# Final Report on the ENUM Field Test

## DENIC eG

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# Introduction

As an Internet standard, ENUM is now five years old[1]. For Internet circumstances, that is a long time, especially considering that the functionality that ENUM offers has been eagerly awaited for a long time already. The idea behind ENUM is simple yet brilliant: to use telephone numbers for addressing Internet resources. In this way, ENUM can be seen as a bridge between the world of telephony and that of the Internet and, at the same time, it makes it possible to make the most out of modern communication technology in an environment that users are familiar with.

In order to understand why ENUM needed such a long lead time, it would be wrong to view things merely from the technical perspective. It is important to bear in mind that linking together various communication worlds has meant that, on the administrative side, several organizations were involved with responsibilities for the administration of Internet and telephony resources.
To begin with, for instance, procedures and rules needed to be agreed on between the Internet Architecture Board (IAB)[2], the International Telecommunication Union (ITU)[3] and the Réseaux IP Européens Network Coordination Centre (RIPE NCC)[4] as regards the provision and operation of the ENUM Top Level Domain, e164.arpa. This process was brought to a conclusion at the start of 2002.
When it became known that ENUM resources had become available, DENIC's members and other Internet participants called on DENIC to apply for the German national ENUM domain with the national dialling code +49. With the granting of this application, DENIC became the first registry in the world to receive the delegation for an ENUM domain assigned to a national dialling code. DENIC then set about starting the ENUM trial with a sense of urgency, and this trial continued in the form of the ENUM field test as of August 8, 2003. A massive commitment went into shaping the systems and processes in such a way that it would be possible for service providers, network operators and final customers to make profitable use out of ENUM as an innovative technology.

This final report of the ENUM field test describes in detail what has happened over the last two years. Chapter 1 is an introduction to ENUM, presenting its basics and its application potential. Chapter 2 then goes on to describe the field test at DENIC. It deals not only with the technical systems provided by DENIC, but also with DENIC's commitment on the communication front, through which it has shaped the ENUM field test over a period of two years in such a way as to create a broad basis for the technology's rollout.
Chapter 3 then turns to individual technical matters and the search for answers to particular questions and implementations of specified requirements, which were drawn up in the course of the field test. For each of these questions, the outcome is stated briefly in the form of a few sentences on fundamental findings.
Chapter 4 contains the overall conclusions that can be drawn from the field test and outlines a roadmap on how to proceed with the following stage of making the transition from ENUM's trial phase to regular, productive operation.

[1] The first RFC specifically on ENUM was [RFC2916]. The idea behind ENUM is even somewhat older still and was already contained in [RFC1486] in 1993. The first implementation was made at Ericsson in 1996-1997.
[2] IAB, http://www.iab.org.
[3] ITU, http://www.itu.org,
[4] RIPE NCC, http://www.ripe.net , cf. section 2.6.3.2.

# 1 ENUM Basics

The term “ENUM” is derived from telephone number mapping. Basically, ENUM is a protocol [RFC3761], by means of which resources from the spheres of telecommunications and the Internet can be combined with one another. It defines a rule for the unique mapping of a telephone number to an Internet domain[5]. This domain can then be used for addressing various services, such as telephone, telefax and mobile-telephone numbers, voice-mail systems, e-mail addresses, IP-telephony addresses, webpages, GPS coordinates, call diversions or unified messaging.

ENUM does this by making use of the Domain Name System (DNS), which has been established for many years (Figure 2). One of the tasks of the DNS is to create logical links between the addresses of computers connected up to the Internet (which are identified only by means of purely numerical IP addresses) and domains, which have the advantage that people find them a lot easier to remember. Nearly all Internet users are familiar with domains in connection with e-mail addresses or web presences. In future, however, the DNS infrastructure and the ENUM protocol are going to make it possible for Internet communication services to be called using telephone numbers too. This is made possible through so-called ENUM domains. By way of contrast to .de domains, users are not free to choose their ENUM domains, since there is a mandatory rule as to how the ENUM domain corresponding to a telephone number is to be formed. Each ENUM domain can thus only be applied for by the legitimate holder of the corresponding telephone number.

Figure 2 illustrates how ENUM works by giving an example: Subscriber A sets out to call Subscriber B.

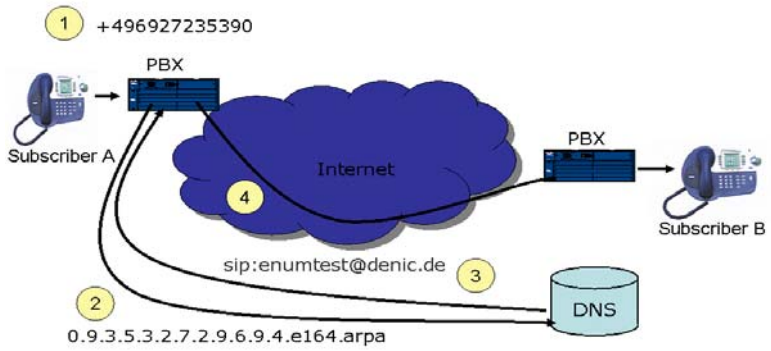



Figure 1: Application scenario for Voice over IP (VoIP) with ENUM

1. An ENUM-enabled subscriber terminal device or PBX[6] translates the request for the number +49 69 27235 390 in accordance with the rule described in [RFC3761] into the ENUM domain 0.9.3.5.3.2.7.2.9.6.9.4.e164.arpa.
2. A request is sent to the Domain Name System (DNS) asking it to look up the ENUM domain 0.9.3.5.3.2.7.2.9.6.9.4.e164.arpa.

[5] The algorithm according to [RFC3761] runs as follows:
- Put the telephone number in its international format.
- Reverse the order of its digits.
- Remove all spaces and special characters.
- Place dots between each of the individual digits.
- Append the infrastructure domain, .e164.arpa, to the end.

[6] PBX = private branch exchange.

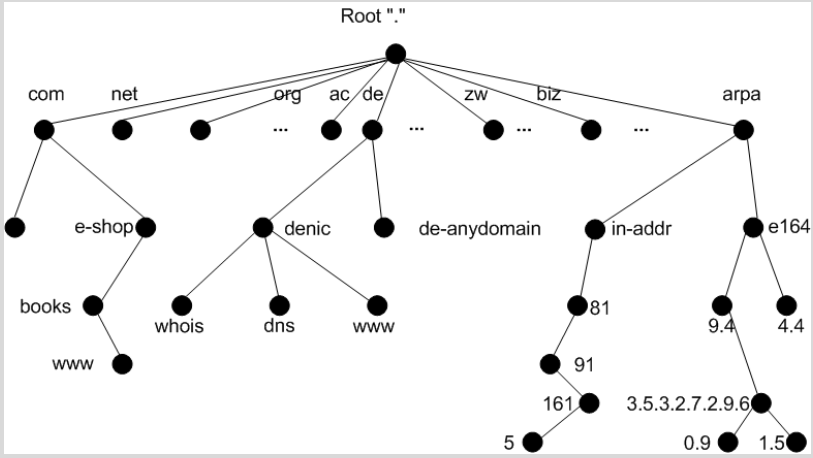
3. The query returns a result in the form of so-called Naming Authority Pointer Resource (NAPTR) records ([RFC3403]). In the example above, the response is an address that can be reached in the Internet using the Vo IP protocol, SIP [RFC3261].
4. The terminal application now sets up a communication link, and the call is routed via the Internet.

The Domain Name System

The Domain Name System ("DNS" for short) is a technical standard, which was adopted by the IETF[7] back in 1987 [RFC1034], RFC1035] and which has been of central importance for the operation of the Internet ever since. It is through the DNS that the now familiar worldwide hierarchical Internet name space is formed. The standard describes how the assignment of a domain to a numerical Internet address is established through simple technical lookups. The DNS is thus the very foundation for the easy use of all familiar Internet services, such as the Web or e-mail.

The highest level in this hierarchy, immediately under the root, is formed by the so-called Top Level Domains (TLDs). A distinction is made between generic TLDs, such as .com, .net and .org, and country code TLDs, such as .de (for Germany) or .ch (for Switzerland). The ccTLDs are administered by the local registries. In the case of Germany, it is DENIC that fulfils this function.

For Internet users, the use of the DNS is also becoming more and more important for services based on telephone numbers too. [RFC3761] is an IETF standard, which describes the process for converting telephone numbers into Internet domains (so-called ENUM domains). In this way the DNS can be used to address Internet resources by entering the appropriate telephone number. The figure below illustrates the structure of the DNS, including a segment of the ENUM branch immediately below the Top Level Domain for ENUM, .e164.arpa.




The practical implementation of the DNS is in the form of a large number of nameservers distributed throughout the Internet, holding directories of the IP addresses corresponding to the hostnames or the ENUM domains assigned to telephone numbers. Each of these nameservers is only responsible or "authoritative" for a part of the domain hierarchy, known as a zone. It is only when lookups are submitted to authoritative nameservers that they will obtain authoritative data as a response.

Figure 2: Technical background to the Domain Name System

[7] IETF = Internet Engineering Task Force, an international body responsible for the development and adoption of so-called "requests for comments" (RFCs). For detailed information, visit: http://www.ietf.org.

The advantages of ENUM, such as the use of telephone numbers for Internet applications and low-cost telephony, are self-evident. But that is by no means the end of the ENUM story! Numerous scenarios supporting modern communications have been developed and evaluated in the course of the field test. One such scenario is described in detail in section 1.2.

## 1.1 Administration of ENUM Domains

One of the essential ideas underlying the DNS is the clear assignment of responsibilities. The storage and administration of the information is not centralized but decentralized. Whoever is responsible for a zone (i.e. a branch of the domain tree) can grant responsibility for part of this space to another body. This is known as "delegation".

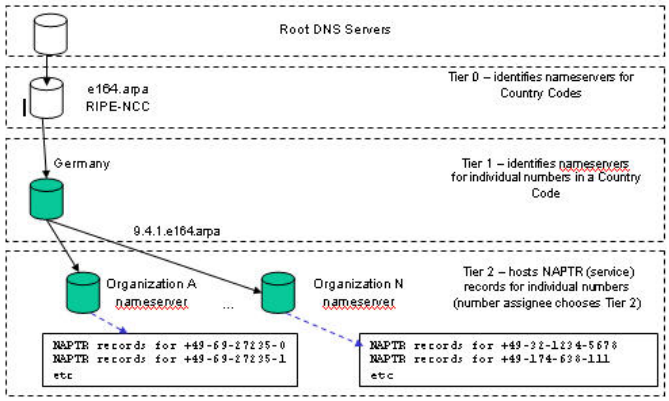



Figure 3: Reference architecture

An international organization called ICANN is responsible for the root level of the DNS and coordinates the administration of the root nameservers belonging to it. The .arpa Top Level Domain is administered by the Internet Architecture Board (IAB[8]). ENUM domains are then delegated down over three further layers (habitually known as "tiers"). The IAB has delegated the technical administration of the "ENUM Top Level Domain", e164.arpa (Tier 0), to RIPE NCC[9] in Amsterdam. The delegation of the individual ENUM domains belonging to the E.164 country codes to the corresponding organizations follows a procedure agreed on between the IAB, the ITU-T SG2[10] and RIPE NCC (called "ENUM administration ad interim"[11]). E.164 is the standard in which the ITU-T[12] describes the international numbering plan for telecommunications. In the case of the +49 national dialling code, the 9.4.e164.arpa ENUM domain (Tier 1) has been delegated to DENIC. DENIC then takes charge of the further delegations for numbers and number blocks below 9.4.e164.arpa to those who have the right to use the corresponding E.164 telephone numbers. If a "legitimate holder" of a telephone number wants to have the corresponding ENUM domain, they can submit a delegation request for it, going through a registrar (Tier 2).
From the above, the delegation model might sound rather abstract, so an example might make it easier to understand, taking the telephone number +49 69 27235 390.

[8] Internet Architecture Board http://www.iab.org.
[9] RIPE Network Coordination Centre, http://www.ripe.net.
[10] International Telecommunication Union Telecommunication Study Group 2 http://www.itu.int/ITU-T/studygroups/com02/index.asp
[11] ITU-T Standardization Sector Study Group 2, "ENUM administration ad interim", February 24, 2005. http://www.itu.int/ITU-T/inr/enum/procedures.html.
[12] http://www.itu.int/ITU-T.

The telephone number +49 69 27235 390 is connected via a PBX with the number +49 69 27235 0, which has been registered for DENIC. So DENIC itself receives the delegation for the 5.3.2.7.2.9.6.9.4.e164.arpa zone, which is derived from its telephone number and in which it can save the corresponding communication data for all the devices connected to its PBX. It takes its telephone number, +49 69 27235 390, forms the corresponding, ENUM domain, 0.9.3.5.3.2.7.2.9.6.9.4.e164.arpa, and saves the appropriate NAPTR records for it in the DNS.
The "9.4.e164.arpa" TLD does not contain any direct NAPTR records for the delegated zones under it, just a reference to those nameservers that hold authoritative data for these zones. As a general rule, the specific NAPTR records with communication addresses are to be found only on these nameservers.

## 1.2 Application Scenario

When new means of communication appear on the scene, they are usually accompanied by new communication addresses. This situation creates numerous difficulties for users concerning the administration, maintenance and correct updating of these addresses. With ENUM, it is possible to call all terminal devices and very many services all through just one telephone number – "a single number for all services". The result of this is that the list of contact addresses that communication partners need to administer is short and thus more up-to-date, since the address owners have the much easier task of keeping just a few items of contact data up-to-date at one central point. Scenarios for selecting suitable terminal devices or call-forwarding mechanisms promise a great deal of potential for the future, with the additional integration of such diverse applications as e-mail, presence services, SMS or telefax. This makes it possible to send messages to addresses that do not depend on the particular application, such as sending e-mails to telephone numbers. Here, ENUM creates convergence at the user interface, thereby simplifying the operation and reducing complexity. It also facilitates access to Internet technology for new user groups.
At the time of writing, the use of telephone numbers for VoIP is one of the most important applications of ENUM. What happens is that a user dials a telephone number from their VoIP telephone (such as in the example Figure 1: +49 69 27235 390). Either directly from this telephone or from the VoIP server which it is logged on to, the telephone number dialled is then automatically mapped to an ENUM domain and, in the background, a query is submitted to the DNS asking what communication services are assigned to that particular ENUM domain. In its response, the DNS returns the available communication records.
There are numerous other possible applications in addition to this one. One scenario that is simple to implement using the combined potential of VoIP and ENUM is call-forwarding with ENUM, and one way of doing this is illustrated in Figure 4. The caller uses the telephone to dial the number of another subscriber, which leads to an ENUM lookup. The DNS responds to the caller by returning a list with NAPTR records for VoIP communication, telephone numbers and e-mail addresses. Next, an attempt will be made, using the VoIP record from this list, to establish a connection with the subscriber. If the subscriber is not online, the next record selected will be that for a connection to a PSTN or mobile telephone. If this attempt fails too, a voice message will be sent to the subscriber via a listed e-mail address.

