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Using E.164 numbers with the Session Initiation Protocol (SIP)

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Abstract

There are a number of contexts in which telephone numbers are employed by Session Initiation Protocol (SIP) applications, many of which can be addressed by ENUM. Although SIP was one of the primary applications for which ENUM was created, there is nevertheless a need to define procedures for integrating ENUM with SIP implementations. This document illustrates how the two protocols might work in concert, and clarifies the authoring and processing of ENUM records for SIP applications. It also provides guidelines for instances in which ENUM, for whatever reason, cannot be used to resolve a telephone number.

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1. Introduction

ENUM (E.164 Number Mapping, RFC 3761 [1]) is a system that uses DNS (Domain Name Service, RFC 1034 [4]) in order to translate certain telephone numbers, like '+12025332600', into URIs (Uniform Resource Identifiers, RFC 2396 [9]), like 'sip:user@sipcarrier.com'. ENUM exists primarily to facilitate the interconnection of systems that rely on telephone numbers with those that use URIs to route transactions. E.164 [10] is the ITU-T standard international numbering plan, under which all globally-reachable telephone numbers are organized.

SIP (Session Initiation Protocol, RFC 3261 [2]) is a text-based application protocol that allows two endpoints in the Internet to discover one another in order to exchange context information about a session they would like to share. Common applications for SIP include Internet telephony, instant messaging, video, Internet gaming, and other forms of real-time communications. SIP is a multi-service protocol capable of initiating sessions involving different forms of real-time communications simultaneously.

The most widespread application for SIP today is Voice-over-IP (VoIP). As such, there are a number of cases in which SIP applications are forced to contend with telephone numbers. Unfortunately, telephone numbers cannot be routing in accordance with the traditional DNS resolution procedures standardized for SIP (see [14]), which rely on SIP URIs. ENUM provides a method for translating E.164 numbers into URIs, including potentially SIP URIs. This document therefore provides an account of how SIP can handle telephone numbers by making use of ENUM. Guidelines are proposed for the authoring of the DNS records used by ENUM, and for client-side processing once these DNS records have been received.

The guidelines in this document are oriented towards authoring and processing ENUM records specifically for SIP applications. These guidelines assume that the reader is familiar with Naming Authority Pointer (NAPTR) records (RFC 3403 [6]) and ENUM (RFC 3761 [1]). Only those aspects of NAPTR record authoring and processing that have special bearing on SIP, or that require general clarification, are covered in this document; these procedures do not update or override the NAPTR or ENUM core documents.

Note that the ENUM specification has undergone a revision shortly before the publication of this document, driven by the update of the NAPTR system described in RFC 2915 [12] to the Dynamic Delegation Discovery System (DDDS) family of specifications (including RFC 3403). This document therefore provides some guidance for handling records designed for the original RFC 2916 [16].

The remainder of this document is organized as follows: Section 3 suggests general behavior for SIP user agents that encounter telephone numbers; Section 4 provides an overview of the intersection of SIP and ENUM; proposed normative guidelines for ENUM record authoring and processing in the context of SIP are described in Section 5, and Section 6 respectively; some considerations relevant to the revision of RFC 2916 are given in Section 7.

2. Terminology

In this document, the key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" are to be interpreted as described in RFC 2119 [3] and indicate requirement levels for compliant SIP implementations.

3. Handling Telephone Numbers in SIP

There are a number of reasons why a user might want to initiate a SIP request that targets an E.164 number. One common reason is that the user is calling from the PSTN through a PSTN-SIP gateway; such gateways usually map routing information from the PSTN directly on to SIP signaling. Or a native SIP user might intentionally initiate a session addressed to an E.164 number - perhaps because the target user is canonically known by that number, or the originator's SIP user agent only supports a traditional numeric telephone keypad. A request initially targeting a conventional SIP URI might also be redirected to an E.164 number. In most cases, these are requests for a telephony session (voice communication), though numerous other services are also reached through telephone numbers (including instant messaging services).

