PacketCable™

ENUM Server Address Resolution Specification

PKT-SP-ENUM-SRV-I01-100630

ISSUED

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Key to Document Status Codes

Work in Progress	An incomplete document, designed to guide discussion and generate feedback that may include several alternative requirements for consideration.
Draft	A document in specification format considered largely complete, but lacking review by Members and vendors. Drafts are susceptible to substantial change during the review process.
Issued	A stable document, which has undergone rigorous member and vendor review and is suitable for product design and development, cross-vendor interoperability, and for certification testing.
Closed	A static document, reviewed, tested, validated, and closed to further engineering change requests to the specification through CableLabs.

Trademarks

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1 INTRODUCTION

1.1 Introduction and Purpose

This specification defines the signaling protocols that can be used by a Routing Function to obtain routing information from an ENUM-SIP Addressing Server. A Routing Function uses the procedures defined here to query the ENUM-SIP Addressing Server to resolve the Address of Record of a VoIP subscriber into the routing information required to properly route a dialog-initiating SIP request to that user. These procedures allow cable operators to consolidate all routing information for SIP-based services in the ENUM-SIP Addressing Server. For example, the ENUM-SIP Addressing Server can resolve an AOR that belongs to a peer network into both the egress route from the home network, and the ingress route into the peer network. The ENUM-SIP Addressing Server routing database can be portability corrected to eliminate the need for separate Local Number Portability database dips.

This specification defines two functional entities; an ENUM-SIP Addressing Server and a Routing Function. The Routing Function represents the SIP proxy elements defined for PacketCable networks, such as the CMS in PacketCable 1.5, and the CSCF, BGCF and IBCF in PacketCable 2.0. This specification defines two alternate address resolution protocols between the Routing Function and the ENUM-SIP Addressing Server; DNS ENUM as specified in [RFC 3761], and Session Initiation Protocol (SIP) as specified in [RFC 3261]). It describes how the ENUM-SIP Addressing Server uses the data model defined in [ENUM-PROV] to satisfy address resolution queries, and how the Routing Function uses the query response data to route SIP requests. Finally, this specification defines other requirements associated with the interfaces between the Routing Function and the ENUM-SIP Addressing Server, including transport, security, and fault isolation and recovery.

1.2 Requirements

Throughout this document, the words that are used to define the significance of particular requirements are capitalized. These words are:

"MUST"	This word means that the item is an absolute requirement of this specification.
"MUST NOT"	This phrase means that the item is an absolute prohibition of this specification.
"SHOULD"	This word means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
"SHOULD NOT"	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
"MAY"	This word means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

2 REFERENCES

2.1 Normative References

In order to claim compliance with this specification, it is necessary to conform to the following standards and other works as indicated, in addition to the other requirements of this specification. Notwithstanding, intellectual property rights may be required to use or implement such normative references.

[RFC 1034] IETF RFC 1034/STD0013, Domain names - concepts and facilities, November 1987.

[RFC 2560] IETF RFC 2560 X.509, Internet Public Key Infrastructure Online Certificate Status Protocol - OCSP, June 1999.

[RFC 2671] IETF RFC 2671, Extension Mechanisms for DNS (EDNS0), 1999.

[RFC 3261] IETF RFC 3261, SIP: Session Initiation Protocol, June 2002.

[RFC 3263] IETF RFC 3263, Session Initiation Protocol (SIP): Locating SIP Servers, June 2002.

[RFC 3761] IETF RFC 3761, The E.164 to Uniform Resource Identifiers (URI) Dynamic Delegation Discovery System (DDDS) Application (ENUM), April 2004.

[RFC 3764] IETF RFC 3764, ENUMSERVICE registration for Session Initiation Protocol (SIP) Addresses-of-Record, April 2004.

[RFC 3966] IETF RFC 3966, The tel URI for Telephone Numbers H. Schulzrinne, December 2004.

[RFC 4415] IETF RFC 4415. IANA Registration for Enumservice Voice R. Brandner, February 2006.

[RFC 4694] IETF RFC 4694, Number Portability Parameters for the tel URI, October 2006.

[SEC1.5] PacketCable 1.5 Security Specification, PKT-SP-SEC1.5-I03-090624, June 24, 2009, Cable Television Laboratories, Inc.

2.2 Informative References

This specification uses the following informative references.

[ENUM-PROV] ENUM Server Provisioning Specification, PKT-SP-ENUM-PROV-I04-100415, April 15, 2010, Cable Television Laboratories, Inc.

[RFC 3402] IETF RFC 3402, Dynamic Delegation Discovery System (DDDS) Part Two: The Algorithm, October 2002.

[RFC 3403] IETF RFC 3403, Dynamic Delegation Discovery System (DDDS), Part Three: The Domain Name System (DNS) Database, October 2002.

[RFC 4114] IETF RFC 4114, E.164 Number Mapping for the Extensible Provisioning Protocol (EPP), June 2005.

2.3 Reference Acquisition

- Cable Television Laboratories, Inc., 858 Coal Creek Circle, Louisville, CO 80027; Phone +1-303-661-9100; Fax +1-303-661-9199; Internet: http://www.cablelabs.com/
- Internet Engineering Task Force (IETF) Secretariat, 48377 Fremont Blvd., Suite 117, Fremont, California 94538, USA, Phone: +1-510-492-4080, Fax: +1-510-492-4001, http://www.ietf.org.

3 TERMS AND DEFINITIONS

This specification uses the terms defined in the following table.

Egress SBE	An SBE through which internally originated, outbound session signaling is sent.
Ingress SBE	An SBE through which externally originated, incoming session signaling is received.
Point-of-Interconnect (POI)	The geographic location where two networks interconnect and exchange traffic. Typically, one or more SBE(s) are allocated to secure the POI at the session peering level.
Signaling path Border Element (SBE)	Provides signaling-related functions. Typically deployed on a domain's border as a Back-to-Back SIP User Agent (B2BUA), SBEs provide signaling functions such as protocol inter-working, identity and topology hiding, and call admission control.

4 ABBREVIATIONS

This specification uses the following abbreviations:

AOR	Address of Record
BGCF	Breakout Gateway Control Function
CMS	Call Management System
CRL	Certificate Revocation Lists
CSCF	Call Session Control Function
DNS	Domain Name System
ENUM	Telephone Number Mapping
ESPP	ENUM Server Provisioning Protocol
IBCF	Interconnection Border Control Function
LNP	Local Number Portability
LRN	Local Routing Number
MGC	Media Gateway Controller
NAPTR	Naming Authority Pointer
NCS	Network Call Signaling
OCSP	Online Certificate Status Protocol
PSTN	Network Call Signaling
Regx	Regular Expression
Rn	Routing Number
RR	Resource Record
SA	Service Area
SBE	Signaling path Border Element
S-CSCF	Serving CSCF
SIP	Session Initiation Protocol
SRV	Server

SSP	SIP Service Provider
TCP	Transmission Control Protocol
TLS	Transport Layer Security
TNREnd	Telephone Number Range End
TNRStrt	Telephone Number Range Start
UDP	User Datagram Protocol
URI	Uniform Resource Identifier

5 OVERVIEW

This specification, together with the PacketCable ENUM Server Provisioning Specification [ENUM-PROV], defines a standard architecture and a set of protocols to support the CableLabs Registry Service. The PacketCable ENUM Server Provisioning Specification [ENUM-PROV] defines the requirements on the ENUM Resolution Server to provision routing data in the ENUM-SIP Addressing Server. It also defines a data model to represent the routing data in the ENUM-SIP Addressing Server. This, the PacketCable ENUM Server Address Resolution Specification, builds upon and extends those requirements by specifying how a Routing Function obtains and uses the routing information from the ENUM-SIP Addressing Server.