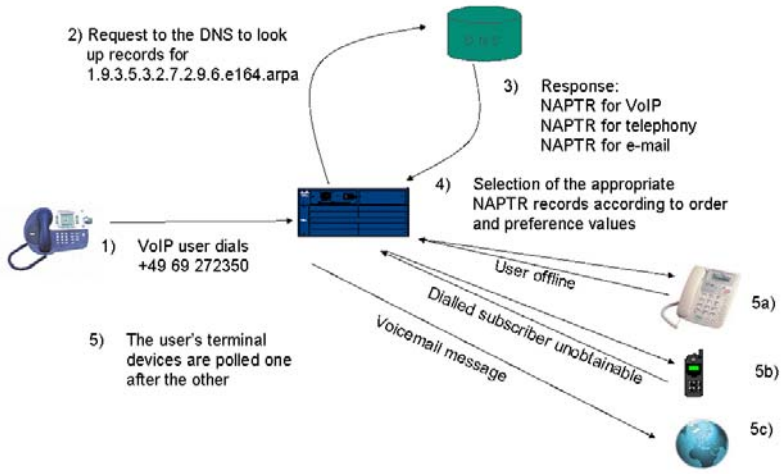



Figure 4: Call forwarding with ENUM

The effect of coupling different technologies together is that the subscriber is accessible without being dependent on a particular terminal device. VoIP in particular has the advantage that the information about the subscriber's presence (i.e. their online status) can be passed on, and the subscriber remains accessible without any geographic constraints. There is massive potential here for future applications.

Other scenarios, products and applications are to be found on DENIC's "ENUM Application Potential" webpage, http://www.denic.de/en/enum/anwendungspotential/index.html, and also in Annex B of this report.

# 2 The ENUM Field Test at DENIC

## 2.1 History of the ENUM Field Test

Early in 2002, IAB entrusted RIPE NCC with the task of performing delegations under the .e164.arpa domain.
Since then, it has been possible to apply for the delegation of each particular national ENUM domain. It was as a reaction to numerous queries and proposals from within the German Internet Community that DENIC asked for the ENUM TLD, 9.4.e164.arpa, to be delegated to it. This occurred on May 21, 2002. It was not long afterwards that DENIC started the ENUM trial.
This trial formally became the field test on August 8, 2003, following the conclusion of a contractual agreement between the Regulatory Authority for Telecommunications and Postal Services (RegTP)[13] and DENIC [DENIC RA]. Figure 5 shows the most important events that occurred during the field test. The end of the field test has been scheduled for the end of 2005, when it is planned to make the transition to the regular ENUM operation.

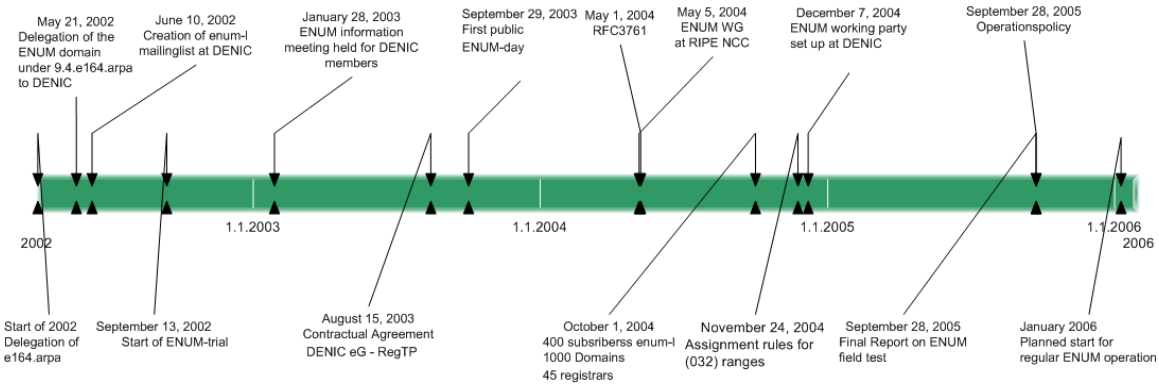



Figure 5: Milestones in the ENUM field test at DENIC

Chapter 2 sums up the most important steps taken by DENIC and the participants in the ENUM field test. The results and experiences are presented in detail in Chapter 3 and form the basis for DENIC's ENUM Operations Policy [DENIC OP].

## 2.2 Aim of the Field Test

Even though ENUM is an Internet protocol and even though primarily Internet communication protocols are used in the selection of services, the actual starting point is an E.164 telephone number, which, once converted into an ENUM domain, forms the basis for all DNS lookups. The only domains permitted as ENUM domains under 9.4.e164.arpa are those that are mapped from telephone numbers that have corresponding numbers in the German number space [DRP 2005]. ENUM domains that do not map an assigned telephone number are inadmissible. At the time of writing, only a subset of the total German number space is to be released for ENUM domains (Table1):

[13] On July 13, 2005, it was renamed the German Federal Network Agency (*Bundesnetzagentur*) http://www.bundesnetzagentur.de.

| |
|---|
| Geographic-area numbers |
| Mobile-telephone numbers |
| Free-phone services (0)800 |
| Personal telephone numbers (0)700 |
| National subscriber numbers (0)32 |

Table 1: German telephone-number ranges that are available as ENUM domains

Table 1 lists those telephone-number ranges that belong to the subset of the German national numbering plan that have so far been authorized for ENUM. All the listed number ranges were already available for registration during the field test, with the exception of the (0)32 range, that was only defined and released by the Federal Network Agency in the course of the ENUM field test.

The aim of the field test was to build up and try out the necessary infrastructure, considering both technical and administrative angles. In the context of the test operation, the intention was to develop services and devices for the new technology and to test their suitability for use in practice. Another task was to work out procedures for checking that a person really does have the right to use an E.164 telephone number as claimed – a process normally called "validation". Validation has not been the only process needing to be resolved; there are others that occur in the lifetime of a telephone number that need to be considered, such as transferring from one legitimate holder to another. The results obtained on these particular points in the course of the ENUM field test are summarized in section 3.2.

## 2.3 Participant Community

Since the beginning of the ENUM trial in 2002, participation has been open to anyone with an interest in ENUM. This openness and transparency have turned out to be beneficial, firstly, in the large range of participants in the field test and, secondly, in the quality of the results obtained. An analysis of the composition of the participants led to the identification of ten distinct groups:

DENIC

In its function as registry and the German Federal Network Agency's contract partner for the ENUM field test, DENIC has been the promoter and central contact for all participants. Even during the field test, DENIC has been assuming important infrastructure tasks. It is DENIC's job to decide on the final shape in the sense of effective processes, giving due consideration to the overall national and international environment, as expounded in the ENUM Operations Policy and also forming the basis for the Operations Model.

German Federal Network Agency (formerly: Regulatory Authority for Telecommunications and Postal Services, RegTP)

The Federal Network Agency for Electricity, Gas, Telecommunication, Post and Railway is an autonomous federal authority acting in the area for which the Federal Ministry of Economics and Labour holds overall responsibility. This agency has been DENIC's contract partner for the ENUM field test. It has been accompanying the ENUM field test and has been kept regularly informed of its state of advance through quarterly reports and consultations.

DENIC members

As registrars of ENUM domains, DENIC members have been providing support throughout the entire duration of the field test with their know-how and process knowledge. They

have been actively involved in designing the ENUM field test. The number of members offering ENUM domains to their final customers has risen to 60 in the course of the field test. This figure corresponds to about a quarter of all DENIC members.

ENUM service providers

ENUM service providers offer ENUM registration services and ENUM-DNS services as well as solutions for final customers that are built on them.

Telecommunication providers

The traditional providers of telecommunication services have been pursuing an interest in building up know-how and in participating in an emerging growth market. Synergetic effects have been particularly large here, since the world of telecommunications (just like the Internet) follows its own paradigms. Generally speaking, this group has been regarding ENUM as an innovation and as a promising market for the future, bringing about changes and additions to their existing fields of business activity.

Final customers

Final customers have been particularly strongly encouraged to become involved in the ENUM field test through the public ENUM Meetings organized by DENIC and the resultant media reporting on them, which has had a clearly positive impact on the public. One key aspect of this has been to kindle general public interest and thereby increase demand for ENUM, even while the field test was still running. Final customers have also voiced their ideas and wishes for ENUM services and made these known to the manufacturers and/or ISPs.

Manufacturers of telecommunications equipment and terminal devices

ENUM, of course, requires the necessary infrastructure to be provided for it, but in addition to that, it is indispensable for hardware manufacturers to provide the appropriate devices with ENUM support, so that they can be adapted to the current market trend of VoIP and other communication services.

Academia

In the course of the field test, close cooperation has evolved with various universities. This group's interest in ENUM has not only been from the perspective of researching new technologies but has also been motivated by the possibility of offering added value to students and university employees by installing ENUM on their campuses.

Data-protection organizations

Before the ENUM field test had even started to run, data protection had been a central issue for the project. The field test has presented an excellent opportunity for finding the best arrangements for coping with the pre-existing provisions and for dispelling reluctance in relation to this innovative technology in cooperation with those responsible for data protection. It has thus proven possible to draw up rules and recommendations for treating the ENUM DNS appropriately.

## 2.4 DENIC as the Operator of the Field Test

### 2.4.1 Organization and Responsibilities

In Germany, as in many other European countries, the administration of the country code Top Level Domain is organized by private business, and this organization was originally set up as an outcome of an initiative taken by the sector concerned. This form of self-administration is entirely in tune with the open structures of the Internet as a global medium. It is based on the principles of the

distribution of responsibilities and resources as well as self-regulation by the interest groups concerned. The decision to give DENIC the legal form of a registered cooperative (that's what the letters "eG" after its full name signify) facilitates an open structure for the registry too, since any business can become a member of the cooperative at any time.

DENIC's central function is to administer and operate the domains under the Top Level Domain .de, including all the tasks associated with that. These include:

- registration and administration of domains under the TLD .de throughout the whole of Germany
- operation of the primary nameservers for the TLD .de
- provision of various database and information services
- coordination of contributions to international cooperation as regards domain administration and active involvement in the corresponding international bodies.

As far as the technical operation of the German Internet is concerned, the most important facet is the reliable technical operation of the nameservers. The central nameserver for all .de domains is located in Frankfurt am Main. Copies of the information held on this primary nameserver are also supplied on ten secondary nameservers. These servers are located in different places all around the world, so the information is available quickly everywhere all the time. Every day, responses are supplied to more than 700 million queries received by the nameservers. All of the services provided by DENIC must be secure and scalable and have a high availability. DENIC succeeds in meeting these requirements through using top-grade hardware and software components and through the competent specialists working for it, who develop the software and look after the services.

Any organization with a stable financial basis that administers domains in Germany can become a member of DENIC. Currently more that 230 members belong to the DENIC Cooperative, and sixty of these are already registering ENUM domains.

## 2.4.2 Technical Competence

DENIC runs a very extensive computer and data network in order to be able to fulfil its functions. All relevant services are implemented in a primary computer centre and also in a backup computer centre. Storage Area Networks (SANs) ensure that the necessary data is available at both computer centres, which are permanently linked to one another by dedicated lines. Both locations are equipped with uninterrupted power supplies and are thus immune to power cuts.
Full redundancy is provided at the level of each of the services, but, in addition to this, the computers and storage systems themselves have been designed to be failsafe through the inclusion of redundant components (disk mirroring, power supplies, CPUs, and so on). Load balancers are also in use and they ensure greater automation and minimized switching times when switching over to a replacement for a failed server. The servers share the incoming queries as a function of availability and the load on each of them in the two fully-redundant computer centres. This configuration achieves a twofold benefit: further-reduced likelihood of failures and an enhancement in performance.

### 2.4.2.1 Network connections

DENIC's network is connected to the Internet through a multistage firewall, with each stage independent of the others. This applies to both the primary computer centre and the backup one. Those services that are accessible from the outside run on servers defended by the first firewall, in what is sometimes familiarly known as the "demilitarized zone" ("DMZ"). The actual storage and processing

of data is performed on DENIC's internal private networks, which are secured behind further firewall components.

#### 2.4.2.2 Security concept

Security at DENIC is more than a firewall, a fully-redundant hardware component or an additional power supply. Security is a concept that leaves nothing out. It is a concept that begins with planning the technical infrastructure, takes in employee motivation and information and extends finally to physical access control and alarm systems protecting the premises and the electronic services. Numerous individual measures have been put in place to ensure the integrity and availability of all its data. Although the standard already reached is a high one, DENIC never tires from continuously striving to improve its security and operational concept and of making appropriate adaptations in the light of the latest state of knowledge and developments.

#### 2.4.2.3 Data security

Only DENIC members have access to the electronic registry system. Several measures are in force to check the identity of the sender and the integrity of the contents of each ENUM domain request, and these include OpenPGP signatures.

In the administration of ENUM domains, data protection and data security are closely dovetailed with one another. One example of this is that personal data can only be changed by the DENIC member in charge of the particular record. Even DENIC's members only have access to personal data and ENUM domains to the extent that is indispensable for their work. A detailed analysis dealing with data protection is to be found in section 3.3.

By no means the least important factor contributing to the success of the security measures is ensuring that DENIC's own employees are provided with extensive information and made fully aware of the first-hand responsibility borne by each and every one of them. These measures are further underpinned and complemented by the use of an effective anti-virus system, a powerful yet ergonomic data-backup system and the utmost care in the setting up and maintenance of the server systems and workstation computers.

#### 2.4.2.4 Safeguarding and Monitoring the Operation

The permanent monitoring of the availability of the services is a crucial part of the security concept. During normal business hours, the ongoing operation is monitored by employees in the DENIC-operations department and also by System Administration. At all other times of the day and night, it is the standby service that performs this monitoring. All relevant services are also kept under continuous surveillance by automatic monitoring software. In order to make sure that an adequate performance will remain possible in future too, DENIC carries out trend analyses, runtime monitoring and correlating observations of various technical metrics with the assistance of the SightLine service-level management system.

DENIC has also taken the necessary precautions for the eventuality of a failure in the mains supply and has had its own uninterrupted power supply (UPS) installed. For this purpose, the energy utility laid a fully-redundant mains supply to the building housing the primary computer centre at the start of 2001. A down-line UPS module, which is kept in online mode, ensures that the operation will not go down during the process of switching over to the second mains supply. This UPS module is rated at 330 kVA, which means that it is adequately dimensioned to be able to handle future requirements too.

