below are two examples scenarios of VoIP calls being made. In the first scenario a call is made between 2 SIP enabled phones. Both scenarios are based on IMS networks. In the SIP-to-SIP phone case, the following steps are carried out to route the call through the IP network.

1. SIP Client A requests E.164 number for the dialed call. 1-222-333-5555
2. The network communicates with the Application server to provide subscriber services.
3. The DNS/ENUM server is queried based on the E.164 number and returns the SIP URI: SIP:ClientB@home.com. (Note in most networks the DNS and ENUM servers are usually separate servers, but are illustrated below as a single server for simplification.)
4. The DNS/ENUM server is again queried for host IP Address for routing: SIP:ClientB@192.1.0.0
5. The Calling party's home network communicates with the Application Server to provide subscriber services.
6. The call is routed through the IP network to SIP:ClientB

An example network for a SIP-to-SIP step-by-step process is provided in Figure 3.

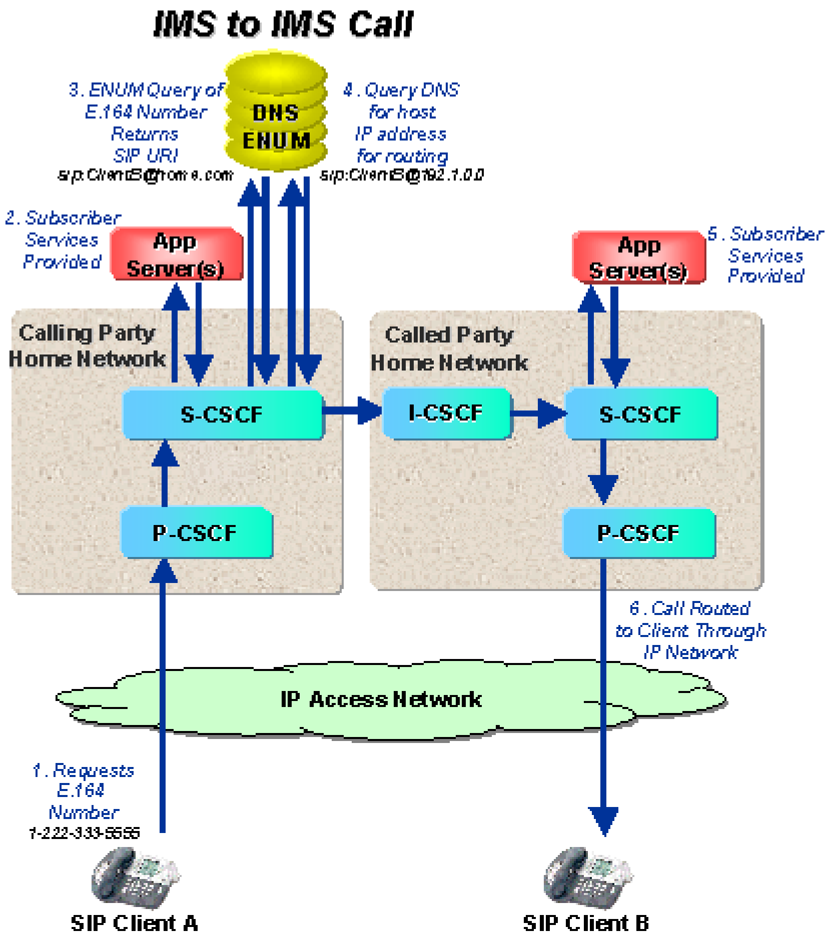

Figure 3 - SIP-to-SIP Calling Scenario

In the SIP-to-PSTN phone case, the following steps are carried out to route the call through the IP network.

1. SIP Client A requests E.164 number for the dialed call. 1-222-333-5555
2. The network communicates with the Application server to provide subscriber services.
3. The DNS/ENUM server is queried based on the E.164 number and does not return SIP URI: tel+1222333555
4. The call is routed to PSTN Gateway
5. The call is routed through PSTN network to 1-222-333-5555

An example network for a SIP to PSTN step-by-step process is provided in Figure 4.