5.1 Reference Architecture

Figure 1 shows the pkt-espp-1 and pkt-espp-2 reference points that are used by the ENUM Resolution Server to push routing data into the ENUM-SIP Addressing Server as defined in [ENUM-PROV]. This specification defines a new component called the Routing Function, which represents SIP routing entities in a PacketCable 1.5 network such as a CMS and MGC, and in a PacketCable 2.0 network such as a CSCF, IBCF, and BGCF. This specification also adds two new reference points which the Routing Function can use to obtain address resolution data from the ENUM-SIP Addressing Server:

- pkt-esrv-1: Address resolution is supported using DNS ENUM.
- pkt-esrv-2: Address resolution is supported using SIP. The ENUM-SIP Addressing Server plays the role of a SIP Redirect Server in support of this interface.

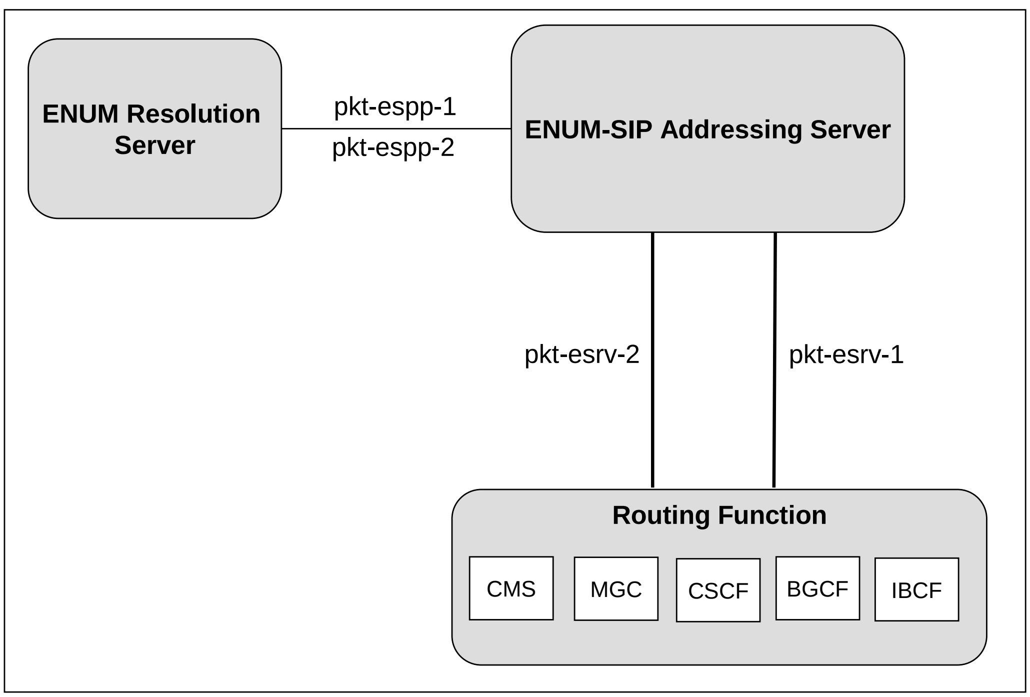

Figure 1 - Address Resolution Reference Architecture

5.2 Routing Data Flow

The PacketCable ENUM Server Provisioning Specification [ENUM-PROV] defines a data model that is used to represent the call routing data for an operator's network. A simplified view of this data model is shown in Figure 2. The data model defines "identity" objects such as LRN, TNRange, and Public Identity that represent the target destination entity for the call (e.g., the Public Identity object represents the identity of a called user). The data model links these identity objects via a Service Area object to one or more Route objects that represent the routes to that identity. Each Route object is linked to one or more NAPTR objects which contain the actual routing information that can be used to route dialog-initiating SIP requests to that identity. (Please refer to [ENUM-PROV] for the formal definition of the ESPP data model.)

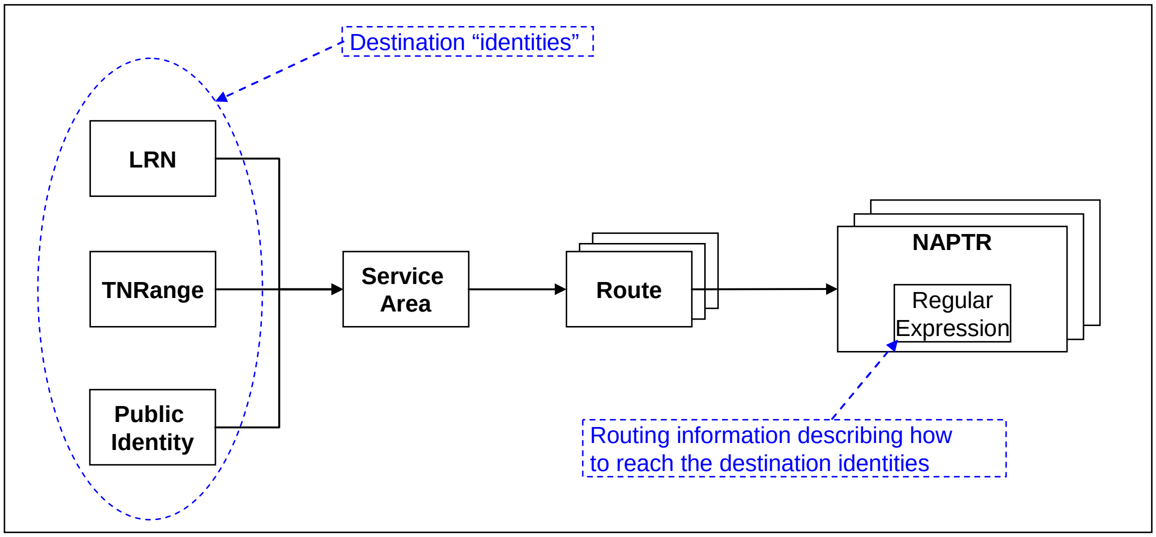

Figure 2 - Simplified ESPP Data Model

As shown in Figure 2, the routing information within a NAPTR object is stored in the form of a Regular Expression. The Regular Expression mechanism provides a programmatic means to express the routing data in many different ways. For example, the routing data could be expressed as:

- The host portion of a URI that identifies the ingress domain of a peer network.
- URI parameters, such as trunk group parameters, that are understood by the network SIP Routing Proxies based on locally configured data.
- SIP methods and headers such as an INVITE Route header that contain routing information.

This specification does not mandate a specific form for carrying the routing data within the Regular Expression construct. Rather, it assumes that the Regular Expression encodes the routing data in a way that is understood by the Routing Function. This is illustrated in Figure 3; the form of the routing data contained in the Regular Expression provisioned at [1] and retrieved at [2] is not specified, and whatever form is used is assumed to interwork with the SIP routing procedures configured in the Routing Function.