## 2.5 Operating

Building still further on experience that already stretches back over more than ten years in the administration of .de domains, DENIC has also been making the necessary infrastructure services for ENUM available to its members, the trial participants and the Internet users since the beginning of the field tests and has been consistently expanding them too.
The DNS service for the 9.4.e164.arpa ENUM TLD has been fine-tuned and adapted in detail to the requirements of ENUM and has been operational without a break since the start-up of the ENUM trial.
While the field test was going on, DENIC also created a special ENUM working party. This has had the function of drawing up the technical and organizational proposals for questions related to validation, the registry/registrar interface and the Operations Policy.
Each of the services is presented briefly in the following sections and in some cases compared with the Top Level Domain .de.

### 2.5.1 Name service

DENIC currently makes the necessary ENUM domain information for the 9.4.e164.arpa zone available on three powerful nameservers. The primary nameserver is located in Frankfurt am Main, whilst the two secondaries are in Amsterdam and Vienna. This infrastructure is being continuously expanded. Other locations in Germany and other European countries, as well as the USA and Asia, would be ready to assume operation at short notice as requirements increase. Compared with the millions of queries about .de domains, the load on the ENUM nameservers is still rather modest with only around 100 000 lookups per day. The expectation, however, is that, once the regular ENUM operation is launched, the load on the nameservers in the longer term will be similar to that experienced for the .de name service.
The computers used as nameservers are SUN and IBM servers with different processors, operating systems and name-server software (BIND software in versions 8 and 9 as well as NSD). This threefold diversification guarantees that, should there be security problems with one of the components, the residual capacity would still be adequate for responding to all queries without failures or lost responses. Currently, the 9.4.e164.arpa zone is updated at least eight times a day, with the latest ENUM domain data loaded on all three nameservers.

### 2.5.2 Registry system and database

Given the growing requirements made of the registry system, DENIC has continued to develop this further for ENUM domains in parallel with the ongoing ENUM field test. Whereas this was originally only a semi-automated system, the registrars will have a fully automated system available to them when the regular ENUM operation starts. This is necessary in order to be able to process the large number of ENUM business transactions promptly. For this purpose, DENIC provides its members with direct electronic access to the registry system. A log is kept of all transactions, and senders are sent acknowledgements. DENIC has developed its own realtime registry interface (RRI) along the lines of the IETF's EPP standard. This satisfies all the requirements for use at DENIC and has already been operational for .de domains since the second quarter of 2005.
The plans are that, once the regular ENUM operation is running, the registry system will be available round the clock, and that it will be possible to accept registry requests at any time and process them immediately. The individual types of ENUM domain request are listed in Fig. 6.

### Types of ENUM domain request

Requests are only to be submitted to DENIC if registrars have received instructions from customers. The individual processes have the following functions.

| Process | Description |
|---|---|
| CREATE | Requests the creation of an ENUM domain. |
| UPDATE | Makes changes that concern only the technical or administrative data in the records for an ENUM domain. |
| CHHOLDER | Transfers the ENUM domain from the previous legitimate holder to the new one. |
| RENEW | Extends the existence of the ENUM domain following a revalidation of the legitimate holder of the E.164 telephone number underlying the ENUM domain. |
| CHPROV | Transfers an ENUM domain from the registrar who has administered it to date to the one who is to administer it in future. |
| DELETE | Removes an ENUM domain and erases the ENUM domain data. |

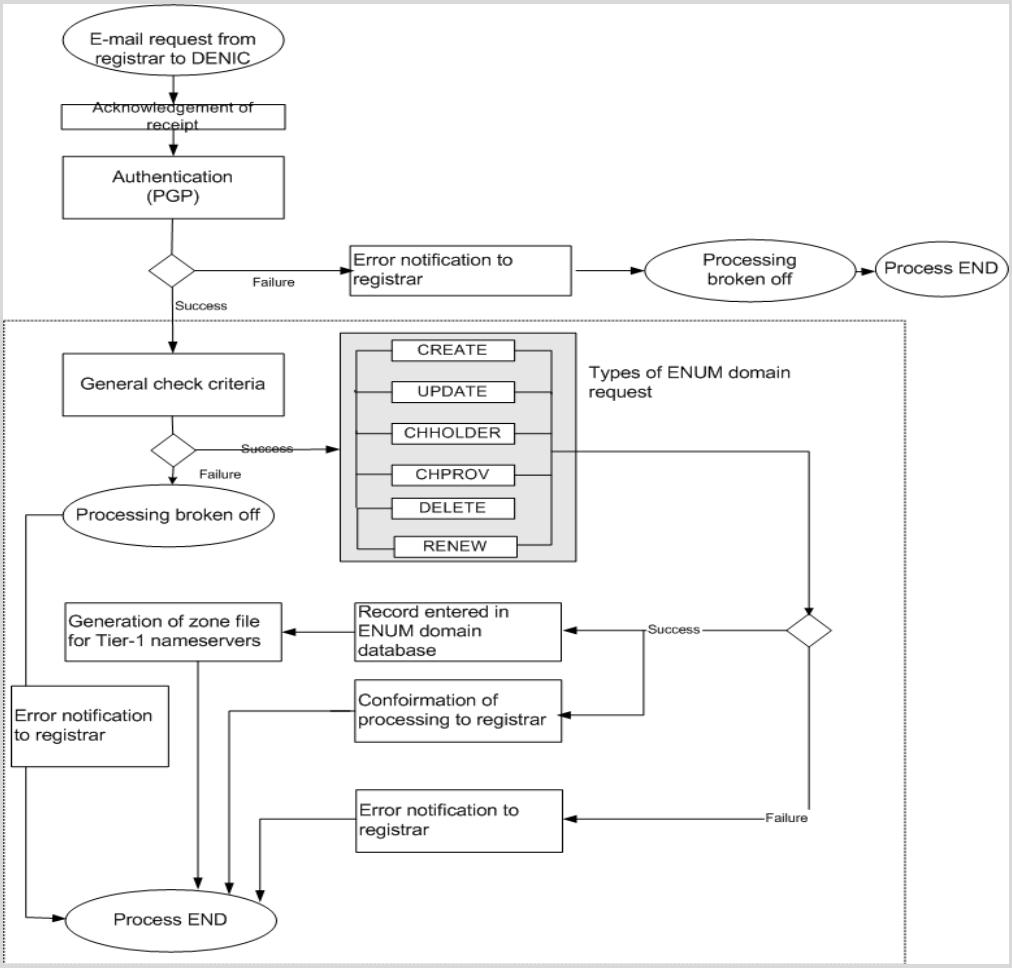
Figure 6: Types of ENUM domain request

At the time of writing, the number of requests for ENUM domains adds up to fifty transactions per day. Here again, the system has been so designed that it is ready for the expected increase in ENUM domain requests. By comparison: the registry system for .de domains processes several tens of thousands of requests per day.

The current MRI[14] for ENUM domains is described in Figure 7. The processes in the RRI are comparable.

[14]Mail Registry Interface

The e-mail interface is used by DENIC members to submit requests to DENIC concerning the administration of ENUM domains.




When DENIC receives an e-mailed request, it sends back an e-mail to acknowledge receipt. It then checks the authenticity and integrity of the request by means of electronic signatures in accordance with the OpenPGP standard [RFC 2440]. The digital signature protects the data against manipulation during transport and makes it possible to verify the identity of the sender.
The e-mail requests are then processed by the ENUM domain registry system. A distinction is made between six different types of request. Once processing has been successfully completed, the results are written to the ENUM domain database, and the data is ready for generating the zone file for the ENUM Domain Name Service. The zone file contains the ENUM domains and the pointers to the authoritative Tier-2 nameservers. Once all this processing has been completed, a confirmation is sent to the original sender. If a syntactic or semantic error occurs during processing, this is broken off and the sender is informed of this error by e-mail.

Figure 7: Flowchart of the ENUM domain registry system

### 2.5.3 whois

The whois information service is one of the important standardized means for submitting queries about domain data. It is described and defined in [RFC3912]. In the case of ENUM, this service will become available with the start of the regular operation. It is possible to access whois either via the TCP Port 43 on DENIC's whois server, whois.enum.denic.de, or via the website at

http://www.denic.de. User guidance can be called either by entering the command whois -h whois.enum.denic.de HELP or from the online documentation [DENIC WH]. This service is to have an ultra high availability. The most recent experience with .de is that around 25 000 queries are processed per minute, and at peak times this value even rises to 40 000 per minute.

## 2.6 Communication, Information and Public Relations

Throughout the entire ENUM field test, DENIC has taken a very broad view of its duty to communicate. The idea behind this has been to provide an exhaustive information platform for all those interested in ENUM and thus to keep the DENIC members and the general public continuously involved in the field test.

### 2.6.1 Available information channels

#### 2.6.1.1 Webpages

DENIC's public ENUM webpages http://www.denic.de/en/enum/index.html give a complete introduction and an overview of the current status. Nearly all of these are available in both German and English and include:

- General Information: A short general introduction to ENUM and the advantages it brings.
- Application Potential: A summary of modern communication scenarios that can be implemented with ENUM as well as products providing support for ENUM. A number of application scenarios describe ENUM implementations that have already become reality.
- Field-Test Participants (DENIC members offering ENUM domains): A continuously updated list of all field-test participants through whom it is possible to register ENUM domains.
- External Links: A list of all the national and international organizations who have something to do with ENUM.
- Technical Information: The technical background to ENUM, including references to and explanations of individual RFCs and drafts.
- Events: Documentation from DENIC's own ENUM Meetings as well as other organized events at which DENIC has actively participated.
- Current Status: As part of the effort to make the ENUM field test as transparent as possible, the current status of the test operation and the most up-to-date documents can be consulted here. This is also the place to find the quarterly reports, which form the official documentation.

In the course of the last six months, the ENUM webpages have been visited more than 170 000 times. DENIC has also asked its members for feedback about the information provided on the ENUM pages, and 70% have rated it as "very well structured and informative". These public webpages are supplemented by secure pages for DENIC's members only, giving them specific information about handling registrations.

#### 2.6.1.2 Mailing list

DENIC set up a mailing list, enum-l@denic.de, to coincide more or less precisely with the start of its ENUM trial, and 150 interested subscribers joined it almost straightaway. This list has been used as a medium for discussing topical issues and trends. In combination with the announcements about the ENUM field test, this mailing list has given participants an information-exchange

forum. All the messages have been saved in an archive and remain available for consultation from the ENUM webpages. The number of subscribers has grown steadily and now stands at 600.

#### 2.6.1.3 Quarterly reports

One of the duties accepted by DENIC under the terms of its contractual agreement with the German Federal Network Agency was that it would document the progress of the ENUM field test every three months. These quarterly reports have not only described the actual state of the field test and any results it has produced but have also described the progress made in the international ENUM trials and in the official bodies concerned with ENUM. All these reports have been made publicly accessible to anyone interested in them on the ENUM webpages at: http://www.denic.de/en/enum/aktuelle_arbeit/quartalsberichte/Quartalsberichte.html. This once again emphasizes the transparency of the field test.

#### 2.6.1.4 Training for DENIC members

Since 2004, an ENUM block has been included in the training that DENIC provides for its members. Participation in this training scheme is compulsory for all DENIC members, and showing that they have understood the contents by passing an acceptance test is a prerequisite for being allowed to register domains.

#### 2.6.1.5 Bilateral conversations

Since the start of the field tests, DENIC has actively sought contacts with companies. The aim has been to make sure that they were giving due consideration to ENUM as an innovative, long-lasting bridge between classical telephony and the Internet. It emerged that there was a big need for information, especially amongst smaller businesses.
There have also been opportunities to present the field test internationally. ENUM formed part of the programme for the visits of both the Communications Commission of Kenya in March 2005 and the China Internet Network Information Centre (CNNIC). The visitors from outside of Germany were particularly interested in DENIC's Operations Model for ENUM and the technical processes underlying it.

### 2.6.2 ENUM Meetings and the ENUM Working Party

Since the field test started, DENIC has organized public ENUM meetings at intervals of roughly half a year. The interest in these events has grown over time, and there were already 140 participants at the most recent ENUM Meeting held on March 1, 2005. What has made these events particularly attractive for those attending them has been the blend of pooling experience, technical lectures, contributions from application developers and device manufacturers and, by no means least, demonstrations of applications. The positive reaction has also been reflected in increased registration activity for ENUM domains. The ENUM Meetings have also been used to talk individually with participants and to encourage them to become actively committed and to join in ENUM domain registration.
At the time of writing, the next ENUM Meeting is planned for September 28, 2005 in Frankfurt. All the presentations made at past ENUM meetings, along with other information about them, can be viewed at: http://www.denic.de/en/enum/veranstaltungen/denic_enum-tage/index.html.
In order to help it steer the ENUM field test, DENIC itself has always been greatly interested in people's motivations for participating and in how satisfied they have been with the running of the test operation. For that reason, it developed a feedback questionnaire in October 2004 and sent it out to all the registrars who were participating in the field test. The questions dealt with general communication, the technical processes and the subject of validation.
The response rate was some 72%. One of the most important findings of this survey was the desire of the registrars to set up a working party to discuss so-far unresolved problems and to work to-

wards solving them. This working party has subsequently dealt with subjects such as validation and data protection, but its biggest single activity has been to define the technical registry processes, which have subsequently been implemented by DENIC. The working party has met four times since December 2004 and has also laid the foundation for DENIC's ENUM Operations Policy.

## 2.6.3 Attendance at conferences

While the field test has been going on, a number of DENIC employees have attended various conferences with a view to gaining additional know-how and to exchanging information. These events are listed in Table 3 in Annex A.
The exchange of information and the transfer of knowledge between conference participants from the fields of research and development, marketing and production has been an important element in the German ENUM field test.

### 2.6.3.1 IETF

The Internet Engineering Task Force (IETF, http://www.ietf.org/) is an open, international organization of network designers, professional users and manufacturers, who contribute to the development of the Internet and its smooth operation. Their work concentrates, in particular, on the further development of the most important Internet standards. Cooperation within the IETF is organized in the form of subject-specific working groups.
Both standardization and the further development at protocol level are important for ENUM. Regular attendance at the IETF's series of international conferences has proven to be a successful means of looking after interests related to the German ENUM field test. Details of the ENUM protocol-standardization work done by the IETF's ENUM Working Group are described in Chapter 1 of this final report and also at http://www.ietf.org/html.charters/enum-charter.html.

### 2.6.3.2 RIPE NCC

The Réseaux IP Européens Network (RIPE, http://www.ripe.net) was set up in 1989 and has its headquarters in Amsterdam. It is the coordination centre of the European operators of IP-based wide area networks. The organization's primary goal is to ensure the administrative and technical coordination that is necessary for the operation of a European IP network.
The operational side of these functions is in the hands of RIPE NCC (RIPE Network Coordination Centre), which is one of the world's five Regional Internet Registries (RIRs). In the case of ENUM, RIPE NCC takes charge of the delegations of the national dialling codes under e164.arpa.
RIPE NCC has set up its own ENUM working party[15]. This meets three times a year, coinciding with RIPE meetings. Its work is further supported through the discussion fostered by an ENUM mailing list[16]. It is also a platform for observing initiatives, such as the ENUM trials taking place around the world.

