ENUM in everyday practice – is it a dream or an opportunity?

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Reviewed

The aim of this paper is to elaborate on Electronic NUmber Mapping (ENUM) technology. In the introduction, the role of ENUM is presented. Afterwards an ENUM measuring method is introduced, and several determining parameters are identified and it is shown how these parameters influence the performance of ENUM. The closing part shows overall ENUM and DNS performance parameters, apart from the DNS server raw performance. Finally, as a sanity check, the Hungarian voice communication profile is compared with the measured ENUM performance in order to have sizing guidelines for ENUM related services.

1. Introduction

ENUM is an IETF standard that makes it possible to assign phone numbers (in E.164 format) and standard domain names used on the Internet. ENUM is also a tool that allows to access Internet based services via phone numbers. Consequently, ENUM is one of the relatively new technologies that pave the way towards convergent networks, the so called Next Generation Network.

The IETF working group was established in 1999, its core standard in RFC 3761 was published in 2004 which is an update of RFC 2916 from 2000. Current development activity in the ENUM working group is focusing on:

– continuously broadening services based on DNS,
– definition of new services in the DNS
   that use ENUM,
– separation of user ENUM and
   infrastructure ENUM,
– interworking issues with
   other IETF working groups like SPEERMINT.

An E.164 phone number provides universal access for phones, and using this number several value added services can be provided, like SMS or MMS. The Universal Resource Identifier (URI) supports communication between computers that are connected to the Internet. The assumption is that telephony services and Internet services will coexist for a long time, so in order to establish synergy there is a need for a standardised gateway between the traditional telephone services and Internet services. In this respect ENUM is one of the mechanisms that ties together the two worlds of communication systems, as convergent services are provided by the applications. It is well known that the first *Voice* over the Internet was realised in the mid-nineties. The SIP IETF signalling standard is dating back to 1999 (RFC 2546, RFC 3261).

By 2008 the term convergence became commonplace as service platforms that are merging continuously. However, there are warnings that make people and businesses very cautious. An announcement of Nominum [1] in March 2005 assured the public that Nominum's DNS solution for ENUM were more than satisfactory. A study [2] of several US ISP's DNS service concluded that the SLA of DNS services needs significant improvement.

In this article we will assess if ENUM as a technology is mature enough to be deployed and the concerns over ENUM's performance are substantiated.

2. ENUM measurement scheme

Applications that need ENUM make DNS requests and interpret the responses.

The overall set-up is very simple: there is a DNS server that answers the ENUM requests *(Fig. 1)*. DELL 1855 blade servers were used, with a blade of 2 CPU-s. There were two blades that participated in the measurements; it provided very good physical coupling, and compact arrangement. The blades were dually connected to the network but this does not have any impact as the level
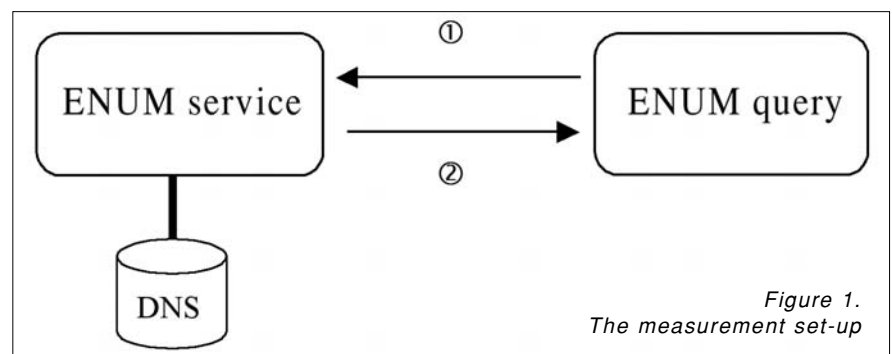

Figure 1.
The measurement set-up

of network traffic was much less than the 2*1 Gbps capacity of the network interface card. The blades each have 2 Gbyte of RAM and two Intel 3.2 GHz hyper threading Xeon processors, the operating systems were Linux with 2.6 kernel.

Our obvious choice as DNS server was BIND 9 [3]. The software that was used for issuing the requests was Nominum's *dnsperf* [4]. The same software was used as in Nominum's case, so the differences caused by different software requester packages were eliminated.