Unlike a URI, a telephone number does not contain a host name, or any hints as to where one might deliver a request targeting a telephone number on the Internet. While SIP user agents or proxy servers could be statically provisioned with a mapping of destinations corresponding to particular telephone numbers or telephone number ranges, considering the size and complexity of a complete mapping, it would be preferable for SIP user agents to be able to query as needed for a destination appropriate for a particular telephone number.

In such cases a user agent might use ENUM to discover a URI associated with the E.164 number - including a SIP URI. URIs discovered through ENUM can then be used normally to route SIP requests to their destination. Note that support for the NAPTR DNS resource record format is specified for ordinary SIP URI processing in [14], and thus support for ENUM is not a significant departure from baseline SIP DNS routing.

Most of the remainder of this document provides procedures for the use of ENUM, but a few guidelines are given in the remainder of this section for cases in which ENUM is not used, for whatever reason.

If a user agent is unable to translate an E.164 number with ENUM, it can create a type of SIP Request-URI that contains a telephone number. Since one of the most common applications of SIP is telephony, a great deal of attention has already been devoted to the representation of telephone numbers in SIP. In particular, the tel URL RFC 2806 [8] has been identified as a way of carrying telephone routing information within SIP. A tel URL usually consists of the number in E.164 format preceded by a plus sign, e.g.,: tel:+12025332600. This format is so useful that it has been incorporated into the baseline SIP specification; the user portion of a SIP URI can contain a tel URL (without the scheme string, like sip:+12025332600@carrier.com;user=phone). A SIP proxy server might therefore receive a request from a user agent with a tel URL in the Request-URI; one way in which the proxy server could handle this sort of request is by launching an ENUM query itself, and proxying the SIP request in accordance with the returned ENUM records.

In the absence of support for ENUM, or if ENUM requests return no records corresponding to a telephone number, local policy can be used to determine how to forward SIP requests with an E.164 number in the Request-URI. Frequently, such calls are routed to gateways that interconnect SIP networks with the PSTN. These proxy server policies might be provisioned dynamically with routing information for telephone numbers by TRIP [15]. As a matter of precedence, SIP user agents should attempt to translate telephone numbers to URIs with ENUM, if implemented, before creating a tel URL, and deferring the routing of this request to a SIP proxy server.

4. Design Principles

Although the applicability of ENUM to SIP has always been clear, the exact way in which the two should cooperate has been a subject of some controversy. How many SIP URIs should appear in ENUM, what kind of URIs they are, whether or not the "service" field of NAPTR records should contain capability information - numerous questions have arisen around the authoring, and interpretation of ENUM records for SIP consumers. The following, then, is a statement of the particular philosophy that has motivated the recommendations in this document:

> Address-of-record SIP URIs appear in ENUM, not contact address URIs. Roughly speaking, an address-of-record is the canonical identity of a SIP user - it usually appears in the From field of SIP requests sent by that user; a contact address is the URI of a device. The process of registration in SIP (using the REGISTER method), for example, temporarily binds the contact address of a device to the address-of-record of a user. A DNS record has a long time-to-live when compared with the timeframe of SIP registrations. The availability of an address-of-record also transcends the availability of any single device. ENUM is more suitable for representing an long-term identity than the URI of any device with which a user is temporarily associated. If ENUM were purposed to map to specific devices, it would be better to translate telephone numbers to IPv4 addresses than to URIs (which express something richer).
>
> SIP URIs in ENUM do not convey capability information. SIP has its own methods for negotiating capability information between user agents (see SDP [13], the use of Require/Supported to negotiate extensions in RFC 3261, and callee capabilities [11]); providing more limited capability information within ENUM is at best redundant and at worst potentially misleading to SIP's negotiation system. Also, addresses-of-record do not have capabilities (only devices registered under an address-of-record have actual capabilities), and putting contact addresses in ENUM is not recommended.
>
> Only one SIP URI, ideally, appears in an ENUM record set for a telephone number. While it may initially seem attractive to provide multiple SIP URIs that reach the same user within ENUM, if there are multiple addresses at which a user can be contacted, considerably greater flexibility is afforded if multiple URIs are managed by a SIP location service that is identified by a single record in ENUM. Behavior for parallel and sequential forking in SIP, for example, is better managed in SIP than in a set of ENUM records.