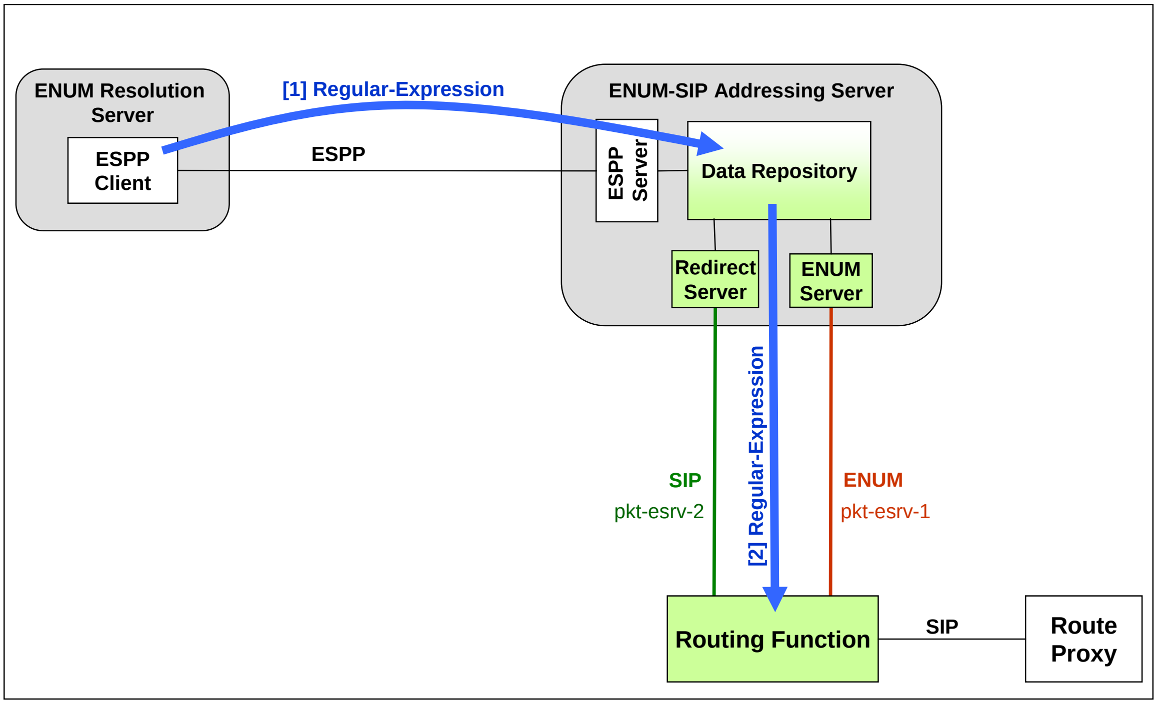

Figure 3 - Routing Data Flow

5.3 Description of Operation

5.3.1 Address Resolution using ENUM

Figure 4 shows the message flow when the Routing Function obtains routing information using ENUM via the pkt-esrv-1 interface.

To resolve an E.164 number into routing information, the ENUM Client located within the Routing Function builds an ENUM query which it sends via pkt-esrv-1 to the ENUM Server located within the ENUM-SIP Addressing Server. The ENUM Server fetches the routing information for the target E.164 number from the Data Repository, formats the data into an ENUM response, and returns the response via pkt-esrv-1 to the ENUM Client.

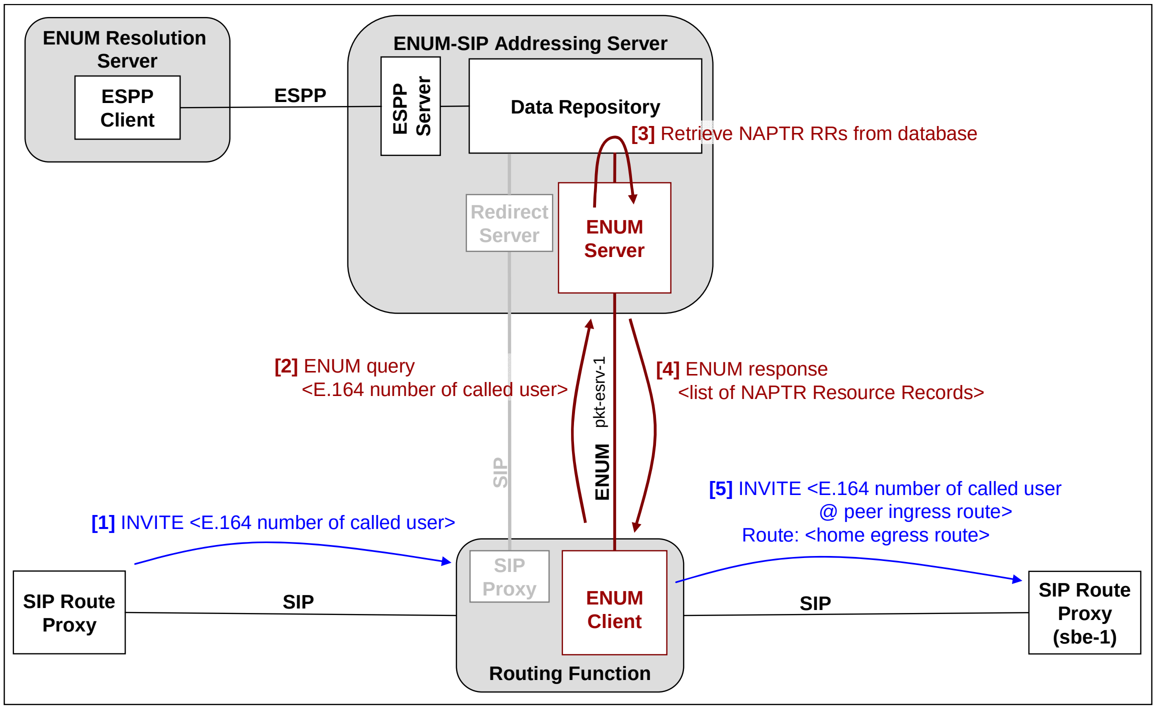

Figure 4 - Address Resolution using ENUM

1. The Routing Function receives [1] INVITE identifying the called user in the Request-URI. In the general case, the incoming request could be any SIP dialog-initiating request.

2. If the Request-URI received at [1] identifies a domain that the Routing Function is responsible for (e.g., the domain of the home network), then the Routing Function builds an ENUM query based on the contents of the Request-URI.

   Note: When the host portion of the received Request-URI identifies a domain that the Routing Function is not responsible for (e.g., the domain of a remote network), the action taken by the Routing Function is outside the scope of this specification.

   If the Request-URI contains a SIP URI identifying the E.164 number of the called user (as indicated by a leading '+' character in the user-part, and a "user=phone" URI parameter), then the Routing Function may need to obtain LNP routing information for the called user (the decision is based on local policy). If LNP data is obtained, and the called user's number is ported, and the ENUM-SIP Addressing Server is not portability corrected, then the Routing Function uses the LNP routing number to build the ENUM query. Otherwise, the Routing Function uses the called user's number to build the ENUM query.

   The Routing Function sends the resulting ENUM query to the ENUM-SIP Addressing Server at [2].

   The pkt-esrv-1 interface cannot be used to determine routing information for email-style URIs. If the Routing Function supports only the pkt-esrv-1 interface for address resolution, then the procedures used by the Routing Function to resolve email-style URIs are outside the scope of this specification.

3. On receiving the ENUM query at [2], the ENUM-SIP Addressing Server obtains the digit string from the query and uses it as a database key to retrieve the NAPTR RRs from the data repository at [3]. The ENUM-SIP Addressing Server first finds LRN, TNRange, or Public Identity object that matches the key, and then retrieves the NAPTR RRs linked to that object using the data model defined in [ENUM-PROV].

4. The ENUM-SIP Addressing Server returns the list of NAPTR RRs to the Routing Function in an ENUM response at [4].

5. On receiving [4], the Routing Function selects the NAPTR based on the order and preference, and retargets the incoming request received at [1] to the SIP URI specified by the NAPTR regular-expression field. The Routing Function also retrieves any nested header fields from the selected NAPTR RR (e.g., Route header), and adds them to the retargeted request. It then sends the retargeted request at [5] using normal SIP routing procedures.