Common elements of the measurements are that different DNS zone files were generated by a home made software. The zone files in the measurements represented different complexities in terms of ENUM responses.

Our aims with the measurements were to determine:
– the number of responses per second of DNS servers that are loaded with zone files being different in ENUM resolving complexities
– what other parameters affect the number of served DNS requests per second

3. ENUM performance measurements

3.1. DNS responses by number of records

This is a baseline performance measurement. The DNS zone files did not contain any ENUM specific values. The result was that a simple DNS server without any tuning could respond more than forty thousand requests per second *(Table 1)*. Compared with the original Nominum press release and article [2] the expected throughput was much lower.

Table 1.
DNS performance differences by number of records

Nr. of records	Queries per sec
10^1 (0-1)	43770
10^2 (0-2)	43274
10^3 (0-3)	42909
10^4 (0-4)	42854
10^5 (0-5)	42732
10^6 (0-6)	42221
10^7 (0-7)	40412

3.2. DNS server performance and CPU capacity

For this test the BIND DNS was tested running on an old Intel P3 machine.

Table 2.
DNS performance with low capacity CPU

Zone file name	Number of records	Queries per sec	CPU load%
1-1-1	10^2	975	73.05
2-1-1	10^3	982	72.56
3-1-1	10^4	974	71.54
4-1-1	10^5	929	69.89
5-1-1	10^6	914	69.82

Due to memory limitations only one million records could be loaded to the server. The sixth test reassures us that ENUM needs cannot be met by very low performance CPU-s *(Table 2)*. It also indicates why DNS could also have been a bottleneck in the early stages of the development of the Hungarian Internet.

3.3. Resolving ENUM records by different type of DNS servers

The performance difference *(Table 3.)* of the two BIND versions is attributed to different software versions, and whether local optimization of the code was allowed or the pre-packaged version was used. NSD [5] is the open source version of the root name servers.

We conclude something very trivial: if the number of NAPTR records is growing than the DNS performance is slightly decreasing. NSD and BIND 9.4.0 are roughly equivalent in performance apart from the problem of the inability of NSD of loading ten million records.

The message of this test is that a simple DNS server providing ENUM records could surpass the 40000 resolutions per second. In our case the DNS servers utilised the modern Linux kernel with SMP and multi-threaded functionality. It is good to keep in mind that an authoritive DNS server that is responsible for lots of ENUM records needs more memory, in our case the usable memory was 2 Gbyte.

Table 3.
DNS servers' performance resolving simple ENUM records

File name	Nr.of records	BIND 9.3.2			BIND 9.4.0.rc1			NSD 3.0.4		
		query per sec	memory req.	CPU load	query per sec	memory req.	CPU load	query per sec	memory req.	CPU load
1-1-1	10^2	42278	70340	74.12	55798	74664	71.68	65860	20976	10.78
2-1-1	10^3	41795	70340	74.78	55079	75632	72.10	59423	23140	12.07
3-1-1	10^4	41792	71660	74.71	54313	77048	72.21	53250	23676	13.12
4-1-1	10^5	40657	86180	75.28	53267	90384	73.31	46945	85804	14.51
5-1-1	10^6	39824	232048	76.06	51917	234720	74.08	40440	645908	15.66
6-1-1	10^7	33033	1542756	79.81	48958	1663488	75.41		*failed*	

Figure 2.
Test measurement
arrangement
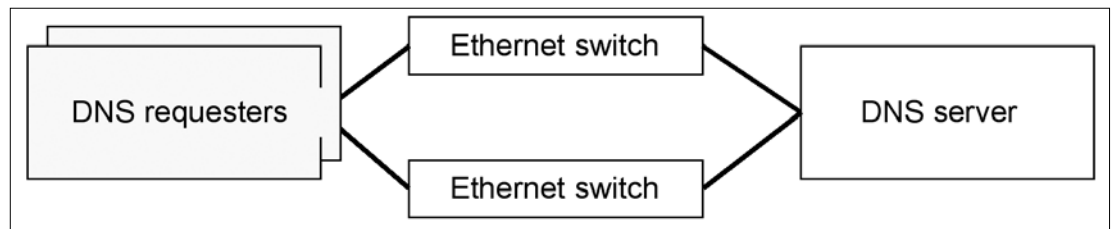
3.4. The effect of parallel requests on DNS server performance

The performance of the DNS server was measured with requests from two computers at the same time *(Fig. 2)*. The NAPTR (ENUM) structures were the same as in the previous measurement. From the results we conclude that the server handles the requests independently and the aggregated performance is the same as in the previous test *(Table 4)*.