### 2.6.3.3 ETSI

ETSI, which stands for European Telecommunication Standard Institute, http://www.etsi.org/, is a body with responsibility for the standardization of telecommunication systems and services in both PSTNs and mobile networks. Its remit extends to radio and television and also to information technology in general.
It was set up 15 years ago as a reaction to pressure from the European Commission. Its members are administrations, manufacturers and research institutes (mostly from Europe).
The purpose of joining in ETSI's ENUM workshops is to promote the exchange of information between the various ENUM trials, to establish the progress made in the individual trials and to set

[15] http://www.ripe.net/ripe/wg/enum/
[16] http://www.ripe.net/mailman/listinfo/enum-wg/

about answering as-yet unanswered questions. In addition to user ENUM, which is the main focus of the international trials, another aspect, infrastructure ENUM, has also moved into the forefront of ETSI's commitment. It has been an important objective for ETSI in its work involving ENUM to prepare and carry out an ENUM plug test[17].
A "plug test" is best understood as an interoperability test, at which researchers and developers (even from competing organizations) come together to test their products as regards conformity with a standard or a draft standard as well as its various implementations. The intensive exchange at these events and the attempt to find solutions to the sometimes clearly diverging perceptions of the participants has represented genuine added value for the specific application and product development in the German ENUM field test.

#### 2.6.3.4 Domain pulse

Domain pulse[18] is the name of an event created and organized jointly by the registries nic.at (Austria), SWITCH (Switzerland and Liechtenstein) and DENIC (Germany) for dealing with topical themes, tendencies and trends in everything that concerns domains. As a competence forum, Domain pulse offers specialists from the German-speaking world the opportunity of direct and active communication. At each of the most recent events, there has been a separate agenda item dedicated to ENUM, which has made it possible to keep an intensive ENUM dialogue going with the other German-speaking participants and registries. A good example was the report in February 2004 by representatives of the Austrian field test, in which they shared their experience up until then and presented their ideas for the future as regards the ENUM business model for Austria. This was followed in 2005 with the opportunity to form a picture of all the German-language ENUM trials and to hear about the success of the regular commercial operation that had started in Austria four months previously.

#### 2.6.3.5 Other organized events

The active participation of the ENUM project team at events focusing on VoIP represented excellent opportunities for presenting ENUM to a wider audience. The discussions that followed these presentations showed that there was a clear shortfall in the level of information people had about ENUM. DENIC reacted to this finding by stepping up the amount of lecturing activity in the course of the field test, in order to be able to present ENUM to an even broader public. A list of the more specific ENUM conferences attended by DENIC as well as events supported in the form of an ENUM contribution is to be found in Table 4 of Annex A.

### 2.6.4 Publications

As a means of familiarizing more people with ENUM and in the hope of reaching potential users who had simply not heard of the field test up until then, various articles have been published in newspapers and specialist magazines. Special press releases have been issued in connection with each of the ENUM Meetings:

- DFN-GI-Edition: Lecture Notes in Informatics. (Eds. Jan von Knop, Wilhelm Haverkamp, Eike Jessen), Düsseldorf 2004. *ENUM – der Brückenschlag zwischen Telephonie und Internet.* Vol. P 55. 2004. (Stefan Dieterle / Petra Blank, DENIC eG)
- IHK-Zeitschrift: Telekommunikation Spezial. *ENUM - eine Nummer für alle Dienste*. 02/2004. (Dr. Klaus Herzig, DENIC eG)
- KMUplus-Magazin: *ENUM – eine Nummer für alle Dienste*. 05/2005. (Dr. Klaus Herzig, DENIC eG)

[17] http://www.etsi.org/plugtests/History/2005ENUM.htm
[18] http://www.domainpulse.org/?lang=german

- iX-Magazin: *ENUM – Anschluss unter dieser Nummer*. 10/2005. (Stefan Dieterle / Petra Blank, DENIC eG)
- Radio interview with Star FM on March 15, 2005 on the subject of ENUM. (Sabine Dolderer, DENIC eG)

## 2.7 International Exchange

In parallel with the field test that has been running in Germany for two years, several other countries have also been building up experience with ENUM in various different trials. The international exchange concerning the various practical formats of the ENUM trial has been most useful to DENIC in setting about working out its own solutions. For that reason, visitors from outside of Germany were frequent participants at the ENUM meetings.

## 2.8 Outcome

The ENUM field test at DENIC has been brought to a successful conclusion with more than 3500 ENUM domains registered (Figure 8). The continuous growth in the number of ENUM domain registrations since the beginning of the test operation and the increasing number of participants in the test operation serve to show that there is a big interest in the new technology. As part of the field test itself, it proved possible to work out a consensus-based ENUM Operations Model and also to lay the foundation for its technical implementation. The commitment shared by all the participants in the field test has created the springboard for ENUM to become firmly anchored in the industry as a possible future technology in the form of a bridge between classical telephony and the Internet. It is not only the fact that 27% of DENIC's members are now registering ENUM domains for customers, it is also the professional provision of the technical wherewithal for the registry and DNS services by DENIC and the widely available information that have prepared ENUM for its regular operation and positioned it ready for the nationwide rollout of 9.4.e164.arpa in Germany.

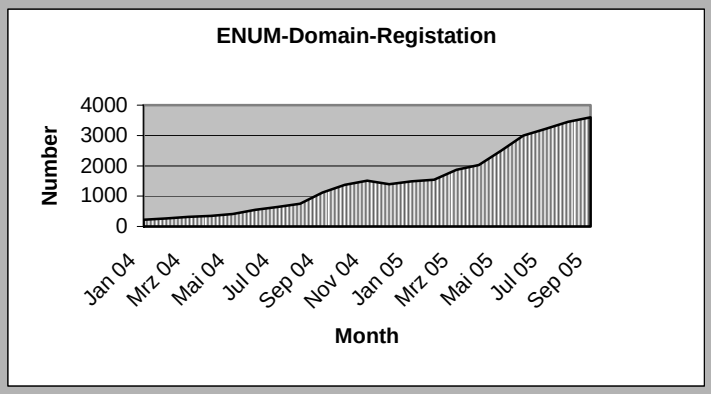



Figure 8: Number of ENUM domains

# 3 Results of the Field Tests

Each of the following subchapters presents a detailed analysis of individual technical matters that were worked on during the ENUM field tests by the field-test participants and DENIC.

## 3.1 User Authentication

Authentication is the term used in the ENUM context for the identification of a user. Checking the users' identity is crucial to make it impossible for ENUM services to be abused by those not entitled to use them. In this description, it is necessary to distinguish between different systems and/or services and the users entitled to use them, namely:

- the ENUM domain registry system,
- the whois and DNS services.

The identification of legitimate holders of E.164 telephone numbers is dealt with in the section on telephone-number validation, namely 3.2.4.

### 3.1.1 ENUM domain registration

DENIC provides an automated registry system for ENUM domains for its members; this is described in section 2.4.2. Various formal and technical preconditions need to be met before a member can use this registry system for ENUM domains. These are necessary for guaranteeing security and preventing unauthorized use.
Any member who wants to be able to communicate using DENIC's mail registry interface (MRI) must first of all set up an OpenPGP signature. They must also create a set of master data using the provider template and link this into the registry system.
As soon as the member's OpenPGP keys and the provider template have been successfully activated, the registry system will accept requests submitted by that member.
The use of public-key cryptography thus ensures that only authorized and verified requests get through to DENIC for processing.
With the realtime registry interface (RRI) planned for the future, there is to be a twofold authentication at the levels of both Transport Layer Security (TLS) and the protocol. This authentication must be two-directional; simple user authentication is inadequate.
DENIC's server possesses a digital X.509v3 certificate from a recognized certification body and this is delivered to clients when they set up an RRI connection. This makes it possible for clients to use server authentication, eliminating the threat of man-in-the-middle attacks. Client authentication has been moved to the RRI level and takes the form of an RRI login and an RRI password. None of the sensitive information (which includes all protected personal data) is transmitted via the network as clear text; rather, the underlying encryption mechanisms or the corresponding TLS suites guarantee confidentiality and integrity. The only TLS suites used are the most modern ones and those that go beyond the basic IT protection level in accordance with the recommendations of the German Federal Office for Information Security (*Bundesamt für Sicherheit in der Informationstechnik,* BSI).
Potential threats to the registry interface are analyzed continuously. For the future, it is planned to introduce client certificates at the TLS level too.

### 3.1.2 DENIC services

Security and authentication are of decisive importance for DENIC's public services too. Without them, it is not possible to guarantee that the resources will be used properly and will thus be relia-

bly available for all Internet participants, seven days a week and 24 hours a day. DENIC is to make the following services available for ENUM:

***whois***

The whois service (section 2.5.3, *http://www.denic.de/de/whois/*) is an anonymous one, which is to be open for everyone, once the regular ENUM operation is running. It is to be implemented on a comparable platform to that of the whois for .de. There is, however, one difference compared with the .de whois, namely that only very limited information will be output, unless the registrant wants to make more information publicly available. This is known as an "opt-in" and is described in section 3.3.2. The frequency of queries to this service is to be monitored, and no-one will be allowed to exceed a predetermined number. The limit has been reasonably generously set, so that no bottlenecks will occur as long as the service is used on a normal scale.
For the future, the IETF is working on a new standard, to be called CRISP [RFC 3707], and DENIC is actively involved in this work. CRISP will support not only anonymous access but also considerably more flexible authorization statuses.

**ENUM Domain Name Service**

DENIC is to provide the Domain Name Service for ENUM domains under 9.4.e164.arpa, and will enter the delegations in the ENUM nameservers for the nameservers specified by holders for their individual ENUM domains. The operators of delegated nameservers are fully responsible for the provision of the service for DNS lookups and for the service qualities to be agreed with the ENUM domain holders. The ENUM DNS query is an anonymous service, and all Internet participants can use it without any form of discrimination. The DNS service for the 9.4.e164.arpa ENUM TLD is to be continuously monitored and is to be capable of massive scaling, so that, should there ever be any abnormal lookup activity (caused, for instance, by a faulty configuration on the user side), it will be possible to react to it instantaneously.

### 3.1.3 Outcome

The experience in the provision of DENIC's services both to authorized users and the general Internet public is based on DENIC's many years or experience in operating the Top Level Domain .de. The development and implementation of the ENUM systems has followed similar lines to the .de domain registry system. Testing the systems has taken place during the ENUM field test in the form of intensive rollout tests performed by internal teams at DENIC. The successful service provision has been documented through its integration in DENIC's operational monitoring system, but during the field test it has also been possible at any time for DENIC members, field-test participants or any other Internet user to check it.
The procedures deployed by DENIC for checking the authenticity of authorized participants in the registry operation and the verification of the integrity of the requests satisfy all the requirements that are laid down for secure systems.
For those services that are available to all Internet users without access restrictions, particular attention is paid to 7/24 availability, failsafeness and extensive scalability.

## 3.2 Processes based on Telephone Numbers

The mapping of telephone numbers to domains and the administration of them makes it necessary to give due consideration to requirements resulting from the use of PTSN telephone numbers. For this reason, DENIC and the field-test participants have analyzed these requirements during the ENUM field test and have considered them in the processes for administering ENUM domains. The results are described in the following sections.

### 3.2.1 Telephone-number space

One of the criteria for choosing the telephone-number ranges to be made available for ENUM domains under 9.4.e164.arpa was the lack of any available means for invoicing based on DNS lookups and/or individual IP services. That means that it is not possible to charge for services in a comparable way to added-value services. Although the operators of otherwise chargeable added-value services would fundamentally have the right to decide to offer their services free via the Internet or to use a different means of invoicing, it was decided not to offer the registration of the corresponding ENUM domains during the field test (and it is also a fact that there was no real interest in this amongst the participants).
Towards the end of the ENUM field test, however, there were those who voiced the need for other telephone-number ranges to be added, such as the 0180 range. At the time of writing, the possible use of ENUM based on these numbers and how they would be linked in is undergoing evaluation.

### 3.2.2 Porting telephone numbers

The porting of a telephone number is the move away from one service provider (who used to provide a subscriber with telephony services) to another service provider, but keeping the same number. Since the holder of each ENUM domain is also the legitimate holder of the corresponding telephone number, they are able to communicate the information about the technical Infrastructure corresponding to such a move by means of a simple update through their registrar, or it may even be that the registrar offers this service directly.

### 3.2.3 Surrendering telephone numbers

Telephone numbers that are no longer used by the legitimate holder of the E.164 number are returned to the network operator. These numbers are not reassigned until after the end of a waiting period. These periods are not the same for all the number ranges, nor are there any uniform procedures. In order to ensure that a number that has been surrendered is no longer delegated as an ENUM domain, at the time of the future regular ENUM operation, each ENUM domain holder is to enter into a contractual obligation to communicate any change in legitimate use immediately. In order to be able to detect any breaches of this duty, ENUM domain contracts are to be limited to a period of twelve months. To extend the life of the ENUM domain beyond this period will call for an active act of renewal, which will entail a revalidation. The combination of these two measures ensures a high degree of data integrity and, at the same time, satisfies the requirements for an attractively-priced, efficient registry system.

### 3.2.4 Telephone-number validation

Telephone-number validation is the term applied to checking who has the right to use a telephone number. The check is performed before the ENUM domain registration takes place. Various different approaches have been discussed during the ENUM field test, and some of them have also been implemented. For good reasons, Germany has no central database for the administration of its telephone numbers, in which all the information about the assignment of individual numbers or whole number blocks is stored, and so there can be no system of validation against central records. The approach evaluated in the ENUM field test has taken this situation into account and has drawn up evaluation procedures that are particularly appropriate for the individual ranges and their administrative characteristics. These procedures use the advantages that are inherent in decentral procedures compared with central ones. One such advantage is that it is easier for providers to integrate their own particular requirements, and these can be tailored to their business and their customers.

Decentral procedures also offer the possibility of having competition for validation procedures between various suppliers on the market, which might also have an impact on the costs of validation. If an infrastructure product, such as ENUM, is to be competitive compared with alternative solutions, cost containment is of decisive importance.