5.3.2 Address Resolution using SIP

Figure 5 shows an example message flow when the Routing Function obtains routing information using SIP via the pkt-esrv-2 interface.

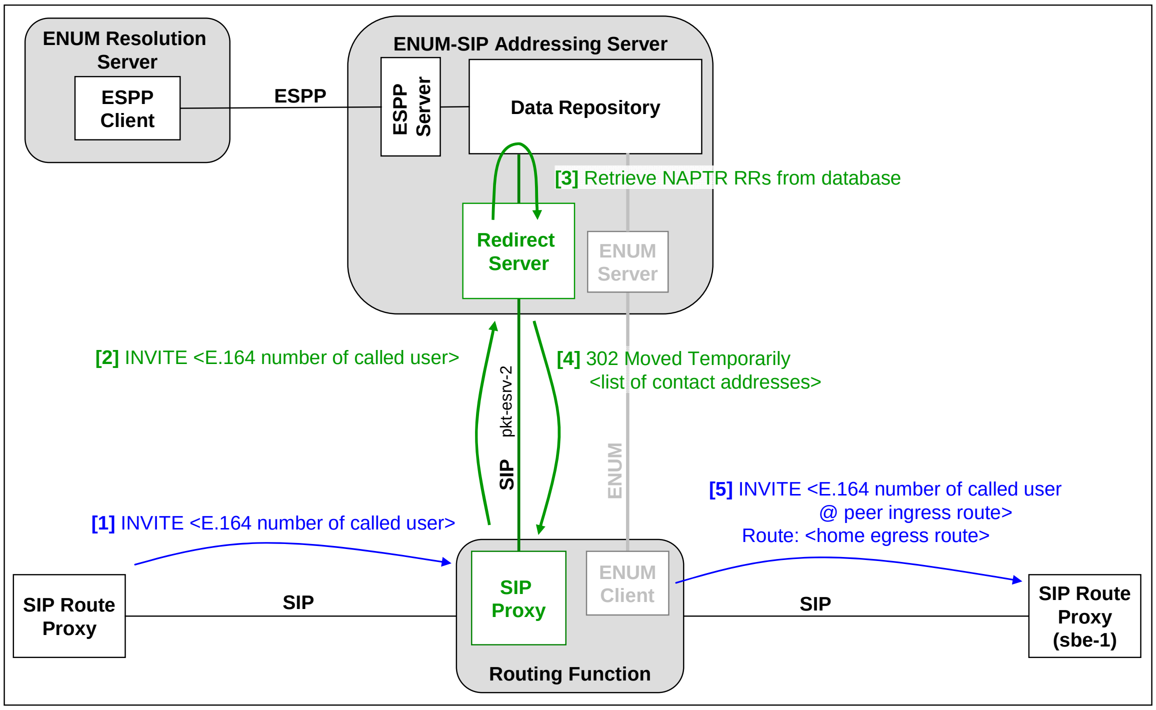

Figure 5 - Address Resolution using SIP

1. The Routing Function receives [1] INVITE identifying the called user in the Request-URI. In the general case, the incoming request could be any SIP dialog-initiating request.
2. The Routing Function proxies the incoming INVITE via pkt-esrv-2 to the ENUM-SIP Addressing Server at [2]. The Routing Function may need to manipulate the identity of the called user in the Request-URI before forwarding the request to the ENUM-SIP Addressing Server:
   - If the Request-URI received at [1] contains an email-style SIP URI, then it is sent to the ENUM-SIP Addressing Server without modification.
   - If the Request-URI received at [1] contains a SIP URI identifying an E.164 number (as indicated by a leading '+' character in the user-part, and a "user=phone" URI parameter), then the Routing Function may need to obtain LNP routing information for the called user (the decision is based on local policy). If LNP data is obtained, the Routing Function adds the data to the Request-URI using the Tel URI number-portability parameters 'npdi' and 'rn', as defined in [RFC 3966].
3. On receiving [2] INVITE request where the host portion of the Request-URI identifies a domain that the ENUM-SIP Addressing Server is responsible for (e.g., the domain of the home network), the ENUM-SIP Addressing Server obtains the target identity from the Request-URI, based on the form of the URI as follows:

- If the Request-URI received at [2] contains an email-style SIP URI, then the ENUM-SIP Addressing Server removes "sip:" service indicator, removes all URI parameters, and uses the resulting alpha-numeric string as a key into the database.
- If the Request-URI received at [2] contains a SIP URI identifying an E.164 number, then the ENUM-SIP Addressing Server simply uses the called user's E.164 number as the database key. However, if the data repository is not number-portability-corrected, then the ENUM-SIP Addressing Server uses either the E.164 number of the called user if the number is not ported, or the E.164 number contained in the 'rn' parameter if the number is ported, as the database key.

Note: When the host portion of the Request-URI identifies a domain the ENUM-SIP Addressing Server is not responsible for (e.g., the domain of a remote network), the action taken by the ENUM-SIP Addressing Server is outside the scope of this specification.

4. Once it has obtained the database key, the ENUM-SIP Sever retrieves the NAPTR RRs for that key from the data repository at [3].
   - If the database key is an alpha-numeric string as described in step-3 above, then the ENUM-SIP Addressing Server looks for a matching Public Identity.
   - If the database key is a digit string representing an E.164 number, then the ENUM-SIP Addressing Server looks for a matching LRN, TNRange, or Public Identity object, and retrieves the NAPTR RRs linked to the matching object.
5. The ENUM-SIP Addressing Server converts each NAPTR RR into a contact address as follows:
   - Use the NAPTR RR Regular Expression field to build a SIP URI.
   - Derive a contact address q-value from the NAPTR RR order and preference fields.

   The ENUM-SIP Addressing Server then returns the contact addresses to the Routing Function in a 302 (Moved Temporarily) response at [4].
6. On receiving [4], the Routing Function selects the contact address with the highest q-value, and retargets the Request-URI of the request received at [1] to the selected address. The Routing Function also retrieves any nested header fields from the selected contact address (e.g., Route header), and adds them to the retargeted request. It then sends the retargeted request at [5] using normal SIP routing procedures.

The Routing Function can use the pkt-esrv-2 interface to support address resolution of non-INVITE requests. Figure 6 shows an example message flow where the Routing Function receives a dialog-initiating SUBSCRIBE request. Note that the Routing Function has a choice on what message to send at [2]; it can proxy the incoming request received at [1] as shown in Figure 6, or it can always send an INVITE request at [2] independent of the request received at [1].