Zone file name	Number of records	query per second 1	query per second 2	Memory usage	CPU load%
1-1-1	10^2	21276	21264	68968	74.91
2-1-1	10^3	21185	21152	69172	75.15
3-1-1	10^4	21021	20953	70492	75.36
4-1-1	10^5	20703	20670	85012	75.78
5-1-1	10^6	19894	19879	107072	76.45
6-1-1	10^7	16693	16633	249344	80.66

Table 4. DNS performance with dual load

3.5. Serving non-existing DNS records

In this measurement the performance of the DNS server was tested against non-existing records.

For BIND 9.3 implementation there was only a slight degradation of the performance for serving non-exis-tent records *(Table 5)*.

Table 5.
Performance data serving non-existing DNS records

Zone file name	Number of records	query per second	CPU load%
1-1-1	10^2	47041	72.89
2-1-1	10^3	46606	73.67
3-1-1	10^4	45276	74.27
4-1-1	10^5	44862	74.69
5-1-1	10^6	40186	77.33
6-1-1	10^7	34664	80.65

3.6. The effect of EDNS0 on BIND performance

The original DNS used UDP protocol with a maximum of 512 bytes of payload. When it turned out that the DNS responses might grow over 512 bytes, two so-lutions were introduced. One of the solutions is the DNS over TCP protocol but its drawback is the performance penalty, which results in slow responses. The other option is to allow longer responses up to 4096 bytes. When a DNS client is able to handle longer responses, it is indicated with an OPT element, so the DNS server can respond with longer UDP records.

In this measurements the effect of longer respons-es, with EDNS0 are assessed. In this particular test the structure of the ENUM record be-comes gradually more complex in re-spect of the *response size*. During the measurement the number of records and the size of the NAPTR records are increased. It is a real life test in terms of usage, as it is equi-valent the assignment of several `sip://`, `mailto:`, `IM`, etc. records to the same phone number. This measurement scenario represents a big provider with user ENUM en-abled. The standard also allows the truncation of DNS response to 512 bytes provided the server was not specifically asked to respond with long records if it was needed.

The tests were carried out with and also without EDNS0 support.

As our measurements show the BIND DNS server performance depends on EDNS0. There is a slight de-crease in performance, provided the responses are big-ger. Although the whole range of possible response sizes in this test were not measured, the results show that with moderate long size DNS responses the performance is realistic *(Table 6)*.

3.7. How the response size affects DNS performance

In this measurement the DNS response size is in-creased for two data sets, and the DNS performance is analysed.

According to the DNS Response Size Issues inter-net draft the DNS response size can be larger then the original 512 byte limit maximum.

Our aim is to find out how the response size affects ENDS0 operations.

In one of the data sets there were 100 records, with different sizes up to 4096, in the other data set there were 100,000 records and the response size changed accordingly *(Table 7)*. The results of this test show that the response size affects the performance *heavily:* with growing response size the DNS performance becomes significantly less.

File name	Memory	CPU load%	Query per second (without EDNS0)	Query per second (withEDNS0)	Response size (byte)
5-1-1	216112	76.49	39607	36774	149
5-1-2	264316	77.23	39272	35825	210
5-1-3	341016	77.58	38077	34608	271
5-1-4	370132	78.54	36873	34117	332
5-1-5	430564	78.96	36529	33551	393
5-1-6	470260	79.24	35819	32883	454
5-1-7	525376	80.19	*35168*	32530	515
5-1-8	562648	79.56	*35581*	31885	576
5-1-9	623440	79.47	*35255*	31298	637

Table 6. The effect of EDNS0 on BIND performance

This concludes to the following design rule: for bigger DNS performance requirements one needs higher speed CPU-s, and higher speed memory access. The need for longer NAPTR records is expected in the future, as user ENUM registration is becoming a service.