### 3.2.5 Revalidation

It is a fundamental rule that an ENUM domain is only valid for as long as its holder remains the legitimate holder of the assigned telephone number, but never for more than one year. Renewals are always possible for a year at a time. Each renewal is tied to an assurance to be given by the DENIC member involved that a revalidation has taken place. The DENIC member has a duty to keep records of positive validations for each ENUM domain administered by them, and these must never be more than twelve months old. What this means is that a revalidation must take place every twelve months after the conclusion or renewal of a contract.
To assist with administration, DENIC is to generate up-to-date lists for each member of the ENUM domains administered by them, including their expiry dates, and to make these lists available via a web server. In addition, DENIC is to send each member weekly information as to which ENUM domains have only a few days left to run.
Given that revalidation is simply a reconfirmation of the original validation and that this will only have any practical impact if the ENUM domain holder commits a breach of their contractual duties, the procedure has been kept simpler than the procedure for the initial validation, since it presupposes that customers were properly identified at the time of initial validation. A distinction is made between active and passive procedures:

- **Active procedure**

Before the right to use an ENUM domain expires, its holder is informed of the need for a revalidation. The domain holder must then reply to the ENUM domain registrar confirming that they still have the right to use the telephone number and the ENUM domain assigned. In the absence of such a confirmation, the registrar will not renew the ENUM domain with DENIC.

- **Passive procedure**

Before the right to use an ENUM domain expires, its holder is informed of the need for a revalidation. If the ENUM domain holder does not contradict the revalidation, the registrar will renew the registration for them at the contractually agreed terms and conditions.

During the ENUM field test, good experience has been built up, especially with the passive procedure. Registrars did indeed inform their customers regularly regarding the continued use or deletion of their ENUM domains. In the regular ENUM operation, both the registration of ENUM domains and renewal with DENIC following revalidation are to be subject to charges. The usual situation will be that the DENIC member will pass these charges on to their final customers or will incorporate them in other contractual arrangements between the registrar and the customer. This procedure has worked well in the field test, and it was observed that ENUM domains that were no longer used were indeed allowed to lapse and those that were actually used were also regularly renewed through the registrar.

### 3.2.6 Providers of validation services

Since, as already pointed out in section 3.2.4, there is no central telephone-number database in Germany, there is no basis on which to offer central validation services. The idea proposed, in harmony with the corresponding international proposals, is to have validation performed decen-

trally. In this situation, the validation can be performed either by the registrars themselves or by specialized third parties (sometimes called validation-service providers).
During the ENUM field test, various solutions were developed for the operation of a validation-service provider and these were presented to the field-test participants. The following sections describe two solutions actually implemented, whose development is particularly advanced and which have been used successfully in the ENUM field test.

### Deutsche Telekom's validation agency

T-Com is one of the operations within the Deutsche Telekom group and it has been offering registrars participating in the ENUM field test the possibility of validating telephone numbers from the German number space.
The nature of this validation is that of a countercheck against T-Com's databases, i.e. based on existing customer relationships. The only telephone numbers so far admitted for validation are those of Telekom customers who have numbers belonging to geographic area dialling codes. The prototype system communicates by means of e-mail. This prototype is capable of further optimization (as agreed by the field-test participants). It is expected that any registrar using this agency will sign an agreement recognizing data-protection obligations and committing themselves to refrain from any commercial exploitation of its outputs. At the time of writing, no results are available concerning the integration of this procedure in the systems of other providers.
Further information about Deutsche Telekom's validation system is to be found on its special project site at: http://www.validierung-enum.de.

### Portunity's validation solution

Since May 2004, the Portunity company has been offering a call-back procedure. If the number registered is from the mobile-telephone range, the system uses a web-based assistant to automatically generate an SMS with a random numerical code and to send it to the mobile-telephone device that has been assigned the number to be registered. If the number is not one belonging to a mobile phone, the PIN code is not communicated by SMS, but by means of a call via the PSTN, and, when the subscriber accepts the call, the numerical code is "read out" to them by Text2Speech software. The web-based assistant then requests the subscriber to enter the numerical code. It is only if the numerical code is correct that the web-based assistant will complete its work, which includes automatically submitting the telephone number to DENIC for registration of the ENUM domain.
The advantage of this validation procedure as it has been set up is that it is possible to complete the whole cycle automatically in a matter of minutes and that the telephony supplier to whom the number is switched no longer has to intervene in any way. Other points that are important for widespread application are that each verification costs very little and that it is easy to implement.
This validation technique is offered to both final customers (http://www.portunity.
net/article16929-3087.html) and resellers and providers
(http://www.portunity.net/article17010-3083.html). So other registrars can also use it to validate their own customers.
In future, Portunity intends to offer this procedure for blocks of telephone numbers too. If, for example, the number concerned is actually a PSTN range (with, say, ten numbers), the assistant will call two of these numbers and read out a five-digit numerical code to each of them. For bigger ranges, correspondingly more telephone numbers will be polled.
Further information on the process described here is available at: http://www.enum-validierung.de.
Portunity's procedure works for both existing customers and new ones. Its features include simple handling and easy implementation, and, amongst the approaches so far tested, it is easily the one that appeals best to final customers.
Both validation procedures have led to the clear-cut conclusion that it is advantageous to leave responsibility for validation and the choice of the validation method in the hands of the registrars.

This leaves it open to them to use special validation techniques that are best suited to individual customer situations.

### 3.2.7 ENUM-COMPLAINT

Anyone applying to register an ENUM domain is required to give an assurance that they are the legitimate holder of the corresponding telephone number or are acting on behalf of the legitimate holder. This condition must be met before the registrant can become the holder of the corresponding ENUM domain. The legitimate holder is one of the items checked as part of validation.
Should it ever happen, despite all these precautions, that a person who is not the legitimate holder of the corresponding telephone number manages to register an ENUM domain, DENIC has drawn up a process for coping with such a situation, called ENUM-COMPLAINT. The process has been designed to be a both quick and effective means for checking the correctness of the authorization for the delegation of an ENUM domain in individual cases and of being able to take action, if appropriate. The process is to be made available to coincide with the start of the regular ENUM operation.
Those who are authorized to initiate an ENUM-COMPLAINT process are DENIC members, legitimate holders of E.164 telephone numbers (but only insofar as the corresponding ENUM domains are involved) and third parties (in justified cases). After checking the request and the evidence submitted with it, DENIC informs the member in charge that an ENUM-COMPLAINT has been made. The DENIC member then hands over to DENIC its documentary records of the validation of the ENUM domain.

DENIC examines the facts of the case and the evidence submitted to it and take an immediate decision regarding the delegation of the ENUM domain, terminates the domain contract (if appropriate), and disconnects the ENUM domain. The plans are that is should normally be possible to complete an ENUM-COMPLAINT procedure within two working days.

### 3.2.8 Outcome

The administration of the ENUM domains assigned to E.164 telephone numbers is strongly guided by the requirements resulting from the specific characteristics of these E.164 telephone numbers. This has been explicitly taken into account in shaping the ENUM domain processes. The processes for the validation and revalidation of ENUM domains, in particular, guarantee a synchronicity between the E.164 telephone number and the ENUM domain.
One effect of the setting up of decentral validation procedures is that competition is encouraged between the validation-service providers – with a positive impact on pricing and service. Another important result to emerge from the ENUM field test is that the reliability of the validation procedures is enhanced by the use of decentral procedures.
Given that different telephone-number blocks and ranges have been authorized for the registration of ENUM domains, there is no one single procedure that is suitable throughout, but rather different procedures for the various number blocks and/or ranges. Consideration needs also be given to specific preconditions of individual providers as well as to individual circumstances, such as pre-existing customer relations, which it might even be possible to integrate in the validation procedure. Having the validation service performed by the registrar (or by a validation agency appointed by the registrar) ensures precise control over the processes as they run and thereby provides further support for security.
Should ever a registration be made that should not have been made, the DENIC member who made it is liable and has the duty to clear the situation up as quickly as possible. DENIC provides support for this with its ENUM-COMPLAINT process.

## 3.3 Data Protection

DENIC's rules on the storage of personal data have been formulated in such a way as to be entirely in line with the data-protection provisions contained in currently applicable legislation. Absolute top priority is attached to complying with the laws and all other relevant provisions.
For that reason, users' personal data is only made available on call if the users give their informed consent. This is also entirely in line with international recommendations for ENUM operation, as expressed by the International Working Group on Data Protection in Telecommunication [IWGDS 2004], [DENIC QB].

### 3.3.1 Data Model

Taking the provisions of data-protection law as the starting point, the ENUM field test was used for drawing up a data model for ENUM data and for using it in the test operation. Distinctions are made here between operational data, contact data and customer data. Operational data is data that is necessary for running the infrastructure. Contact data is data that is needed for getting in touch with the technical and administrative contacts. Customer data is data that is recorded in the context of the contractual relationship between the DENIC member and the ENUM domain holder. Table 4 lists the resulting responsibilities and the data used in the ENUM Data Model for 9.4.e164.arpa.

| Responsibility | Responsible party |
|---|---|
| Definition of contractual relationships | DENIC eG |
| Acquisition of a data | DENIC eG |
| Acquisition of customer data | DENIC member |
| Telephone-number validation | DENIC member |
| Storage of administrative data | Registry / DENIC member |
| Setting up technical infrastructure | DENIC member / domain holder (registrant) |
| Initial check and storage of technical data | Registry |
| Operation of central infrastructure | Registry |
| Check of correctness of administrative data | Domain holder (registrant) |

Table 4: Responsibilities according to the data model

#### Recording data for ENUM domains

There are various items of data about the ENUM domain and the technical and administrative contacts that the DENIC member must record for the purpose of the administration of ENUM domains by DENIC. Figure 9 contains brief descriptions of each of these items of data.

Data about the ENUM domain holder

The mandatory data to be recorded for the ENUM domain holder is their full name and postal address. A P.O. Box number is not adequate for this purpose. In the case of legal entities, their name must be recorded in full and must include the indication of their legal form (in Germany, typically “GmbH” or “AG”). If the ENUM domain holder is not domiciled in Germany, they are required to nominate an administrative contact domiciled in Germany and to give a postal address for this administrative contact that is suitable for the service of official and court documents. A P.O. Box number is not adequate for this purpose.

It is possible for the ENUM domain holder to consent to the publication of this data (known as “Opt-in 1”). This declaration states which items of data are to be publicly accessible through DENIC’s whois service (section 2.5.3).

Data about the administrative contact

The administrative contact (admin-c) is the authorized representative of the domain holder with all the necessary powers as well as the duty to take binding decisions on all matters affecting the domain. It is possible for the administrative contact and the domain holder to be the same person, but that is subject to the condition of the domain holder being domiciled in Germany. The full name, address, telephone number and e-mail address must be communicated for the administrative contact. If the domain holder is not domiciled in Germany, the administrative contact is their representative for receiving the service of official or court documents. In this case, a full postal address suitable for formal service of documents must be given, i.e. a mere P.O. Box number will not do. In the case of .de domains, all the data so far mentioned (with the exception of the e-mail address and telephone number) can be publicly consulted via the whois service. The administrative contact’s personal data is treated in the same way as that of the domain holder and is only made publicly accessible with the explicit consent of the domain holder or the administrative contact.

Technical contact data

The name, address, telephone and telefax as well as the e-mail address must be provided for both the technical contact (tech-c) and the zone administrator (zone-c). The technical contact data is important for maintaining the ENUM operation, since it is essential to be able to react quickly in the event of disruptions and to be able to get in touch with a responsible contact. It is thus an operational necessity to make this data publicly available using the whois service. This practice has had an excellent track record for the .de operation in ensuring effective liaison in the event of disruptions, so it is to be used for ENUM too.

Communication data

Communication data is data that is used for communication between the users through communication services (telephone, e-mail, VoIP, etc). Communication data is comprised of address data, such as telephone numbers and e-mail, SIP and web addresses, and also besides. It is generally the case that it is in the user’s interest to keep this data up-to-date and to make it available to their communication partners. This data is available for public queries. However, individual users may decide, for reasons of data protection, to load pseudonym data only, as described in section 3.3.3. It is the domain holder who decides which records (uniform resource identifiers, URIs) are to be loaded in the NAPTR records for a given ENUM domain. This is known as “Opt-in 2” [DENIC-05].

This communication data is administered by the registrars in Tier 2 and supplied through the name service. Final customers are at liberty to provide this service themselves if they want to.

Figure 9: Types of personal data and its storage and publication

### Data about members

DENIC keeps records of data about its members, which it needs for administrative purposes. In addition, those members participating in the ENUM field test are named publicly on DENIC's web-pages at http://www.denic.de/en/enum/teilnehmer_am_testbetrieb/enum.jsp.
Further data (IP addresses, OpenPGP keys, special e-mail addresses, etc.) is recorded for the purposes of access authorizations and technical cooperation.

### Data about customers

Additional data about customers, going beyond the items listed in Figure 9, may, in some cases, be recorded by registrars subject to their arrangements with their customers; this could be data about technical systems or the like. The recording and use of this data has nothing directly to do with the registration of ENUM domains. The place for settling details of relevance for data protection is therefore in the contracts between the registrars and their final customers.

### Technical data

The ultimate purpose behind every ENUM domain registration is public access to the registered ENUM domain in the worldwide Domain Name System. To that end, DENIC keeps records of the necessary technical data regarding the authoritative nameservers of each ENUM domain and makes the data available through the DNS.

## 3.3.2 Public information services for ENUM

In addition to the Domain Name Service (DNS), which is based on the ENUM standard, DENIC is also to provide a whois service [RFC3912] for all Internet users as of the commencement of the regular ENUM operation. The following paragraphs describe how these two services are to be provided in the light of the experience with the .de operation and the lessons learnt from the ENUM field test.

### whois

DENIC's proposed ENUM Domain Guidelines [DENIC DG] lay down what information is necessary for publication in the context of the whois information service. In accordance with the proposals of European data-protection bodies [IWGDS 2004], it is only the technically necessary information that is to be published in the whois service. The publication of any additional administrative information requires the domain holder's informed consent ("opt-in"). Technically necessary data consists in any case in that information that is already accessible through the DNS regarding the ENUM domain's authoritative nameservers as well as the information concerning the technical contacts. The actual format for the output from the whois service is to be along similar lines to the standards applicable to domains. Examples of whois outputs are illustrated in Annex C.

### ENUM DNS

DENIC operates the authoritative nameservers for the 9.4.e164.arpa ENUM zone in Tier 1 and grants the delegations for the telephone numbers or number blocks under it. For this purpose, infrastructure and communication data is provided through the ENUM DNS.

- **Infrastructure data**

For each registered domain, DENIC enters the authoritative nameservers as specified by the domain holder and makes these available through the DNS. This process is referred to as "delegating an ENUM domain". Before any ENUM domain is delegated to Tier 2, a functional test is performed on the specified nameservers to make sure that they do not affect the zone's technical integrity and to be also to trap faulty delegations. It is only on the authoritative nameservers that the actual

communication data for the ENUM domain is provided. The supply of this infrastructure data is a mandatory necessity for the technical operation.