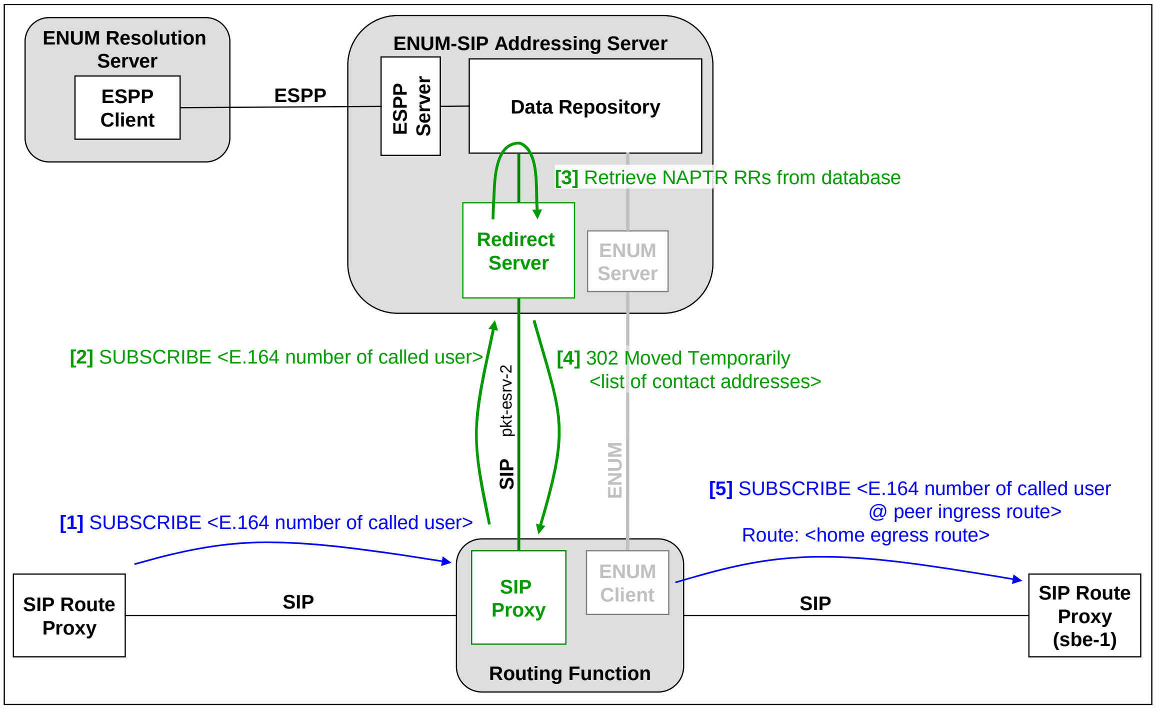

Figure 6 - Address Resolution for non-INVITE Requests

5.3.3 Routing Function Route Selection

Figure 7 shows an example peering configuration where MSO-A has two egress sites (Site-A and B) connected to two ingress sites in MSO-B (Site C and D). Each site contains some number 'n' SBEs. This peering arrangement creates 2*n possible routes for calls from MSO-A to MSO-B. Say MSO-A and MSO-B agree on the following routing priority:

1st priority: Site-A → Site-C

2nd priority: Site-B → Site-D

Also, MSO-A and B agree on a routing policy where all calls from MSO-A to MSO-B are load-balanced across the routes in Site A-C. If Site A-C fails (i.e., Site A-C has no active routes) then calls are load-balanced across the routes in Site B-D.

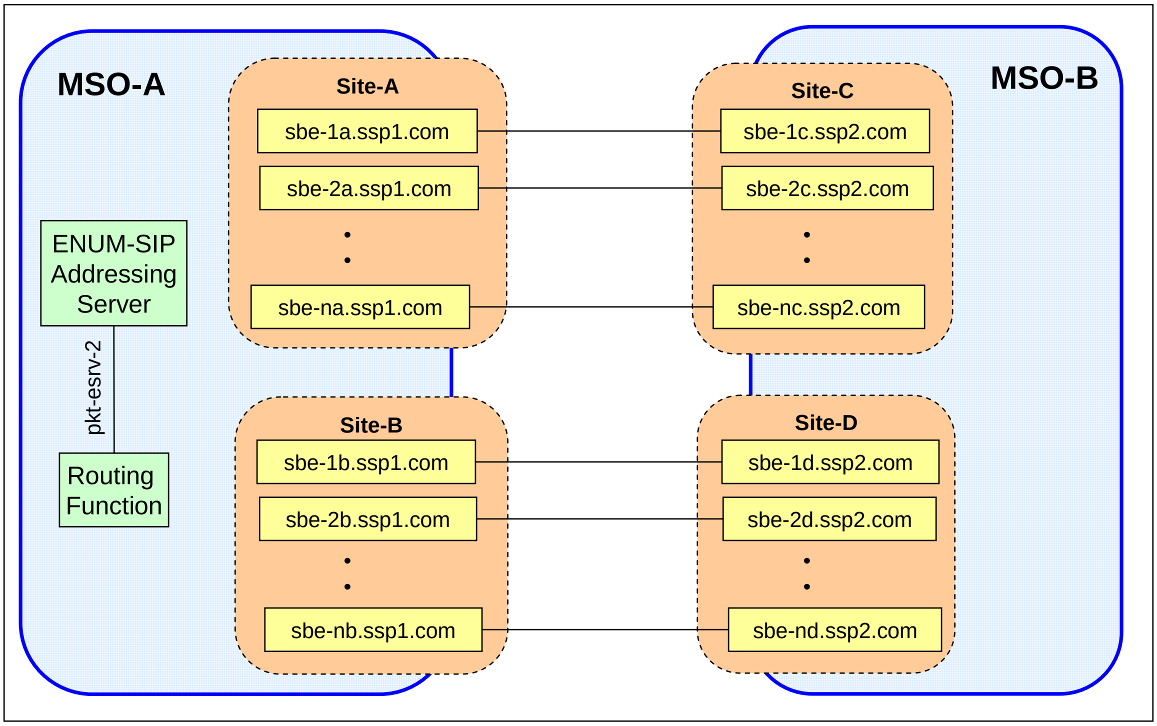

Figure 7 - Failover Example

For example, say a user in MSO-A dials +13035551212, which belongs to MSO-B. The Routing Function sends an INVITE to the ENUM-SIP Addressing Server via pkt-esrv-2. The ENUM-SIP Addressing Server returns a 302 (Moved Temporarily) response to the Routing Function containing the following list of contact URIs:

<sip:+13035551212@sbe-1c.ssp2.com;user=phone?Route=sip:sbe-1a.ssp1.com>;q=0.3

<sip:+13035551212@sbe-2c.ssp2.com;user=phone?Route=sip:sbe-2a.ssp1.com>;q=0.3

…

< sip:+13035551212@sbe-nc.ssp2.com;user=phone?Route=sip:sbe-na.ssp1.com>;q=0.3

<sip:+13035551212@sbe-1d.ssp2.com;user=phone?Route=sip:sbe-2b.ssp1.com>;q=0.1

<sip:+13035551212@sbe-2d.ssp2.com;user=phone?Route=sip:sbe-1b.ssp1.com>;q=0.1

…

<sip:+13035551212@sbe-nd.ssp2.com;user=phone?Route=sip:sbe-nb.ssp1.com>;q=0.1

The Routing Function simply selects the contact URI with the highest q-value. If the Routing Function has knowledge of the availability of the routes to the peer network, then it includes this information in the selection algorithm (i.e., don't select a contact URI associated with an unavailable route).

How traffic is distributed among multiple same-priority routes is governed by local policy. In our example, the operators want the traffic to be load-balanced across the same-priority routes within a site. This could be accomplished by configuring rules in the ENUM-SIP Addressing Server and Routing Function that govern the handling of same-priority routes. For example, the operator could configure the ENUM-SIP Addressing Server to place same-priority routes in random order within the 302 (Moved Temporarily) response, and configure the Routing Function to sequentially select the first route in the set of highest-priority routes identified in the response. Applying this to our example, the Routing Function selects the first available contact URI in the 302 response with a q-value of 0.3. If all the routes with a q-value of 0.3 are unavailable, then the Routing Function selects the first available contact URI with a q-value of 0.1. If the Routing Function receives an error response on the selected route, then it marks that route as unavailable, and selects a new route using the same selection algorithm.