User agents, rather than proxy servers, should process ENUM records. The assumptions underlying the processing of NAPTR records dictate that the ENUM client knows the set of enumservices supported by the entity that is attempting to communicate. A SIP proxy server is unlikely to know the enumservices supported by the originator of a SIP request.

5. Authoring NAPTR Records for SIP

This document makes no assumptions about who authors NAPTR records (service providers or end users), nor about any mechanisms by which a record, once it is authored, may be uploaded to the appropriate DNS servers. Authorship in the context of this document concerns only the processes by which the NAPTR records themselves are constructed.

There are a few general guidelines which are applicable to the authoring of DNS records that should be considered by the authors of ENUM NAPTR record sets. The most important is that authors SHOULD keep record sets relatively small - DNS is not optimized for the transference of large files. Having five or six NAPTR records is quite reasonable, but policies that encourage records sets of hundreds of NAPTR records are not appropriate. Also, DNS records are relatively permanent; authors SHOULD NOT use ENUM NAPTR records to express relationships between E.164 numbers and URIs that potentially exist for only a short time. DNS is most scalable when it can assume records will be valid for a reasonable length of time (at least several hours).

5.1. The Service Field

The Service field of a NAPTR record (per RFC 3403) contains a string token that designates the protocol or service associated with a particular record (and which imparts some inkling of the sort of URI that will result from the use of the record). ENUM [1] requires the IANA registration of service fields known as "enumservices".

An enumservice for SIP has been developed in the ENUM working group (see [7]) which uses the format 'E2U+sip' to designate that a SIP address-of-record appears in the URI field of a NAPTR record. It is strongly RECOMMENDED that authors of NAPTR records use the 'E2U+sip' service field whenever the regexp contains a SIP address-of-record URI.

5.2. Creating the Regular Expression: Matching

The authorship of the regular expression (henceforth regexp) in a NAPTR record intended for use by ENUM is vastly simplified by the absence of an antecedent in the substitution (i.e., the section between the first two delimiters). It is RECOMMENDED that implementations use an exclamation point as a delimiter, since this is the only delimiter used throughout the ENUM core specification.

When a NAPTR record is processed, the expression in the antecedent is matched against the starting string (for ENUM, the telephone number) to assist in locating the proper record in a set; however, in ENUM applications, since the desired record set is located through a reverse resolution in the e164.arpa domain that is based on the starting string, further analysis of the starting string on the client side will usually be unnecessary. In such cases, the antecedent of the regular expression is commonly 'greedy' - it uses the regexp '^.*$', which matches any starting string. Some authors of ENUM record sets may want to use the full power of regexps, and create non-greedy antecedents; the DDDS standard requires that ENUM resolvers support these regexps when they are present. For providing a trivial mapping from a telephone number to a SIP URI, the use of a greedy regexp usually suffices.

Example: "!^.*$!sip:user@example.com!"

Note that when the antecedent of the regexp is greedy, this does not mean that the replacement field in NAPTR records provides a viable alternative to authoring with a regexp. Authors of NAPTR records for ENUM MUST NOT use the replacement field in records with an 'E2U+sip' service field.

5.3. Creating the Regular Expression: The URI

The consequent side of a regexp contains a URI; NAPTR records that are intended to be used for session initiation (including SIP telephony) SHOULD use a SIP URI. While this may not sound especially controversial at first hearing, there are other sorts of URIs that might be considered appropriate for SIP applications: 'tel' URIs, 'im' or 'pres' URIs, or others that describe specific services that might be invoked through SIP are all potentially candidates. While the use of these URIs might seem reasonable under some circumstances, including these in NAPTR records rather than SIP URIs could weaken the proper composition of services and negotiation of capabilities in SIP.