- **Communication data**

In agreement with their customers, the ENUM service providers, who operate the ENUM domains' nameservers in Tier 2, publish those items of customer data that are necessary for communication. ENUM domain holders are free to choose which communication addresses they want to offer under their ENUM domains and which are to be available for calling. That means that they are free to use any service providers they want for communication services. For reasons of data protection, however, it is worth giving careful consideration to the selection of communication addresses. All DNS data is publicly accessible. So it might make sense to work with pseudonym records at this point, in the form in which they are offered by various service providers. From these records there is no direct means of establishing the subscriber's identity. By way of example, the following record in the ENUM DNS zone

2.9.3.5.3.2.7.2.9.6.9.4.e164.arpa. IN NAPTR 100 10 "u" "e2u+sip" "!^.*$! sip:joe.doe@iptel.org!"

contains no reference to the actual name of the user, nor to their employer, just to a pseudonym account with a VoIP service provider. There is no need at all to keep any other address data in the ENUM DNS, since call-forwarding mechanisms can also be set up via the VoIP server. The principle of data thrift for personal data can also be put into practice in the DNS.

### 3.3.3 Telephone spam

For the ENUM data to be available for calling via the DNS, it is a necessary prerequisite for the use of these infrastructure services to make it possible to link up communication subscribers independently of suppliers. However, there are those who see a danger of the use of ENUM-DNS data leading to the distribution of "spam over Internet telephony" (or "SPIT").
It is also possible to scan the DNS systematically for accessible domains or addresses, so it is feasible to work sequentially through a range or block of telephone numbers looking for subscribers, to whom messages can then be sent. Preventing unsolicited advertising messages ought thus to be seen as a general problem with low-cost and/or Internet telephony and not just as a problem specific to ENUM. The fact is that the cheaper telephone calls become, the more there will be a "business case" for resorting to SPIT.
However, by using VoIP technology, it might also be possible to provide better anti-SPIT protection for VoIP users than for PSTN users. Today, VoIP servers already have many different means of applying filters, so it is up to the service providers to create applications for them. It ought to be possible for customers to be offered easy-to-use interfaces so that they can configure their accessibility in such a way that unsolicited advertising calls are not put through to them or, at most, are dumped on an answering machine. Measures such as source filtering, grey lists and white lists, authentication and many more are basically ready. If these measures are successful, they lend themselves to a central administration, filtering and forwarding of all calls in a system. In this respect, ENUM represents an important link in the chain as a bridge between the PSTN and the Internet. Ideas on using technology for various countermeasures against telephone spam were presented at DENIC's third ENUM Meeting
http://www.denic.de/media/pdf/enum/veranstaltungen/ENUM_Tag_DENIC_04_snom.pdf.

### 3.3.4 Outcome

Data protection is an important issue for ENUM users and has thus been investigated thoroughly in the course of the field test. ENUM subscribers can, however, be assured that their personal data will be properly protected through a combination of compliance with all legal provisions on data protection and the requirement for users' informed consent as to which data is to be made generally accessible.

## 3.4 Legal Aspects

### 3.4.1 Telecommunications law

The provisions of Germany's telecommunications law ("TKG") are not relevant for ENUM, since DENIC:

1. does not provide any telecommunication services and is not involved in any,
2. does not assign or provide telephone numbers, and
3. does not provide any telecommunication links for telephone numbers issued by others.

DENIC does provide an information service for the Domain Name Service. It is possible to use this service to ask about information on ENUM domains assigned to particular telephone numbers. As described in section 2.5.1, all that DENIC makes public in this respect are the delegated name-servers, and queries must be submitted to these to obtain the authoritative contact data. The setting up of actual connections and the transmission of signals over them, which is what constitutes telecommunication within the meaning of the German telecommunications law, is thus an activity in which DENIC is not involved. That being so, no data arises at DENIC of the sort that would be of significance, for instance, in the context of § 111 of that law.

### 3.4.2 Requests for information from security authorities

DENIC complies with requests for information from third parties (including security authorities) in accordance with general legal provisions, provided that and to the extent that it is *de facto* and *de jure* in a position so to do.

### 3.4.3 Applicability of German law

DENIC is a registered cooperative domiciled in Germany, so German law applies to it. Contracts between DENIC and its members also explicitly state that they are governed by German law. As regards the contracts between DENIC and the ENUM domain holders, prescribing German law might turn out to be problematical, given that many of the domain holders are private individuals; however, it is to be assumed that nearly all ENUM domain holders will be domiciled in Germany and that German law will thus be applicable anyway, without the need to spell it out. Moreover, as far as public law is concerned, it is worth reiterating that its applicability can be neither prescribed nor excluded by any civil-law agreement.

## 3.5 Competition

Competition is a *sine qua non* for any market to function. This is an important criterion for pricing and market transparency later on. ENUM is only one of many solutions for establishing bridges

between the Internet and telephony, and the following sections describe the alternatives competing with ENUM and also the competitive aspects of ENUM itself.

### 3.5.1 Competitive aspects of ENUM

#### Tier 0

ENUM under e164.arpa is sometimes also referred to as "public ENUM". It is an environment in which the initiative to register the ENUM domain is taken by the user of the telephone number. Along similar lines to [RFC3761], there are various systems available outside of the ENUM Top Level Domain, e164.arpa, for mapping telephone numbers to Internet domains.[19] These include:

- user ENUM, which means mapping telephone numbers under other Top Level Domains, and
- carrier ENUM, which stands for ENUM in the private networks of network operators.

Some such systems are only accessible locally and are used primarily for least-cost routing. The procedure for mapping a telephone number to such a domain is similar to that for public ENUM.
The current development is showing the emergence of a strong competitive situation in parallel to ENUM's Tier 1 both nationally and internationally. The systems and approaches in competition with public ENUM are presented below.

#### Tier 1

With the extension of DENIC's functions to take in the operation of the ENUM domain, established principles that have proven their worth in the .de operation will be applied to ENUM too. A stable, secure and efficient infrastructure operation is guaranteed in Tier 1, which is to the benefit of all Internet participants. Experiments in other ENUM trials show that it is difficult to divide this Tier-1 area up into several Tier-1 registries for just one range or block of telephone numbers[20]. Given the need to set up and operate parallel infrastructures, the operation becomes more complex, more resource-consuming and more expensive. In all these experiments it has been deliberately decided not to have a jointly-operated technical database; rather, the approach was one of having each operator in charge of a particular subset of the numbering plan (one registry would take, for instance, all those domains that commence with 0-4, while another would take all those that commence with 5-9). In a situation like this, there is no genuine competition in Tier 1, since registration is only possible with the registry that is in charge of its own domains. In the German ENUM field test, such an approach has never really been a serious contender, and the lean single-Tier-1 model was considered to be the superior alternative.

#### Tier 2

In Tier 2, the members of the cooperative are in competition with one another. This encourages them to offer innovative services at prices determined by the market.

[19] These are not official, internationally valid ENUM records as defined in [RFC3761].
[20] In the United Kingdom the Tier-1 registry is shared by three companies. In the USA, the +1 number space covers several states, who are to have access to their particular ENUM domain under 1.e164.arpa made available to them through a single registry each.

### 3.5.2 Alternatives to ENUM

#### User ENUM

The compilation of directories outside of e164.arpa is an international alternative to the public ENUM approach under e164.arpa. It is fundamentally conceivable to take any domain as a Top Level Domain. Various suppliers have already moved onto this market or have expressed their commitment to do so:

E164.org

This is a service operated by an Australian group, and it is already possible for users to have their telephone number entered easily and cheaply as ENUM domains under e164.org. The telephone-number validation takes place after registration by means of a call-back-based PIN procedure. For confirmation, the PIN must be entered on the provider's webpage. Further information is available at http://www.e164.org.

.tel

One activity that met with a lively public following in 2004 was the attempt to obtain the .tel Top Level Domain from ICANN. Ten companies put in bids to operate this TLD as the international registry, including the well-known VoIP company, Pulver.com. The intention of its CEO, Jeff Pulver, was to compile an ENUM-based directory under .tel. At the time of writing, ICANN has not yet accepted the request to register the .tel TLD, which does not mean that the underlying concept has definitively failed.

The market advantages of these free providers are:

- no restrictions as regards national rules,
- possibility of a rapid implementation, and
- very large user base on account of their international orientation.

The potential disadvantages for users reside in the risk of the directory not being administered adequately. If it were to disregard the national telephone numbering plans or to map telephone numbers without carefully validating them first, inconsistencies would result. Other as-yet unanswered questions are: which manufacturer would link the particular domain into its product, as well as the order in which the trees would be searched (e164.arpa, e164.org, e164.info, etc.). If a subscriber telephone number happened to have differing communication records in several trees, the result would be unpredictable from the user's perspective.

.mobi

Since the end of 2004, ICANN has been allowing a consortium of software suppliers and carriers, including Microsoft, Sun, Orange and T-Mobile, to register domains under the .mobi TLD. It is also to be expected that these domains will be used for offering concepts similar to ENUM to limited circles of users.

#### Carrier ENUM

Carrier ENUM is run in the network operators' private networks. The network operators' ENUM DNS data is not accessible from the public internet. The network operators use ENUM technology to implement switching/routing functions. For that reason, carrier ENUM does not make any end-to-end service available. It is not used for addressing final customers, but primarily for finding destination networks.

Since carrier-ENUM applications are not public, it would basically be possible to graft them on top of a private instance of the DNS. In other words, the network operators would be able to set up a second private tree with the e164.arpa domain for their own purposes.

Examples of carrier ENUM:

- E164.com: further information at http://www.e164.com.
- Xconnect.net: for interconnecting VoIP islands. Further information at http://www.xconnect.net.
- E164.info: a central directory for telephone numbers. Individual VoIP providers import their telephone-number information into this private directory and thus make information for call routing available to all participants in this peering group[21]. Further information at https://www.e164.info.

Interlinking individual VoIP networks offers the customers of the participating network operators the advantage of being able to reach subscribers of other network operators cheaply. Providers find this attractive for several reasons, including customer retention. Initially, this move came in for considerable media attention, but that has since slackened off, now that there are many VoIP islands and it has come to be recognized that interlinking them may bring disadvantages as well as advantages for customers.
One of the disadvantages is that interlinking VoIP islands may cause confusion for final customers. In some cases, subscribers have to use special dialling codes to be able to access other networks, which makes life more complicated for them. If, on the other hand, a user calls a subscriber in another network which is not a peering participant, the call will be routed via the PSTN and the caller charged correspondingly, even if both partners to the call are VoIP subscribers. In the majority of cases, the caller will not notice that the call has been routed via the chargeable PSTN until they receive their telephone bill.
Subscribers are addressed not only through their SIP addresses but also through their telephone numbers. In this sort of case, the providers assume the role of network operators. One drawback is that customers wishing to move to a new provider cannot port these “assigned numbers”. Moreover, the possibility of reaching subscribers from the Internet is not available, and the opinion of the providers is that customers ought not to be allowed to use it either.
As the VoIP networks grow larger and larger, there is a danger that operators will be administering addresses that are similar to telephone numbers, but have no connection whatsoever with the legitimate holder of the corresponding E.164 telephone number. This leads to generally misleading situations.

By way of contrast to proprietary technologies, public ENUM, being an internationally standardized protocol, makes a defined basis available to all network operators and final users – subject to the condition that the dialling codes for the ENUM domains concerned are available under e164.arpa. Despite that, network operators are still opting for private peering, in order to be involved in the VoIP business from the very beginning and in the hope of building up strong customer retention.

### Other systems

Alternative technologies for addressing are available and already present on the market. The extent of user acceptance depends on the supported service characteristics, the costs, the security properties, the quality of the software and the extent of the technology’s general use. As examples

[21] The process known as “peering” involves the interconnection of data lines with the aim of exchanging data. More specifically in the case of VoIP , “private peering” means that individual network operators have signed agreements committing them to accept VoIP data traffic from other VoIP network operators and to deliver such traffic to them.

of these other systems, the following paragraphs take a look at gatekeeper-based systems and DUNDI.

Gatekeeper

Structures with a central gatekeeper are still in widespread use; they go back to the very beginning of VoIP technology. The gatekeeper executes the functions for the authentication and authorization of the subscribers as well as the resolution of the addresses and dialling codes of all connected-up devices. Such gatekeeper-based central solutions remain in frequent use, especially in large organizations.

It is considered to be one of the disadvantages of the gatekeeper systems that they are solutions with only a limited scalability and that their key central component constitutes a single point of failure. Different locations all need to be linked in through this central gatekeeper. In such cases, it is recommended to add on ENUM for the decentral resolution of telephone numbers [DFN 2003].

DUNDI

DUNDI, http://www.dundi.com, stands for "Distributed Universal Number Discovery" and is a decentral system, based on a peer-to-peer structure[22]. In the case of DUNDI, there is no instance with top-level responsibility corresponding to the ENUM DNS. Instead, peer DUNDI clients, which are identified by means of terminal addresses, are connected together. The individual clients are administered locally and represent individual telephone directories.

The central problem with DUNDI is how to achieve compliance with the numbering plans in a global E.164 environment and to what extent the individual telephone numbers can be offered error-free. In the case of ENUM, it is the hierarchical system that guarantees this and, moreover, ENUM has trustworthy organizations running the entire operation, from the provision of the name service right through to telephone-number validation. In the case of DUNDI, on the other hand, each provider has to trust its peering partners [EC 2004].

### 3.5.3 Outcome

There are various systems in competition with ENUM and they are seeking to become established on the market. The advantages offered by ENUM under e164.arpa have been created through the field tests in Germany and in many other countries. However, ENUM cannot start to compete with other systems until it is present on the market with a regular operation. At the time of writing, other systems are ahead of it on the market. User acceptance is strongly influenced by a product's availability. An important precondition for ENUM to make a successful entry onto the market is for a regular operation to start soon.
In the light of experience with the field of .de, it is more than reasonable to forecast intensive competition between service providers in the ENUM services they set about marketing to final customers. The zero-discrimination access to the registry services and DENIC's impartial behaviour will serve to promote the emergence of an active market.

[22] The term "peer-to peer" (or "peer2peer") is applied to decentral systems which give the user access to information and/or other resources.

## 3.6 Protocol Development

DENIC has been intensively following and supporting the development of work on the ENUM protocol at the Internet Engineering Task Force (IETF). Anyone interested in keeping up with the progress in standardization can do so through the IETF's ENUM Working Group and especially through its mailing list, enum@ietf.org [IETF ENUM]. DENIC employees have been regularly attending the international conferences, which are held three times a year. Information about the results and progress in protocol development has been communicated to the ENUM field-test participants through the quarterly reports. An up-to-date description of the Internet drafts and standards is to be found on DENIC's webpages at:
http://www.denic.de/de/enum/technical_information/standards_and_drafts/.