			N=100	N=100000	
File name	Nr. of test	Response size	Query per second	Query per second	CPU load%
1-1-1	1	141	38722	36861	76.54
1-1-9	9	629	32789	31307	81.15
1-1-17	17	1124	29315	27386	83.54
1-1-25	25	1620	24427	21238	82.35
1-1-33	33	2116	20962	20033	83.97
1-1-41	41	2612	19255	18046	84.97
1-1-49	49	3108	17053	16274	84.99
1-1-57	57	3604	16049	14379	85.59
1-1-65	65	4068	14760	out of mem.	

Table 7.
The DNS performance
change against
the number of records
and length of response

Table 8.
The BIND DNS server update
performance

File name	Nr. of records	Bind 9.3.2			Bind 9.4.0.rc1		
		Update per sec	CPU load%	IO wait	Update per sec	CPU load%	IO wait
1-1-1	10^2	11468	25.45	1.82	12942	24.28	1.49
2-1-1	10^3	7382	15.98	9.88	11504	23.18	2.53
3-1-1	10^4	26	0.10	23.78	39	0.13	24.03
4-1-1	10^5	24	0.22	23.78	21	0.08	24.02
5-1-1	10^6	23	0.08	23.97	20	0.08	24.05
6-1-1	10^7	23	0.05	23.95	19	0.10	24.05

3.8. DNS update performance and ENUM

The purpose of the measurement is to get performance details of DNS server update capability. The update/second is the scale of the measurements (see Table 8).

The update performance of BIND DNS for very low record numbers is relatively high. It is assumed that this is due to some kind of internal cache mechanism. For bigger ENUM sets the DNS performance gets relatively low, and the performance is almost independent from the number record within the DNS zone files. The measurements show that the results are almost identical with newer BIND DNS. The increasing rate of IO WAIT-s show that the upgrade limit is Linux kernel related. The tuning of IO WAIT-s is a possible follow-up of these measurements.

We conclude that DNS update operations is not one of the strong points of BIND 9. Provided we assume the slow change of ENUM records, this update rate allows 1.7 million changes per day/server. This is substantial, although most probably it is not enough for very large customer base and for applications with very heavy change rate. If we stick to the original ENUM idea, the measured rate is definitely enough, as ENUM data is *static* like data on a business card.

3.9. Comparison of the measured results with other sources

1. NLnetlabs published its BIND 9 measurements [6] in October 2005. Their results are comparable to ours. NLnetlabs conclusion is that BIND requires modern 2.6 Linux kernel for higher performance operations.

2. Several publications were published during the summer of 2006, with the key message that the core of the problem of Internet applications responsiveness is the slow DNS answers. Our view is that Nominum started a media campaign in 2006, and journalists got the wrong message, or only half of the picture. An Australian Internet forum clearly attributes the wrong message to Nominum [7].

3. BIND DNS has been with us in the last 15-20 years, it has been updated successfully, and its scalability and reliability are its most advantageous points. Our view is the BIND DNS is capable to serve well mid-ranged ISP-s, till the customer base reaches 10 million. So BIND DNS – and not just alone – is a real, free alternative of Nominum DNS server.

4. Finally, have a look at the original Nominum press release [8]:

Running on commodity hardware*, Nominum's Foundation Authoritative Name Server (ANS) answered to 45,000 queries per second against 200M NAPTR records with an average latency of 2 milliseconds. Nominum's ANS outperformed by as much as four times all the other tested softwares. The company is also hosting a demonstration of its ENUM solution and benchmarks during the VON Conference in San Jose, California.

 * DNS servers were running
 on the following configuration:
 Red Hat Enterprise Linux 3.0,
 Intel Pentium XEON 2.4 GHz, 2 GB RAM,
 160 GB Raid 5 Disk array,
 Gigabit Ethernet Interface.

This announcement clearly indicates the advantages of Nominum. The reason for BIND showing so low performance is the 2.4 Linux kernel. Our measurements show, that by early 2007 in a new environment BIND performs almost equally to Nominum.

5. If we concentrate on the update performance [9] of Nominum DNS server, this is also in the same range as that of BIND – 30 updates/sec vs. 24 updates/ sec.

For example, Nominum tested the Navitas server with a load representative of production carrier environments: 200 millions records, 30 updates/ second, serving simultaneous queries.