It is RECOMMENDED that authors of ENUM records should always use the SIP or SIPS URI scheme when the service field is 'E2U+sip', and the URIs in question MUST be addresses-of-record, not contact addresses.

Users of SIP can register one or more contact addresses with a SIP registrar that will be consulted by the proxy infrastructure of an administrative domain to contact the end user when requests are received for their address-of-record. Much of the benefit of using a URI comes from the fact that it represents a logical service associated with a user rather than a device - indeed, if ENUM needs to target specific devices rather than URIs, then a hypothetical 'E2IPv4+sip' enumservice would be more appropriate.

5.4. Setting Order and Preference amongst Records

For maximal compatibility authors of ENUM records for SIP SHOULD always use the same order value for all NAPTR records in an ENUM record set. If relative preference among NAPTR records is desirable, it should be expressed solely with the preference field.

5.5. Example of a Well-Formed ENUM NAPTR Record Set for SIP

```
$ORIGIN 0.0.6.2.3.3.5.2.0.2.1.e164.arpa.
  IN NAPTR 100 10 "u" "E2U+sip"    "!^.*$!sip:user@example.com!"     .
  IN NAPTR 100 20 "u" "E2U+mailto" "!^.*$!mailto:info@example.com!"  .
```

6. Processing ENUM Records

These guidelines do not by any means exhaustively describe the NAPTR algorithm or the processing of NAPTR records; implementers should familiarize themselves with the DDDS algorithm and ENUM before reviewing this section.

Although in some cases, ENUM record sets will consist only a single 'E2U+sip' record, this section assumes that integrators of ENUM and SIP must be prepared for more complicated scenarios - however, just because we recommend that clients should be generous in what they receive, and try to make sense of potentially confusing NAPTR records, that does not mean that we recommend any of the potentially troublesome authoring practices that make this generosity necessary.

6.1. Contending with Multiple SIP records

If an ENUM query returns multiple NAPTR records that have a service field of 'E2U+sip', or other service field that may be used by SIP (such as 'E2U+pres', see [17]) the ENUM client must first determine whether or not it should attempt to make use of multiple records or select a single one. The pitfalls of intentionally authoring ENUM record sets with multiple NAPTR records for SIP are detailed above in Section 4.

If the ENUM client is a user agent, then at some point a single NAPTR record must be selected to serve as the Request-URI of the desired SIP request. If the given NAPTR records have different preferences, the most preferred record SHOULD be used. If two or more records share most preferred status, the ENUM client SHOULD randomly determine which record will be used, though it MAY defer to a local policy that employs some other means to select a record.

If the ENUM client is a SIP intermediary that can act a redirect server, then it SHOULD return a 3xx response with more than one Contact header field corresponding to the multiple selected NAPTR records in an ENUM record set. If the NAPTR records have different preferences, then 'q' values may be used in the Contact header fields to correspond to these preferences. Alternatively, the redirect server MAY select a single record in accordance with the NAPTR preference fields (or randomly when no preference is specified) and send this resulting URI in a Contact header field in a 3xx response.

Otherwise, if the ENUM client is a SIP intermediary that can act as a proxy server, then it MAY fork the request when it receives multiple appropriate NAPTR records in an ENUM record set. Depending on the relative precedence values of the NAPTR records the proxy may wish to fork sequentially or in parallel. However, the proxy MUST build a route set from these NAPTR records that consists exclusively of SIP or SIPS URIs, not other URI schemes. Alternatively, the proxy server MAY select a single record in accordance with the NAPTR preference fields (or randomly when no preference is specified, or in accordance with local policy) and proxy the request with a Request-URI corresponding to the URI field of this NAPTR record - though again, it MUST select a record that contains a SIP or SIPS URI. Note that there are significant limitations that arise if a proxy server processes ENUM record sets instead of a user agent, and that therefore it is RECOMMENDED that SIP network elements act as redirect servers rather than proxy servers after performing an ENUM query.