[RFC3761] is an Internet standard with the status of "proposed standard". What that means is that the standard is stable and that its requirements and structure/design have been coordinated with all interested parties. The next step towards becoming an official standard is the documentation of the existence of various independent implementations. Some of these have already been implemented in various applications, and several experience reports have been submitted about them. That represents a good starting situation for moving on to the next stage in standardization, namely that of "draft standard".
[RFC3761] is complemented by other documents laying down the standardization of the individual ENUM services. These ENUM services are needed in order to be able to call the communication addresses of the different communication services through the NAPTR records. At the time of writing, some of these ENUM services have already been defined at IANA [IANA ES], and a large number of them are at the draft stage. It is to be reckoned that they will soon become standards, for instance, for e-mail, web telephone conferences, fax, MMS, EMS, SMS and so on. Table 2 lists those ENUM services that have been registered with IANA, along with their field of application.

| Application | ENUM service |
|---|---|
| Voice over IP | sip, sips, h323 |
| Presence services | Pres |
| Web and data-transmission services | web:http, web:https, ft:ftp |

Table 2: ENUM services registered with IANA

The interpretation and evaluation of the NAPTR records and the "enumservice" field contained in them has been laid down in the standards [RFC3403] and [RFC3761]. In order to provide support to developers in the implementation of interoperable services and applications, ETSI has also submitted a document containing recommendations and guidance with practical relevance [ETSI TS1]. In addition, ETSI has also arranged for a plug test, through which manufacturers and developers have had the opportunity of demonstrating the interoperability of their hardware, software, applications and services (section 2.6.3.3) [ETSI 2005].

### 3.6.1 Outcome

The Internet standard for ENUM, [RFC3761], is a stable basis for the implementation of ENUM in applications and services. DENIC is following the further development of the ENUM protocol very closely and is also actively involved in it.

## 3.7 Operating ENUM

On the basis of the findings from the ENUM field test and following the lines of the reference architecture (Figure 3), DENIC has developed an ENUM Operations Model for 9.4.e164.arpa.
What has been important in drawing this up has been the involvement of all interest groups and the consideration given to what customers expect of a product like ENUM. The basics of the hierarchical administration of the various tiers, as displayed in the model, are explained in chapter 1.

### 3.7.1 ENUM Operations Model

This model is characterized by a clear distribution of functions and an equally clear assignment of responsibilities. The foundation for this is the Data Model presented in section 3.3.1.
Figure 10 illustrates the ENUM Operations Model for 9.4.e164.arpa, including all the parties involved in it.

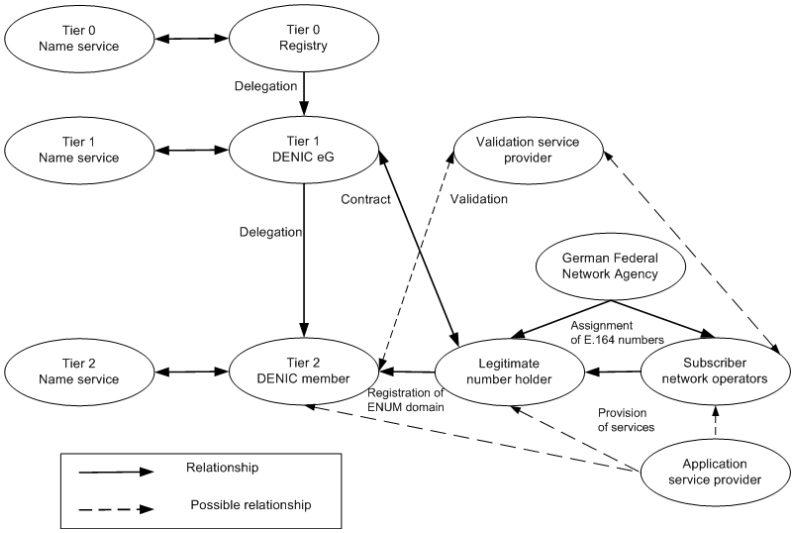



Figure 10: ENUM Operation Model for 9.4.e164.arpa

Tier 1, which is subordinate to Tier 0, is to be operated as a single-Tier-1 model. This makes it possible to provide the DNS and ENUM registrar services efficiently. The operation that is built on this model is described in the document entitled “Operations Policy for 9.4.e164.arpa” [DENIC OP].
Competition takes place in Tier 2: firstly, between the registrars and the ENUM service providers and, secondly, between the providers of validation services. This competition will bring about a state of affairs in which numerous services will be offered as alternatives to one another, which will have positive impacts on the quality and price of the products. This is an important criterion for ENUM to become successfully established on the market. It is also important to satisfy customers’ expectations, which, of course, include failsafeness and efficiency but also an attractively-priced service.
If this model is considered from the point of view of opening up new fields of business on the marketplace, it follows that particular attention is going to need to be paid to the relationship between the providers of validation services and the registrars in Tier 2. Since validation-service providers do not necessarily have to be registrars, this model encourages the setting up of independent validation-service providers.

### 3.7.2 Outcome

ENUM for 9.4.e164.arpa is to be operated within a lean model. The processes that rest on this model are low-priced, suitable for mass operations and efficient. Another important factor is the products' security and quality, which has to be guaranteed at all levels. This will become reality in Tier 2 for ENUM domain registrars and the providers of validation services.

# 4 Conclusions from the Field Test

The ENUM field test at DENIC has shown convincingly and without a shadow of a doubt that ENUM has reached the necessary maturity for applications and the market. All the questions that have arisen in connection with the new communication technology have been worked on intensively in the course of the field tests, and widely-supported, practicable solutions have been found. This was made possible through the close, fruitful cooperation of all those involved in the field test.

The time has now come to end the test phase and to make a smooth transition to a definitive regular operation. It is a propitious point in time, since the growing interest in VoIP, with a rapidly expanding user base, will assist ENUM in achieving fast market penetration. The experience from the German field test, which is similar to that of other countries (such as Austria), demonstrates that an excessively long test phase has a paralyzing effect, once the technical, operational and administrative questions have been sorted out. Product developments advance only sluggishly in field tests. Developments like carrier ENUM show that there really is a need for the fast and uncomplicated transmission of communication data, which will soon turn to looking for alternative solutions if the path to a common industry standard turns out to be too arduous.

Precisely because of these various alternative approaches (see section 3.5.2 for details), competition already exists on the marketplace for VoIP convergence solutions. ENUM is not the only option available for users to decide on. For that reason, regulation is neither necessary nor meaningful and would be much more likely to cause harm. Given the positive experience with the industry's self-organization generally in the field of domains, the German legislator has now stated quite clearly in the telecommunications law that the organization of domains is to remain in the hands of private business in future. That being so, there is not only no need for regulating ENUM domains; there is no legal basis for it either. Just as with the well-proven administration of .de domains, the industry concerned and DENIC have again taken the initiative. All those concerned have carried out the trial together, have developed a consensus-based Operations Model and have provided the appropriate resources. It would therefore be in the shared interest of all those who have been involved in the field test, if the proposals they have developed were to be put into practice as soon as possible.

Another consideration applies here too: the administration of domains needs experience and competence. What users expect (and rightly so) is permanent accessibility, correct and properly updated data and a fast, comprehensive service. DENIC has built up this know-how over more than ten years of work and through the administration of more than nine million .de domains. It has succeeded in guaranteeing a high standard for the ENUM domains in recent years. The necessary interplay between the various parties involved (registry, registrars, ENUM service providers and holders of telephone numbers) has been tested through all its procedures and is now firmly established. The Operations Model for ENUM, that has been drawn up during the field test, with the distribution of responsibilities and the defined roles of the individual parties, can easily be transposed to the regular operation. DENIC is in possession of the necessary technical infrastructure, and this is ready to run. The only remaining task is to fix the terms and conditions for this regular operation in such a way that ENUM can be offered as an attractive product.

So, here are the conclusions from the ENUM field test:

- A stable, secure and efficient operation, as guaranteed by DENIC and its team of employees, is a fundamental precondition for the successful introduction and use of ENUM in Germany;
- Non-bureaucratic access to the resources and an attractive price form the foundations for ENUM as a product on a mass market;
- A lengthy wait for the regular ENUM operation would impair the technology's acceptance.

# References


[DENIC OP] DENIC eG, ENUM Operations Policy Version, 1.0, July 2005.

[DENIC RA] DENIC eG / Regulatory Authority for Telecommunications and Postal Services, Agreement governing the ENUM test operation (German only) http://www.denic.de/media/pdf/enum/ENUM-vertrag.pdf, August 2003.

[DENIC QR] DENIC, Quarterly reports on the ENUM field test 2003–2005 http://www.denic.de/en/enum/aktuelle_arbeit/quartalsberichte/Quartalsberichte.htm

[DENIC DG] DENIC's ENUM Domain Guidelines, August 2005, http://www.denic.de/en/enum-domainrichtlinien.html

[DENIC DB] DENIC's ENUM Domain Terms and Conditions, August 2005, http://www.denic.de/en/enum-domainbedingungen.html

[DENIC WH] Documentation on the whois information service, April 21, 2005. http://www.denic.de/media/pdf/dokumente/DENIC-12p.pdf

[DFN 2003] DFN Mitteilungen, Vol. 62, Juni 2003 (German only), http://www.dfn.de/content/fileadmin/5Presse/DFNMitteilungen/heft62.pdf

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[DNP 2005] German Federal Network Agency: The Number Space of the Public Telephone Network/ISDN in Germany, January 2005. http://www.bundesnetzagentur.de/enid/91410ddbad9f2dc89d4374e74eb0cc75,0/Number_Management/Numbering_Space_1k0.html

[EC 2004] ENUM Center. Digium präsentiert DUNDi - Konkurrenz, Ergänzung or Alternative zu ENUM? (German only) http://www.enum-center.de/article19903-1856.html

[ETSI 2005] ETSI plug test 2005, Press Release: http://www.etsi.org/pressroom/Previous/2005/2005_06_enum.htm, Website: http://www.etsi.org/plugtests/History/2005ENUM.htm

[ETSI TS1] ETSI TS 102 172 V1.2.1 Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN); Minimum requirements for interoperability of ENUM implementations, April 2005, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=20591

[ETSI TS2] ETSI TS 102 172 V1.1.1 Services and Protocols for Advanced Networks (SPAN); Minimum requirements for interoperability of European ENUM trials.

[IANA ES] Standardizied ENUM services at IANA, http://www.iana.org/assignments/enum-services

[ENUM OP] Instructions to the RIPE NCC regarding operations of the domain e164.arpa, http://www.ripe.net/enum/instructions.html

[IETF ENUM] Telephone Number Mapping (enum) Working Group, http://www.ietf.org/html.charters/enum-charter.html

[ITU-T ENUM] ITU-T Study Group 2, ENUM administration ad interim, February 24, 2005, http://www.itu.int/ITU-T/inr/enum/procedures.html

[IWGDS 2004] International Working Group on Data Protection in Telecommunication. Working Paper on potential privacy risks associated with the introduction of the ENUM service. September 2-3, 2003, http://www.datenschutz-berlin.de/doc/int/iwgdpt/enum_en.pdf

[RFC1486] M. Rose, C. Malamud, An Experiment in Remote Printing, July 1993.

[RFC1034] P. Mockapetris, Domain Names - Concepts and Facilities, November 1987.

[RFC1035] P. Mockapetris, Domain Names - Implementation and Specification, November 1987.

[RFC2440] J. Callas et al., OpenPGP Message Format, November 1998.

[RFC2916] P. Faltstrom, E.164 number and DNS, Cisco Systems Inc., September 2000.

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[RFC3401-3405] M. Mealling, Dynamic Delegation Discovery System (DDDS), October 2002.

[RFC3707 A. Newton, Cross Registry Internet Service Protocol (CRISP) Requirements, VeriSign, Inc., February 2004.

[RFC3761] P. Faltstrom, M. Mealling, “The E.164 to Uniform Resource Identifiers (URI) Dynamic Delegation Discovery System (DDDS) Application (ENUM)”, April 2004.

[RFC3912] L. Daigle, WHOIS Protocol Specification, September 2004.

[TKG 2004] BGBl I 2004, 1190, German Telecommunications Law (TKG), June 22, 2004 (German only).

# Annex

# A Organized Events

| Event | Date | Venue |
|---|---|---|
| Voice On the Net (VON) | June 9-12, 2003 | London |
| 57th IETF | July 13-18, 2003 | Vienna |
| 58th IETF | November 9-14, 2003 | Minneapolis |
| 60th IETF | August 4, 2004 | San Diego |
| 61th IETF | November 7-12, 2004 | Washington D.C. |
| 62th IETF | March 6-11, 2005 | Minneapolis |
| 46th RIPE | September 1-5, 2003 | Amsterdam |
| 48th RIPE | May 3-7, 2004 | Amsterdam |
| 49th RIPE | September 24, 2004 | Manchester |
| 50th RIPE | May 2-6, 2005 | Stockholm |
| 1st ETSI Workshop | February 24, 2004 | Sophia Antipolis |
| 2nd ETSI Workshop | November 29-30, 2004 | Sophia Antipolis |
| ETSI plug-test preparation | April 14-15, 2005 | Vienna |
| Domainpulse | February 3-4, 2004 | Zurich |
| Domainpulse | February 5-6, 2005 | Vienna |
| ENUM Summit | June 28-29, 2005 | Miami |

Table 3: Conferences attended by DENIC

| Event | Date | Title of lecture |
|---|---|---|
| 42. DFN Betriebstagung | February 22-23, 2005 | *ENUM – eine Nummer for alle Dienste* |
| 18. DFN-Arbeitstagung | June 1-4, 2004 | *ENUM – Der Brückenschlag zwischen den Telephoniewelten* |
| Freiburg University | July 5, 2004 | ENUM - Eine Nummer for alle Dienste |
| ECO | July 14, 2004 | *Der ENUM Feldtest für 9.4.e164.arpa bei der DENIC* |
| GUUG | January 14-18, 2005 | *ENUM - a practical view, ENUM at DENIC* |
| ZKI RZ-Leitertreffen | March 8, 2005 | *ENUM - Der Brückenschlag zwischen Telephonie und Internet* |
| Communication Commission of Kenya | March 23, 2005 | *DENIC and the German ENUM Trial* |
| CNNIC: China Internet Network *Information Center* | June 20, 2005 | *DENIC and the German ENUM trial* |
| International ENUM Summit | June 27, 2005 | *ENUM in Germany* |

Table 4: DENIC's active support of organized ENUM events

DFN-Betriebstagung ("operations session")

The DFN (Deutsches Forschungsnetz, http://www.dfn.de/content/de/) is Germany's national research and education network. It is a non-profit association self-administered by academia. It provides a network interlinking the German research and education communities and supports the development and testing of innovative applications within the Internet community in Germany. Back in 2003, it implemented ENUM as a prototype. The status update on the ENUM field test and the prospects for the regular ENUM operation were important items of information for participants at this event.