6. Obviously, there are several advantages of Nominum's DNS server:
– It needs much less physical memory, which is an advantage for huge zone files.
– It support DNS EPP protocol.
– There are several extensions that makes Nominum attractive for VoIP providers.
– Service providers very often have more trust in a commercial product than an open-source solution without official support.

Our conclusion is that Nominum's DNS server advantage for ENUM services is not purely in the given performance, as BIND DNS can reach that ENUM performance level too.

4. Deployment considerations of DNS servers supporting ENUM

The primary aim of an ENUM DNS is to serve session setup with proper information that is in a DNS server and can be used within a certain time limit. ENUM is built upon DNS, the delay of the name resolution process has to be minimised.

DNS resolution time depends on:
a) The time the requester needs to issue the request.
b) The time the DNS request travels till it reaches the server that provides authoritive data.
c) The time the authoritive server needs to respond.
d) The DNS response transit time.
e) The processing time of the response at the requester .

In the previous sections ENUM performance data was presented that corresponds to point "c". Points "a" and "e" fully depend on the end user environment in case of user ENUM, therefore a telecommunication service provider cannot affect these time parameters. Due to the modern environment it can be safely assumed that "a"+"e" is smaller than 2-5 msec.

The transit times are constrained by the global IP networks, it cannot be significantly improved at the moment *(Table 9).*

Round Trip delay Time	
Within Europe	cc. 50 msec
East Coast USA	cc. 100 msec
West Coast USA	cc. 180 msec
Australia	cc. 200 msec
South America	cc. 250 msec
Japan	cc. 300 msec

Table 9. RTT as a lower estimate of "b"+"d"

Assume that an average DNS server could resolve 20000 ENUM requests/second, it is equivalent to 0.05 msec. This processing time is negligible compared to the request travelling times within the network.

One consequence of the above mentioned observation is that the geographical distance is the crucial factor between the ENUM DNS server and its user. There are potentially 3 billion phone numbers, so international voice traffic based on simple ENUM requests might have serious problems with call set-up times due to geographic dispersity.

4.1. The effect of DNS service modernization

There has been a significant modernization in the DNS root name servers responsiveness. The aim was that although the number of root name servers is limited to thirteen still a sort of geographically dispersed DNS service should be available for the end users.

The solution is characterized by the so-called Anycast groups [10]. The DNS servers that participate in the Anycast service have the same IP address, and with the help of the properly configured BGP routing protocol this solution allows to find the nearest member of the Anycast group. There are several studies that summarize the effectiveness of the deployment of Anycast services [11].

The consequence of this modernization is that it is possible to deploy DNS servers around the world with phone numbers of the e164.arpa or ie164.arpa domains. Independently of the global Anycast service, the DNS cache servers and secondary servers allow resilient and quick reach of ENUM records for smaller communities.

If and when the Hungarian Regulatory Authority (HRA) starts the Hungarian ENUM trial, its central reference database would prove an important source of information for all the registered phone numbers in Hungary. This central reference database should be used for infrastructure ENUM. It will be HRA, or another organization selected and authorized by NHH that will play the role of the central ENUM registry. This registry will build upon a service that utilizes the Anycast DNS for the e164.arpa and ie164.arpa zone. Hungarian ISP-s, VoIP providers and telecommunication companies could build a very effective service on this basis of ENUM DNS.

4.2. What is the right sized DNS server for ENUM in Hungary?

The purpose of this section is to find out the performance requirements of the future Hungarian ENUM service based on publicly available data. If our aim is to access each Hungarian phone via ENUM, one needs a properly sized ENUM DNS service.

The basic question is: what is the call/second value that corresponds to the Hungarian voice traffic? Our estimation is based upon the Hungarian Central Statistical Office Quarterly Press Release on voice traffic [12].

In this quarter:
– there were 640 million PSTN calls,
– there were 1724 million mobile calls,
– the total number of initiated calls were:
2364 million,
– the length of the quarter was 92 days,
– the average number of calls per day was:
25.7 million,
– the average number of new calls were:
297.4 per second.

The statistics does not give detailed background about the distribution of the calls. It is assumed that the Poisson distribution is applicable, as it is often used in telecommunications.