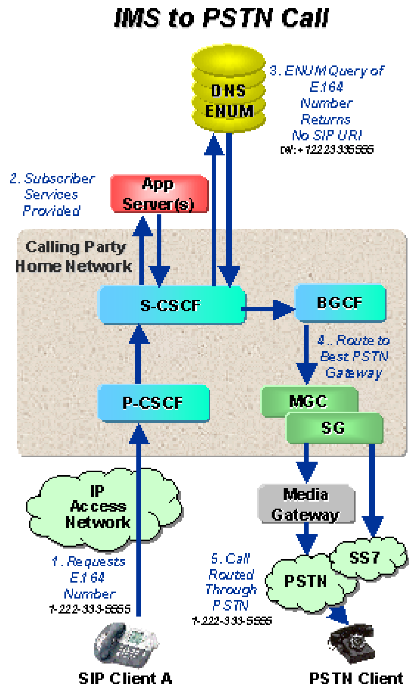

Figure 4 - SIP to PSTN Calling Scenario

ENUM Changes Everything

ENUM was developed to extend an already proven technology, DNS; enabling translation between not only hostnames and IP Addresses, but translation between many different types of information. With the advances in communications over the last several years most of us have many different contact methods for example; home number, office number, mobile number, fax number, office email address, home email address, IM address, etc. ENUM enables using a single registered contact number; all other methods of contact can be mapped to this single known number. For instance, an ENUM compliant email application can query the DNS using an E.164 number and what is returned is an associated email address record. Once the email address is returned the email application can then send an email to the end user. All this was accomplished through the use of only the end user phone number, an E.164 number.

In the near furture intelligent applications will be emerging allowing potentially multiple methods of contacting someone in the event the primary method is unavailable. An example future scenerio that would extend the use of ENUM even further could be using the E.164 number to place a call to an office based on time-of-day. In the event a connection could not be established, or during non-office hours, the call can be automatically sent to the users mobile number. Also, if the call is made during the late evening hours, the call might launch an email application instead. The caller would then have the option of sending an email to the user's office email account. In order for the previous scenerio to take place some additional development and applications are needed. However, ENUM provides a mechanism in which orders and preferences can be assigned to records today. This capability allows the end user to specify between 9AM and 5PM the primary contact method is the office number. From 5PM-10PM the primary contact method becomes the mobile number and all other times send an email.

What ultimately is needed is the integration between applications such as the VoIP application and the user's email application. Additional intelligence is needed in the VoIP application to automatically launch Microsoft Outlook if that is the preference specified.

Comprehensive ENUM Management

ENUM extends the existing infrastructure by adding support for additional types of services in the DNS. This is accomplished through supporting NAPTR records in DNS. Support for NAPTR records in DNS is natively supported in BIND. As such, compliant DNS applications using the appropriate BIND version, technically support ENUM records. In order to effectively and efficiently manage ENUM services, additional functionality is required of the management platform. Any complete ENUM management solution must support the administration of both ENUM domains (e.g., e164.arpa.) and the Naming Authority Pointer (NAPTR) records in both the applications database and the corresponding DNS/ENUM servers.

NAPTR records are supported by BIND, entering and managing the NAPTR records can be cumbersome, as we saw in a previous section. Simply entering and formating the regular expression field can be a cause of major concern. The syntax of the regular expressions lends itself to be error prone if configured manaually. In almost every enterprise, and certainly all service providers, a data store of some type exists. In this data store, employees or subscribers contact information is stored. A method to extract bulk contact information and populate the ENUM database is required to facilitate rapid service turnup. In addition to the bulk interface, an open interface to existing provisioning applications is needed to properly function is some service providers' networks, such as an IMS network. Once the records are imported into the ENUM application the ability to modify the NAPTR records is needed. In the event neither the bulk interface or provisioning interface are exercised, NAPTR records must be manually created, deleted and modifed. A user-friendly GUI enables manual configuration of the essential parameters to be quickly accomplished. The GUI should provide the capability to automatically create the regular expressions as required and provide a level of error checking/validation during the process.

Proper management of the e.164 domains is a mission critical function. ENUM services are expected to significantly increase the DNS management burden. When choosing an ENUM Management platform, the initial consideration should center around the application's DNS management capabilities. If the vendors DNS management platform is limited, chances are ENUM management will also be severely limited. The ENUM management platform must contain the capability to split and merge e.164 domains as the network topology continually changes. By the very nature of the e164.arpa domain structure, the ability to split the domains is supported, however not easily. The following ENUM record will be used to illustrate splitting e.164 domains.