6.2. Processing the Selected NAPTR Record

Obviously, when an appropriate NAPTR record has been selected, the URI should be extracted from the regexp field. The URI is between the second and third exclamation points in the string. Once a URI has been extracted from the NAPTR record, it SHOULD be used as the Request-URI of the SIP request for which the ENUM query was launched.

SIP clients should perform some sanity checks on the URI, primarily to ensure that they support the scheme of the URI, but also to verify that the URI is well-formed. Clients MUST at least verify that the Request-URI does not target themselves.

Once an address-of-record has been extracted from the selected NAPTR record, clients follow the standard SIP mechanisms (see [14]) for determining how to forward the request. This may involve launching subsequent NAPTR or SRV queries in order to determine how best to route to the domain identified by an address-of-record; clients however MUST NOT make the same ENUM query recursively (if the URI returned by ENUM is or contains a tel URL, see [8]).

Note that SIP requests based on the use of NAPTR records may fail for any number of reasons. If there are multiple NAPTR records relevant to SIP present in an ENUM record set, then after a failure has occurred on an initial attempt with one NAPTR record, SIP user agents MAY try their request again with a different NAPTR record from the ENUM record set.

7. Compatibility with RFC 2916

The ENUM specification is currently undergoing a revision in the ENUM WG. The new specification, RFC 3761 [1], is based on the Dynamic Delegation Discovery System [5] revision to the NAPTR resource record specified in RFC 2915 [12]. For the most part, DDDS is an organizational revision that makes the algorithmic aspects of record processing separable from any underlying database format (such as the NAPTR DNS resource record).

The most important revision in RFC 3761 is the concept of enumservices. The original ENUM specification, RFC 2916, specified a number of "service" values that could be used for ENUM, including the "sip+E2U" service field. RFC 3761 introduces an IANA registration system with new guidelines for the registration of enumservices, which are no longer necessarily divided into discreet "service" and "protocol" fields, and which admit of more complex structures. In order to differentiate enumservices in RFC 3761 from those in RFC 2916, the string "E2U" is the leading element in an enumservice field, whereas by RFC 2916 it was the trailing element.

An enumservice for SIP addresses-of-record is described in [7]. This enumservice uses the enumservice field "E2U+sip". RFC 3761-compliant authors of ENUM records for SIP MUST therefore use the "E2U+sip" enumservice field instead of the "sip+E2U" field. For backwards compatibility with existing legacy records, however, the 'sip+E2U' field SHOULD be supported by an ENUM client that support SIP.

Also note that the terminology of DDDS differs in a number of respects from the initial NAPTR terminology in RFC 2916. DDDS introduces the concept of an Application, an Application Specific String, a First Well Known Rule, and so on. The terminology used in this document is a little looser (it refers to a 'starting string', for example, where 'Application Specific String' would be used for DDDS). The new terminology is reflected in RFC 3761.

8. Security Considerations

DNS does not make policy decisions about the records that it shares with an inquirer. All DNS records must be assumed to be available to all inquirers at all times. The information provided within an ENUM record set must therefore be considered to be open to the public - which is a cause for some privacy considerations.

Ordinarily, when you give someone your telephone number, you don't expect that they will be able to trivially determine your full name and place of employment. If, however, you create a NAPTR record for use with ENUM that maps your telephone number to a SIP URI like 'julia.roberts@example.com', expect to get a lot of calls from excited fans.

Unlike a traditional telephone number, the target of a SIP URI may require that callers provide cryptographic credentials for authentication and authorization before a user is alerted. In this respect, ENUM in concert with SIP can actually provide far greater protection from unwanted callers than the existing PSTN, despite the public availability of ENUM records.

Users of ENUM who are nevertheless uncomfortable with revealing their names may, since identities on the Internet are not exactly at a premium, publish a less revealing SIP URI, like 'sip:anonymous00045@example.com' or even 'sip:anonymous00045@anonymous-redirector.example.org', which could in turn point to their internal URI.

An analysis of threats specific to the dependence of ENUM on the DNS, and the applicability of DNSSEC [18] to these, is provided in [1].

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Appendix A. Acknowledgments

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