Load-balancing could also be achieved by configuring the ENUM-SIP Addressing Server to return same-priority routes in the same order across successive 302 responses, and configure the Routing Function to randomly select a route from the set of highest-priority routes. Or, the Routing Function could actively monitor the traffic load of each route, and select the least-loaded route. In general, it is expected that the ENUM-SIP Addressing Server and the Routing Function provide a rich set of configuration options to govern route selection. However, the specific policies supported and used are outside the scope of this specification.

6 NORMATIVE REQUIRMENTS

This section contains the normative requirements to support the pkt-esrv-1 and pkt-esrv-2 interfaces. An ENUM-SIP Addressing Server that claims compliance with this specification MUST support at least one of these two interfaces. Likewise, a Routing Function that claims compliance with this specification MUST support at least one of these two interfaces.

6.1 Address Resolution

A Routing Function uses the services of the ENUM-SIP Addressing Server to resolve address information such as E.164 numbers or email-style SIP URIs into routing information required to route dialog-initiating SIP requests. This section describes these address resolution procedures for both SIP and ENUM.

6.1.1 Resolving an Address via ENUM

The pkt-esrv-1 interface carries ENUM resolution requests to convert telephone numbers into NAPTR RRs as described in [RFC 3761]. The basic procedure is illustrated in Figure 8.

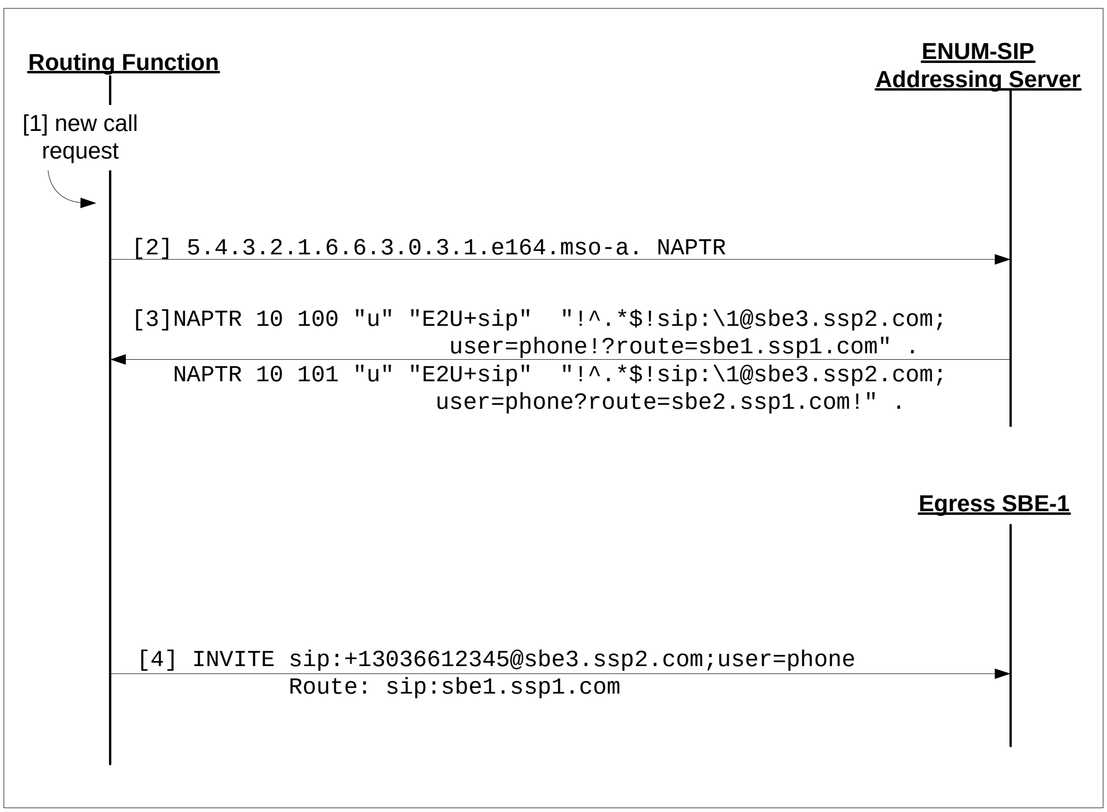

Figure 8 - ENUM Address Resolution Flow

As shown in Figure 8, the Routing Function receives an event at [1] such as a request to initiate a session that requires it to send a dialog-initiating SIP request to a remote user. The Routing Function obtains the E.164 address of the remote user, and sends an ENUM query at [2] to the ENUM-SIP Addressing Server to resolve that address into the routing information required to route the SIP request. On receiving the address resolution request [2], the ENUM-SIP Addressing Server consults the registry database to obtain the set of NAPTR RRs configured for the specified E.164 address, and returns NAPTR RRs to the Routing Function at [3]. In the example shown in Figure 8, two NAPTR RRs are returned. On receiving [3], the Routing Function selects the highest priority NAPTR RR that indicates SIP service, and uses the information in the NAPTR RR to populate the routing information in the outgoing INVITE at [4].

6.1.1.1 ENUM Processing for Routing Function

A Routing Function that supports the pkt-esrv-1 interface MUST conform to the requirements in this section. Additional Routing Function requirements specific to support of an ENUM Client are specified in Annex A.

On receiving an event such as a call initiation request that requires the sending of a dialog-initiating SIP request to a remote user, the Routing Function MUST perform the following procedure to obtain routing information for the SIP request:

1. Obtain the E.164 number for the target remote user. The means of obtaining the E.164 number are outside the scope of this specification, but could include deriving an E.164 number from a digit string received via NCS signaling as part of a call initiation request, or obtaining the E.164 number from the Request-URI of a received dialog-initiating SIP request such as INVITE or SUBSCRIBE. (Note that the Routing Function can obtain an E.164 number from a SIP URI only if it is responsible for the URI domain.)
2. If dictated by local policy, obtain Local Number Portability (LNP) information for the call, either by consulting an LNP database, or from received Tel URI number portability parameters as specified in [RFC 4694].
3. Build a domain-name key for the ENUM database query. As described in [RFC 3761], the domain-name is comprised of the E.164 number (address) to be resolved, and an alpha-numeric string that identifies the ENUM database zone used to resolve the address. The E.164 address to be resolved is either the target user’s E.164 number, or if the user’s E.164 number is ported and the ENUM-SIP Addressing Server database is not portability corrected, the E.164 number representing the LRN of the target user.

   The Routing Function MUST construct the query domain name key as follows:

   - Remove all non-digit characters from the E.164 number (including the '+' character),
   - Add a dot '.' character separator between each digit,
   - Reverse the order of the digits,
   - Append the alpha-numeric string identifying the ENUM zone (string is based on local policy).
4. Send an ENUM address resolution query containing the above domain-name key as specified in [RFC 3761] to the ENUM-SIP Addressing Server via pkt-esrv-1.
5. On receiving an ENUM response on pkt-esrv-1 from the ENUM-SIP Addressing Server, the Routing Function MUST:

   - If the ENUM response returns one or more NAPTR RR for SIP service, then select and use a SIP service NAPTR RR to route the dialog-initiating SIP request as specified in [RFC 3761], [RFC 3403], and [RFC 3263], and as specified in Section 6.1.4.
   - Select a SIP service NAPTR RR associated with an available route, using the selection criteria specified in [RFC 3403]; i.e., select the highest-priority NAPTR RR for an available route, where priority is based on the "order" (most significant) and "preference" (least significant) fields of each NAPTR RR.