5.5.5.5.3.3.3.2.2.2.1.e164.arpa. IN NAPTR 100 10 "u" "sip+E2U" "!^.*$!sip:info@tele2.se!"

In the above record, starting from the left the first 11 digits is the primary phone number in e164 format. The record can be split at any decimal as each decimal represents a level in the DNS/ENUM hierarchy. One logical method to distribute and manage ENUM records is to split the domain into individual zones by country code, area code and/or exchange. In this example the following zones would be created:

1.e164.arpa.	This zone is used to manage country code 1
2.2.2.1.e164.arpa.	This zones is used to manage area code 222
3.3.3.2.2.2.1.e164.arpa.	This zone is used to manage exchange 333

Not only should the ENUM application be able to split ENUM zones, but merging ENUM zones is required. The ability to split and merge ENUM Zones provides flexibility to the ENUM administrators to evolve the ENUM zones as the numbering plans change over time and to support ported numbers.

Lucent Technologies VitalQIP® ENUM Manager

Lucent Technology provides a centralized management solution enabling administration of ENUM domains (e.g., e164.arpa.) and the Naming Authority Pointer (NAPTR) records in VitalQIP® and the Lucent DNS server. The VitalQIP® ENUM Manager provides the ability to administer ENUM records in the VitalQIP® database and manage and update Lucent DNS servers. Lucent's DNS server resolves queries for telephone number to URI/URL translation for On-Net calling and other ENUM capabilities.

Using an XML/SOAP interface, E.164 records can be loaded from a variety of sources into VitalQIP®. The interface supports dynamic loading of new records from provisioning systems, such as Lucent Technologies eSM in IMS networks, and bulk loading records from databases for initial population of E.164 records. ENUM Manager stores this data in the VitalQIP® ENUM database. VitalQIP® ENUM Manager accesses this database, and uses this data to update Lucent DNS servers, either through Dynamic DNS updates or zone file pushes.

Administering ENUM records is via the VitalQIP® Web GUI. The ENUM Manager GUI allows an administrator to manually create, update, delete, and search the NAPTR records. The administrator simply populates a few fields and once executed, the record is pushed to both the VitalQIP® database and the Lucent DNS server.

Once NAPTR records are either manually created or the database populated through the various interface methods, the adminsitration of the records without an intuitive GUI may quickly become burdensome. Each and every user may have multiple associated services with their E.164 number and consequently the size of the ENUM database may grow rapidly. The ability for an administrator to search the ENUM database is an essential component of effective ENUM record management. VitalQIP® ENUM Manger NAPTR record search screen is shown below in Figure 5.

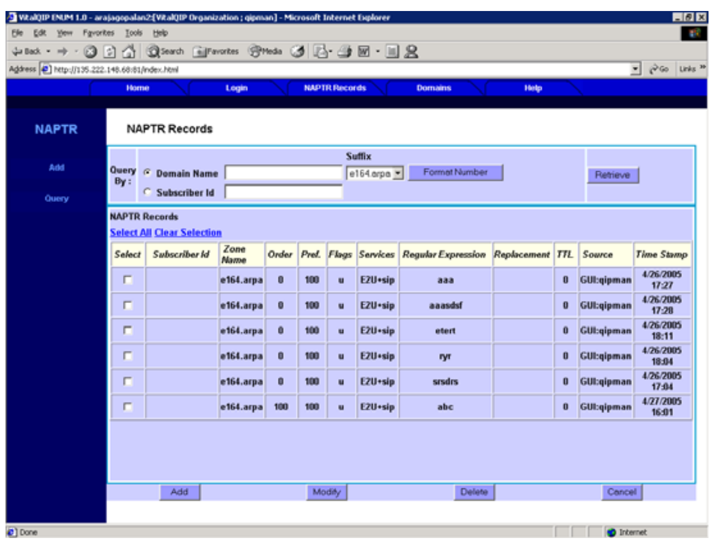

Figure 5 - VitalQIP® ENUM Manager NAPTR record search

The ability to quickly locate the appropriate NAPTR records and providing the administrator tools to take the desired action drastically improves ENUM management over stand-alone BIND support. Administrators can search NAPTR records by either domain or subscriber. Tools provided allow addition, modification and deletion of the NAPTR record.