DFN-Arbeitstagung ("working session")

The DFN's "working conference" is the association's central event for advanced scientific training in promoting Germany's national research and education network. Traditionally, it is divided into an advanced seminar and a technical conference. The proceedings published after this conference (GI-Edition - Lecture Notes in Informatics) include the article accompanying the ENUM presentation which translates as "ENUM – the bridge between telephony and the Internet":
http://www.denic.de/media/pdf/enum/berichte/Dieterle_Blank_DFN_Artikel.pdf

ECO-Forum

The ECO-Forum, http://www.eco.de, is an organization for furthering the interests of the German Internet. The event referred to here was a panel discussion on the subject of "VoIP – on the Threshold of Market Maturity". It emerged very clearly that differing views were held by manufacturers, VoIP providers and final customers. Whereas the top priority for the VoIP providers was broadband market penetration, the final customers attached greater importance to information about applications.

GUUG Telephony Summit

The Telephony Summit organized by the German Unix User Group (GUUG), http://www.guug.de/veranstaltungen/telephony-summit-2005/, was an opportunity for the developers of open-source software solutions and the providers of telephone services to meet. The developers received information about ENUM's potential and its implementation.

ENUM-Summit:

This is a conference at which national and international organizations promoting ENUM, standardization bodies, national regulators, government representatives, telephone-network operators, ISPs and ESPs present and discuss both technical and economic aspects of ENUM in detail.

# B ENUM Products, Applications and Services

| Products |
|---|
| **Software** |
| Asterisk, Open Source Software Telefonanlage, http://www.asterisk.org/ |
| SIP Express Router, http://www.iptel.org/ser/, Open Source Software SIP-Router |
| OpenH323 Open Source Implementierung des ITU-T Standards H.323, http://www.openh323.org |
| GNU Gatekeeper, (H.323 Gatekeeper), http://www.gnugk.org/ |
| GnomeMeeting H.323-Software Telefon, http://www.gnomemeeting.org |
| Vovida Open Source Software Telefon System, Vovida Networks, Inc., http://www.vovida.org |
| Linphone Open Source Telefon auf Linux Basis, http://www.linphone.org |
| |
| **ENUM DNS-Server** |
| Bind vom ISC, http://www.isc.org |
| PowerDNS, http://www.powerdns.com |
| Nominum CNS, http://www.nominum.com |
| MyDNS, http://mydns.bboy.net with NAPTR Unterstützung, http://freshmeat.net/redir/mydns-naptr/57564/url_homepage/mydns-and-naptr.html |
| Netnumber, ENUM Master and Edge Server, http://www.e164.com/products/server.jsp |
| |
| **Software - Packages for Developers** |
| reSIProcate http://freshmeat.net/projects/resip/, Objekt orientierter SIP Stack in C++ for Windows and Linux. http://www.sipfoundry.org/reSIProcate/. Contains DNS requests with support of NAPTR and SRV records. |
| Perl DNS Resolver Module Net-DNS-0.53, http://search.cpan.org/~olaf/Net-DNS-0.53/lib/Net/DNS/Nameserver.pm |
| Perl Modul, DNS Programmcode, Net-DNS-Codes-0.08, http://search.cpan.org/author/MIKER/Net-DNS-Codes-0.08/Codes.pm |
| Japan NIC, http://jprs.co.jp/enum/software/software.html, ENUM-Client library in Perl, ENUM SDK, ENUM registy system. |
| |
| **Registrar-Software** |
| NASK, Registry – Registrar Interface, Extension of the Extensible Provisioning Protocol (EPP) – Protocoll to ENUM, http://www.dns.pl/english/ENUM/ |
| ENUM.at, http://enum.nic.at/software/. |
| |
| **Hardware** |
| SNOM IP-Telefon, SNOM Technology AG, http://www.snom.com |
| FRITZ!Box Fon, FRITZ!Box Fon WLAN, AVM GmbH, http://www.avm.de |
| Innovaphone Hardware, Innovaphone AG, http://www.innovaphone.de/webneu2/de_index.asp |
| VoiceCenter Fusion Servers, Voxeo, http://www.voxeo.com/products/turnkey-ivr-server-turnkey-voicexml-server.jsp |

# ENUM in Use

## ENUM-realisations

Institutszentrum Birlinghoven (IZB, http://www.izb.fhg.de): linking VoIP islanda, http://www.denic.de/de/enum/anwendungspotential/Szenario1.html

T-Systems Nova, ESP SOAP Connector, fourth newsletter, ENUM service-provider SOAP interface for the configuration of NAPTR records, http://www.enum-trial.de/, http://www.denic.de/de/enum/anwendungspotential/sz_t-system.html

Portunity, Callforwarting with ENUM, http://www.enum-center.de/article19456-1856.html

Monduno, http://www.monduno.com/, Implementing ENUM and VoIP with Asterisk, http://www.denic.de/en/enum/anwendungspotential/Monduno.html

UdS VoIP pilot project, VoIP service for all students, http://www.rz.uni-saarland.de/projekte/VoIP/, http://www.denic.de/en/enum/anwendungspotential/Uni-Saarland.html

## ENUM-scenarios

DENIC: “Accessibility of the (0)32 number range via the Internet”, http://www.denic.de/en/enum/anwendungspotential/032-rufnummern.html

DENIC: “Call forwarding with ENUM” (German only), http://www.denic.de/en/enum/anwendungspotential/rufweiterleitung.html

T-Systems, http://www.enum-trial.de/, Newsletter 7., “FollowMe Client for Mobile Telephones, white paper” (German only): http://www.enum-trial.de/docs/ENUM_trial_Projekt-FollowMe_v1_0.pdf - Administration of the ENUM domain from a mobile phone. White paper (German only): http://www.enum-trial.de/docs/ENUM trial_Projekt-Handy-Client_v1_0.pdf

dtms AG – Portunity, “Free access of ENUM numbers from the PSTN” (German only), http://www.enum-center.de/article22800-1856.html

dtms AG, “ENUM lookup by the network operator - the case of “subscriber network operators/mobile telephony” (German only): http://www.denic.de/media/pdf/enum/veranstaltungen/ENUM_800_Denic_280904.pdf

Georg von Zezschwitz: “ENUM scenario with the support of Bluetooth” (German only): http://www.denic.de/en/enum/anwendungspotential/bluetooth.html

## Applications of a pilot nature

Kapsch Carriercom ENUM-Client Software for Windows (German only): http://www.kapsch.net/CarrierCom/de/4627_DEU_HTMLExtranetCD.htm

NASK, ENUM client for mobile devices, http://www.dns.pl/english/ENUM/others.html

NGN scenarios von Netnumber, http://www.netnumber.com/openum/openum.jsp

ENUM.at, generic gateway, http://enum.nic.at/documents/AETP/Presentations/Other/0042-ENUM-based_services.ppt

Netnumber, ENUM-Client SDK for Java or C, http://www.e164.com/developer/home.jsp

AOSA, ENUM-Client Software for Windows, http://www.aosa.at/de/pages/1_4_0.htm

Voxeo IVR - Voxeo VoiceCenter, SIP / VOIP conference and voice-dialogue system (interactive voice response - IVR) with support for von VoiceXML, CCXML, and ENUM. http://www.voxeo.com/products/turnkey-ivr-server-turnkey-voicexml-server.jsp

| Services |
|---|
| **ENUM DNS-Services** |
| Portunity, http://portunity.net/ |
| NetNumber – ENUM directory services for the Internet telephony industry, http://www.netnumber.com |
| Sentiro, http://www.sentiro.com/ |
| Teaked, http://www.tekea.com/ |
| |
| **ENUM DNS-Management** |
| Lucent – Voice over IP OSS Software for Service-Provider, http://www.lucent.com/solutions/oss_software_for_voip.html |
| AG Projects, Managed DNS Services, NGN Service Plattform auf SIP, http://www.ag-projects.com/ManagedDNS.html |
| AG Projects, NGN Routing Engine, http://www.ag-projects.com/ENUM.html |
| NetNumber, Online tool for account management, ENUM domain maintenance and reporting, http://www.netnumber.com/developer/home.jsp |
| |
| **ENUM-Lookup** |
| ENUM Center.de, http://www.enum-center.de |
| T-Systems, http://www.enum-trial.de |
| Sentiro's ENUM lookup webpage http://www.enum2go.com |
| Alex Mayrhofer's ENUM lookup webpage http://nona.net/features/enum/ |
| Adrian Georgescu's Managed DNS lookup webpage, https://secure.dns-hosting.info/enum_lookup.phtml |
| The Voice Peering Fabric – ENUM Lookup Page, http://www.thevpf.com/, http://www.thevpf.com/?action=enum |
| Kapsch Carrier, ENUM Query Client for Windows, http://www.kapsch.net/CarrierCom/de/4624_DEU_HTMLExtranetCD.htm |
| |
| **ENUM domain-registration** |
| DENIC keeps an up-to-date list of its members who are actively involved in the field test with registration services for the +49 national dialling code at: http://www.denic.de/de/enum/teilnehmer_am_testbetrieb/enum.jsp. At the time of writing, 60 members handle the registration of ENUM domains. |
| |
| **Providers of VoIP with ENUM support** |
| Iptel.org, http://www.iptel.org |
| monduno, http://www.monduno.com |
| AG-Projects, http://www.ag-projects.com |
| dus.net, http://dus.net |
| SipSNIP, http://www.sipsnip.com/de/ |
| PURtel, http://purtel.com |
| The Voice Peering Fabric, http://www.thevpf.com |
| Blue Lava Software, http://www.bluelavasoftware.com |
| Tiscali, http://www.tiscali.de |

| Information pages |
| --- |
| DENIC eG, http://www.denic.de/en/enum/ |
| ENUM AT, http://www.enum.at |
| Enum-Center, http://www.enum-center.de |
| VoIP Wiki, http://www.voip-info.org/wiki-ENUM |
| IETF, http://www.ietf.org/html.charters/enum-charter.html. |
| ITU, http://www.itu.int/osg/spu/enum/ |
| Richard Stastny, http://voipandenum.blogspot.com/ |
| Sipcenter, http://www.sipcenter.com/sip.nsf/html/ENUM+Services |

The above list makes no claim to be complete, but does give an overview and will be regularly extended with up-to-date links on DENIC's webpages at:
http://www.denic.de/en/enum/anwendungspotential/.

# C Public whois Outputs

Sample query about the telephone number: +49 69 123 456

## Default output:

### ENUM domain data

| | |
|---|---|
| Domain: | 6.5.4.3.2.1.9.6.9.4.e164.arpa |
| Latest update: | 05.09.2005 |

### Technical contact, zone administrator

The technical contact (tech-c) supports the domain 6.5.4.3.2.1.9.6.9.4.e164.arpa with respect to technical aspects.

The zone administrator (zone-c) supports the name servers of the domain 6.5.4.3.2.1.9.6.9.4.e164.arpa.

| | |
|---|---|
| Name: | AnyProvider |
| Contact type: | ROLE |
| Address: | Platz 26 |
| Zip code: | 60330 |
| City: | Frankfurt |
| Country: | DE |
| Phone: | +49 69 11111-111 |
| Fax: | +49 69 11111-112 |
| e-mail: | isp@example.com |
| Remarks: | Information: http://www.example.com<br>Questions: mailto:ops@example.com<br>Tel.: 0180 1111111 (one tariff unit per call) |

### Technical data

| | |
|---|---|
| Nameserver: | ns1.example.com. |
| Nameserver: | ns2.example.com. |
| Nameserver: | ns3.example.com. |

## More detailed output subject to the consent of the ENUM domain holder:

### ENUM domain data

| | |
|---|---|
| Domain: | 6.5.4.3.2.1.9.6.9.4.e164.arpa |
| Latest update: | 05.09.2005 |

### ENUM domain holder

The ENUM domain holder is DENIC's contractual partner and hence holds the material rights to the ENUM domain..

| | |
|---|---|
| Name and Address: | Karl AnyName<br>Wiesenstrasse 20<br>60329 Frankfurt<br>DE |
| Phone: | +49 69 123-456 |
| Fax: | +49 69 123-457 |
| e-mail: | anyone@de-anydomain.de |

## Administrative contact

The administrative contact (admin-c) is the natural person appointed by the domain holder to act as his/her authorized representative and who also has the duty towards DENIC of taking binding decisions in all matters concerning the ENUM domain 6.5.4.3.2.1.9.6.9.4.e164.arpa.

| | |
|---|---|
| Name: | Karl AnyName |
| Contact type: | PERSON |
| Address: | Wiesenstrasse 20 |
| Zip code: | 60329 |
| City: | Frankfurt |
| Land: | DE |

## Technical contact, zone administrator

The technical contact (tech-c) supports the domain 6.5.4.3.2.1.9.6.9.4.e164.arpa with respect to technical aspects.

The zone administrator (zone-c) supports the name servers of the domain 6.5.4.3.2.1.9.6.9.4.e164.arpa.

| | |
|---|---|
| Name: | AnyProvider |
| Contact type: | ROLE |
| Address: | Platz 26 |
| Zip code: | 60330 |
| City: | Frankfurt |
| Country: | DE |
| Phone: | +49 69 11111-111 |
| Fax: | +49 69 11111-112 |
| e-mail: | isp@example.com |
| Remarks: | Information: http://www.example.com<br>Questions: mailto:ops@example.com<br>Tel.: 0180 1111111 (one tariff unit per call) |

## Technical data

| | |
|---|---|
| Nameserver: | ns1.example.com. |
| Nameserver: | ns2.example.com. |
| Nameserver: | ns3.example.com. |

# D List of Abbreviations and Acronyms

| | |
|---|---|
| ASP | Application service provider |
| CPU | Central processing unit |
| CCTLD | Country code Top Level Domain |
| DENIC | DENIC Domainverwaltungs- und Betriebsgesellschaft eG |
| DMZ | Demilitarized zone |
| DNS | Domain Name System |
| ENUM | Telephone number mapping |
| ETSI | European Telecommunications Standards Institute |
| IAB | Internet Architecture Board |
| ICANN | Internet Corporation for Assigned Names and Numbers |
| IETF | Internet Engineering Task Force |
| ISDN | Integrated services digital network |
| ISP | Internet service provider |
| ESP | ENUM service provider |
| ITU | International Telecommunication Union |
| MRI | Mail registry interface |
| NAPTR | Naming Authority Pointer |
| NS | Name service |
| PBX | Private branch exchange |
| PSTN | Public switched telephone network |
| RFC | Request for Comments |
| RIPE NCC | Réseaux IP Européens Network Coordination Centre |
| RRI | Realtime registry interface |
| SAN | Storage area network |
| UPS | Uninterrupted power supply |
| VoIP | Voice over IP |