   Note: Whether the Routing Function tracks the availability status of the routes, and the mechanism used to determine route availability are outside the scope of this specification. However, if the Routing Function does support such a mechanism, then it should take the availability status into account when selecting the NAPRT RR.

   - If there are multiple SIP service NAPTR RRs at the highest priority and associated with available routes, then select one of those NAPRT RRs. In this case the algorithm to select one among these multiple same-priority NAPTR RRs is outside the scope of this specification (e.g., the Routing Function could simply select the first NAPTR RR in the response that fits the selection criteria).

6. Use the selected NAPRT RR to route the dialog-initiating SIP request as specified in [RFC 3403], [RFC 3761] and [RFC 3263], and as specified in Section 6.1.4.
7. If the ENUM response does not return a NAPTR RR for SIP service or the selection criteria does not yield a result, then either return an error response or select an alternate route for the SIP request, based on local policy.

Note: An ENUM address resolution query failure in the originating network probably means that the E.164 number belongs to the PSTN, or to an SSP that is only reachable via the PSTN. In this case, the most logical routing policy would be to route the call to the PSTN. An ENUM resolution query failure in the terminating network likely indicates that a routing error has occurred, in which case the terminating Routing Function should send an appropriate error response such 404 (Not found) or 604 (Does not exist anywhere). Local policy may dictate other actions (e.g., route to announcement).

6.1.1.2 ENUM Processing for ENUM-SIP Addressing Server

An ENUM-SIP Addressing Server that supports the pkt-esrv-1 interface MUST conform to the requirements in this section.

On receiving an address resolution request on the pkt-esrv-1 interface, the ENUM-SIP Addressing Server MUST remove the alpha-numeric string contained in the trailing end of the query domain-name key and use it to identify the ENUM database zone for this query (the mechanism for identifying the zone is out-of-scope of this document). The ENUM-SIP Addressing Server MUST convert the E.164 address portion of the query domain-name into an E.164 digit string by reversing the order of the digits and removing the dot '.' separators. The ENUM-SIP Addressing Server MUST then use this E.164 digit string to identify the target LRN, TNRange, or Public Identity object in the ENUM database zone as follows:

1. If the digit string matches the Public Identity PubID data element, or the LRN RN data element, then that object is the target object, and skip remaining step.

Note: The above procedure assumes the database is configured such that it will not yield both an LRN match and a Public Identity match. If a duplicate match is found, the action taken by the ENUM-SIP Addressing Server is not specified.

2. Convert the TNRStrt and TNREnd data elements of the TNRange object to unsigned integer values. If the result of the Boolean expression (TNRStrt =< digit string value =< TNREnd) is true, then that TNRange object is the target object.

Note: It is possible that the identity of an LRN or Public Identity object could fall within the range of numbers covered by a TNRange object. If such an overlap exists and results in multiple matches, the order of the above steps ensures that an exact match of an LRN or Public Identity is always selected over the within-range match of a TNRange object.

If a matching LRN, TNRange, or Public Identity is found, then the ENUM-SIP Addressing Server MUST generate a list of NAPTR RRs associated with the target object as specified in Section 6.1.3. The ENUM Server SHOULD support a policy option to order NAPTR RRs having the same "order" and "preference" fields randomly on the list relative to one another, as a means of load-balancing traffic across multiple same-priority routes.

The ENUM-SIP Addressing Server MUST return the list in an ENUM response to the Routing Function via pkt-esrv-1.

If the above procedure does not yield a matching object, or does not yield any NAPTR RRs, then the ENUM-SIP Addressing Server may return a NAPTR RR indicating an alternate route to handle the incoming request (e.g., route to the PSTN). Otherwise, the ENUM-SIP Addressing Server MUST send an error response (e.g., "NXDOMAIN", "NOERROR") to the Routing Function via pkt-esrv-1.

6.1.2 Resolving an Address via SIP

The pkt-esrv-2 interface supports a SIP redirect service that translates a SIP URI into routing information. The basic procedure is shown in Figure 9.

Figure 9 - SIP Address Resolution Flow

As shown in Figure 9, the Routing Function receives an event at [1] such as a request to initiate a session that requires it to send a dialog-initiating SIP request to a remote user. The Routing Function sends an INVITE [2] with a Request-URI containing the AOR of the remote user to the ENUM-SIP Addressing Server. On receiving the INVITE request [2], the ENUM-SIP Addressing Server consults the registry database to obtain the set of NAPTR RRs configured for that identity, and responds with a 302 (Moved Temporarily) response [3] containing a Contact header field populated with the collected routing information; in this case two contact addresses are returned. On receiving the 302 (Moved Temporarily) response [3] the Routing Function selects the contact address with the highest q-value, and uses it to populate the routing information in the outgoing INVITE request at [4].

6.1.2.1 SIP Processing for Routing Function

A Routing Function that supports the pkt-esrv-2 interface MUST conform to the requirements in this section.

On receiving an event such as a call initiation request that requires the sending of a SIP request to a remote user, the Routing Function MUST perform the following procedure to obtain routing information for the SIP request:

1. Obtain the AOR of the remote target user. The means of obtaining this AOR are outside the scope of this specification, but could include building an AOR containing an E.164 number derived from a digit string received via NCS signaling as part of a call initiation request, or using an AOR received in the Request-URI of a received dialog-initiating SIP request such as INVITE or SUBSCRIBE.

2. The Routing Function MUST ensure that the AOR conforms to one of the two following forms:

   - SIP URI containing a Tel URI as indicated by the "user=phone" parameter (see section 19.1.6 of [RFC 3261]), where the user part of the SIP URI contains a global number (i.e., an E.164 number with the leading '+') as defined in [RFC 3966], with no visual separators.

     E.g., sip:+13036612345@example.com; user=phone

   - Email-style SIP URI

     E.g., sip:john-doe@example.com

3. If the AOR is in the form of a SIP URI that contains a global number (i.e., an E.164 number with the leading '+'), and if dictated by local policy, obtain Local Number Portability (LNP) information for the E.164 number either by consulting an LNP database, or from received Tel URI number portability parameters as specified in [RFC 4694]. If an LNP database query is performed, then add the Tel URI 'npdi' parameter, and if the number is ported the 'rn' parameter, to the AOR as specified in [RFC 4694].

4. Send a dialog-initiating INVITE Request (or proxy a received dialog-initiating request) with a Request-URI containing the SIP URI obtained or created in step-1, and possibly modified in step-2, to the ENUM-SIP Addressing Server via pkt-esrv-2.

   Note: The Routing Function does not modify the Request-URI depending on whether the ENUM-SIP Addressing Server database is portability-corrected or not. Rather, it simply provides both the target user E.164 number in the SIP URI user-part, and the LRN E.164 number in the 'rn' parameter, and assumes the ENUM-SIP Addressing Server will use the correct value based on whether or not its database is portability corrected.

   Note: If the event that triggers the address resolution query is an incoming SIP request other than INVITE, the Routing Function can either proxy the incoming request to the ENUM Server, or it can create and send a new dialog-initiating INVITE to the ENUM Server. Both behaviors are compliant with this specification.

5. On receiving a 302 (Moved Temporarily) response to the previous dialog-initiating request on pkt-esrv-2, the Routing Function MUST select a contact URI from the response as follows:

   Note: The Routing Function expects to receive a 302 (Moved Temporarily) response from the ENUM-SIP Addressing Server. The Routing Function action taken on receiving other 3xx responses is outside the scope of this specification.