To handle the growth of your E.164 domain, the ENUM manager features the ability to split and merge ENUM domains in order to fit your network topology. As previously mentioned, one commonly accepted method to manage ENUM zones is to split the record into multiple zones at the country code, city code, area code, exchange and potentially between any digit in the E.164 number. VitalQIP® ENUM Manager provides broad domain management capabilities to the administrator. Through the user-friendly GUI (see

Figure 6 below), domains can be split, merged and deleted quickly. An administrator simply highlights the desired domains, clicks on the appropriate button and the appropriate zone files are pushed to the VitalQIP® ENUM Manager database and the Lucent DNS servers. Over time, as the numbering plans change, the administrator can rearrange the E.164 domains to match the network or to improve performance in demanding areas of the network.

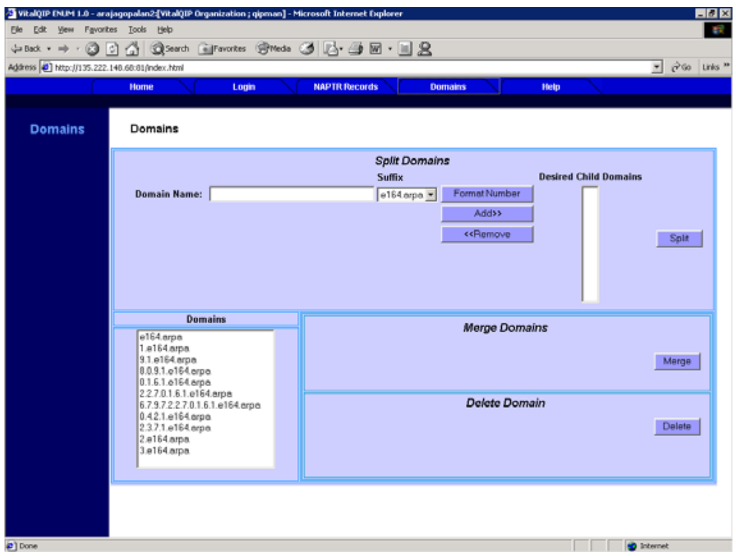

Figure 6 - VitalQIP® ENUM Manager E.164 Domain Management

VitalQIP® Domain Name System/Dynamic Host Configuration Protocol (DNS/DHCP) and IP Management Software is used by hundreds of customers, including Global 1000 companies and top Service Providers around the world, to automate their essential IP name and address services needs. This innovative system has received numerous honors and awards, including the Network World Blue Ribbon Award. VitalQIP® is consistently rated a best-in-class IP management solution by industry analysts and market research firms. Market-leading VitalQIP® software helps you efficiently configure, automate, integrate and administer IP services across your entire network — locally or globally. This powerful management software centralizes planning and administration, enabling you to rapidly provision address space and reliably deliver critical IP name and services throughout your network. Compatible with multiple technologies and platforms, it helps you streamline management tasks with a comprehensive suite of integrated tools and user interfaces.

VitalQIP® software is widely deployed in high-volume distributed network environments, where it has demonstrated its ability to support demanding environments with millions of individual IP addresses and hundreds of thousands of domains. Built-in support for master and slave DNS servers, as well as Dynamic DNS updates, helps you avoid network outages and automate address and name assignments. VitalQIP® ENUM Manager offers comprehensive administration capabilities to effectively leverage the existing DNS infrastructure permitting ENUM services to be deployed in the network.

As your network continues to grow, more IP devices, more traffic and newer technologies such as VoIP continuously increase your management responsibilities. To keep pace — and to make the most of your existing infrastructure investments — you need the automated, highly scalable management tools VitalQIP® software provides.

Lucent Technologies VitalSuite® Network and Service Management Software Portfolio

Lucent Technologies, a proven global provider of multi-vendor, multi-technology software, provides market leading integrated OSS management solutions that deliver today's complex IMS services. Lucent's award-winning VitalSuite® Network and Service Management portfolio is used today by more than 200 fixed, mobile and broadband customers worldwide. Lucent leverages innovations from Bell Labs and experience and expertise from Lucent Worldwide Services to provide highly flexible, scalable solutions that enable converged services, enhance the user experience and accelerate time to revenue. Lucent partners with world-class system integrators, complementary ISVs and hardware vendors to deliver end-to-end solutions that reduce operational complexities, ease integration costs and maximize profitability.