The Poisson distribution is:
• $x = [0;23]$
• $\Lambda = 13{,}7$
(with this value the call distributions gives back 99.915% of the total voice calls,
with peek hours between 10-15.)

The diagram in *Fig. 3.* corresponds to the daily average call distribution of the Hungarian voice calls.

The peak hour is at 11 a.m., that corresponds 3 million calls/hour that is equal to *833.33 calls/second*.

Obviously the demand is distributed unevenly on workdays. It is assumed that on a very busy day the peak hour might take three times higher load than the average. That is equivalent of 2500 calls/second. To be on the safe side let us estimate the topmost DNS resolution requirement is 8000 calls/second. As this is an
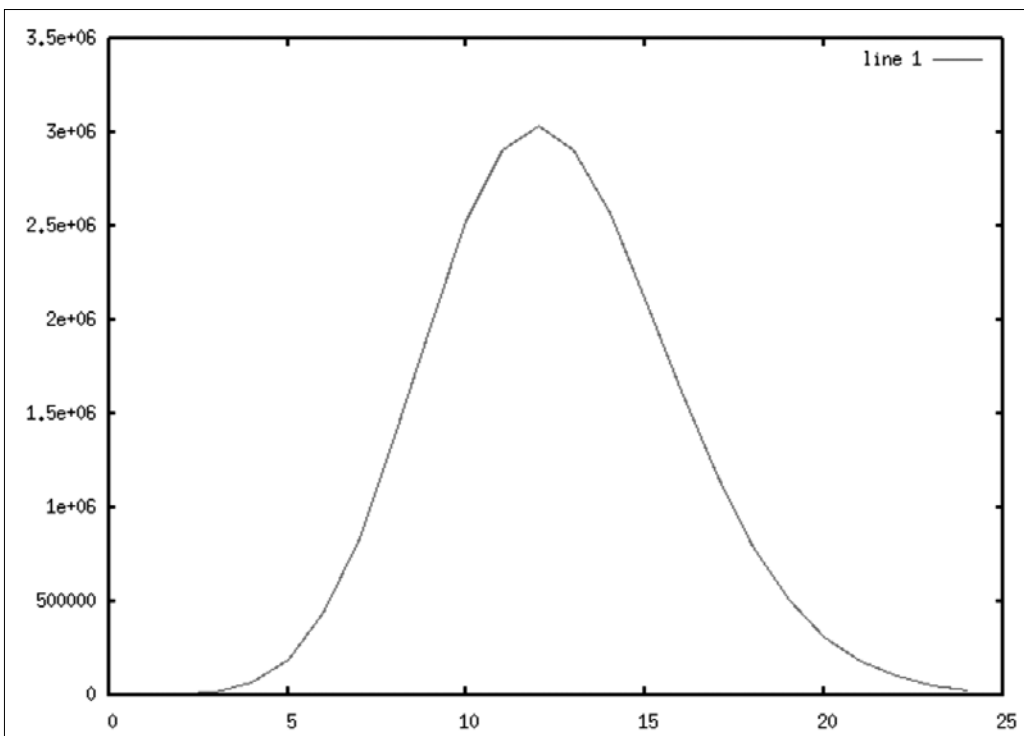

Figure 3.
Estimated call initiation per hour in the Hungary

aggregate value, it is distributed back to telecommunication service providers, to smaller demand values.

Our final conclusion is that for voice call establishment, the ENUM (DNS) requirements for the Hungarian population in a converged network could easily be met by current server computer hardware and software. The technical problems that were shown in the introduction are not relevant in Hungary, so ENUM related services could be introduced and be part of everyday practice. The Hungarian telecommunication industry can firmly build on ENUM technology and utilize the advantages of this new opportunity.

5. Summary

The article is a summary of performance measurement results that were obtained during testing different DNS servers loading with predefined ENUM structures. Several parameters were identified that affect the performance of domain name resolution between E.164 phone numbers and records in e164.arpa domain.

Our conclusions of the measurements are the following: high quality ENUM resolution can be provided for a Hungarian sized population with PC category servers and open-source software packages; ENUM resolution primarily depends on the geographical distance between the caller and the recipient; higher ENUM DNS resolution demand can be addressed with clustering for bigger populations.

The technical conditions and practical experiences to introduce ENUM are available, the new convergent services will appear soon.

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