   - Select the contact URI that is a SIP URI with the highest q-value URI parameter associated with an available route.
   - If there are multiple contact SIP URIs at the highest q-value and associated with available routes, then select one of those contact URIs. In this case the algorithm to select one among these multiple same-priority contact SIP URIs is outside the scope of this specification (e.g., the Routing Function could simply select the first contact URI in the 302 response that fits the selection criteria).

   Note: Per [RFC 3261] a 3xx response can contain multiple contact addresses in a single Contact header field, or across multiple Contact header fields.

   Note: Whether the Routing Function tracks the availability status of the routes, and the mechanism used to determine route availability are outside the scope of this specification. However, if the Routing Function does support such a mechanism, then it is expected to take the availability status into account when selecting the contact URI.

6. For the selected contact URI, the Routing Function MUST:

   - Remove any nested SIP headers from the selected contact URI as indicated by the '?' construct specified in section 19.1.1 of [RFC 3261], and add them to the outgoing dialog-initiating SIP request.
   - Add the selected contact URI to the Request-URI of the outgoing dialog-initiating SIP request.

- Send the dialog initiating request as specified in Section 6.1.4.

Note: The ENUM-SIP Addressing Server can use the nested header mechanism to return Route header fields to be used to route the outgoing SIP request.

7. If the selection criteria does not yield a result, then return an error response based on local policy.
8. On receiving an error response to the dialog-initiating request, the Routing Function MUST:
   - For 404 (Not Found) or 604 (Does not exist anywhere): either return an error response or select an alternate route for the SIP request (e.g., route call via PSTN), based on local policy,
   - For 503 (Service Unavailable): retry the request using an alternate ENUM-SIP Addressing Server address, if one is configured, or return an error response.
   - For any other 4xx, 5xx, or 6xx response: return an error response based on local policy.

6.1.2.2 SIP Processing for ENUM-SIP Addressing Server

An ENUM-SIP Addressing Server that supports the pkt-esrv-2 interface MUST conform to the requirements in this section.

The ENUM-SIP Addressing Server MUST support the Redirect Server requirements defined in [RFC 3261].

On receiving a dialog-initiating request on pkt-esrv-2, the ENUM-SIP Addressing Server MUST select the ENUM database zone used to resolve the address based on local configuration data.

Note: Unlike the ENUM case, there is no way for the Routing Function to signal a database zone to the ENUM-SIP Addressing Server using the pkt-esrv-2 (SIP) interface.

If the Request-URI contains an email-style SIP URI, then the ENUM-SIP Addressing Server MUST convert the URI to its canonical form as specified in section 10.3 of [RFC 3261], and remove the "sip:" URI service indicator. If the resulting string matches the PubId data element of a Public Identity, then that object is the target object.

If the Request-URI contains a SIP-URI which contains an E.164 number (i.e., the user-part has a leading '+' character and the URI has a "user=phone" parameter), then the ENUM-SIP Addressing Server MUST determine the E.164 number to use for the resolution query as follows:

- If the ENUM-SIP database is not portability-corrected, and if the SIP URI user-part contains a Tel URI 'rn' parameter, then use the E.164 number contained in the 'rn' parameter for the resolution query,
- Otherwise, use the E.164 number contained in the user-part for the resolution query.

The ENUM-SIP Addressing Server MUST then use the selected E.164 digit string to identify the target LRN, TNRange, or Public Identity object as follows:

1. If the digit string matches the Public Identity PubID data element, or the LRN RN data element, then that object is the target object.

   Note: The above procedure assumes the database is configured such that it will not yield both an LRN match and a Public Identity match. If a duplicate match is found, the action taken by the ENUM-SIP Addressing Server is not specified.

2. Convert the TNRStrt and TNREnd data elements of the TNRange object to unsigned integer values. If the result of the Boolean expression (TNRStrt =< digit string value =< TNREnd) is true, then that TNRange object is the target object.

   Note: It is possible that the identity of a LRN or Public Identity object could fall within the range of numbers covered by a TNRange object. If such an overlap exists and results in multiple matches, the order of the above steps ensures that an exact match of an LRN or Public Identity is always selected over the within-range match of a TNRange object.

If a matching LRN, TNRange, or Public Identity is found, then the ENUM-SIP Addressing Server MUST generate a list of NAPTR RRs associated with the target object as specified in Section 6.1.3.

If the ENUM database yields one or more NAPTR RRs, then the ENUM-SIP Addressing Server MUST respond to the Routing Function as follows:

1. Convert the REGEXP field of each NAPTR RR into a contact address (e.g., a SIP URI) as specified in [RFC 3403].
2. Convert the NAPTR RR "order" and "preference" fields into a Contact header field 'q' parameter, as follows:
   - Sort the NAPTR RRs from highest priority to lowest priority, where priority is based on the "order" (most significant) and "preference" (least significant) fields of each NAPTR RR. Limit the length of the sort list to 1000 entries by eliminating the lowest priority NAPTR RRs.
   - Map each entry on the sort list to a different q-value. The ENUM-SIP Addressing Server is free to apply any mapping algorithm it chooses as long as the q-value associated with a given NAPTR RR on the list is greater than q-values of all lower-priority NAPTR RRs on the list. NAPTRs with the same "order" and "preference" will be at the same location on the priority list and will therefore have the same q-value.
3. Populate the Contact header field of a 302 (Moved Temporarily) response with each contact address and its associated 'q' header parameter identified in the previous steps, as specified in [RFC 3261]. Place the contact addresses within the Contact header field in order from highest to lowest q-value. The ENUM-SIP Addressing Server SHOULD support a policy option to order contact addresses having the same "order" and "preference" fields randomly relative to one another, as a means of load-balancing traffic across multiple same-priority routes.
4. Send the 302 (Moved Temporarily) response to the Routing Function.

If the ENUM database does not yield a matching object, or does not yield any NAPTR RRs, then the ENUM-SIP Addressing Server may return a 302 (Moved Temporarily) response with a Contact header field containing an alternate route for the request (e.g., route call via the PSTN). Otherwise, the ENUM-SIP Addressing Server MUST send a 404 (Not Found) error response to the Routing Function.

6.1.3 Common ENUM-SIP Addressing Server Requirements

This section describes the ENUM-SIP Addressing Server requirements that are common to both ENUM and SIP address resolution queries (i.e., common to pkt-esrv-1 and pkt-esrv-2 interfaces). An ENUM SIP Server that claims compliance with this specification MUST support the procedures described in this section.

On receiving a resolution request (either ENUM or SIP) for a provisioned LRN, TNRange, or Public Identity object, the ENUM-SIP Addressing Server MUST generate a list of NAPTR RRs containing all the routing information associated with that object.

The ENUM-SIP Addressing Server MUST identify all the NAPTR RRs indirectly linked to the target LRN, TNRange or Public Identity object, as follows :

1. Identify the Service Area linked to the selected LRN, TNRange, or Public Identity object as indicated by the object’s SAId data element.
2. Identify all the Routes linked to that Service Area as indicated by the Service Area RteId data element. Eliminate any Routes that have an IsInSvc value of False.
3. For each Route, determine if there is an associated Egress Route. An Egress Route is associated with a Route if the Egress Route contains an RteId data element identifying that Route.

4. Build a list of NAPTR objects linked to all the Routes identified in step-2, as indicated by the RrId data element in each Route.

   Once it has identified all the NAPTR objects that are indirectly linked to the target LRN, TNRange, or Public Identity, the ENUM-SIP Addressing Server MUST built a response containing a list of NAPTR RRs that reflect the routing information for the target query identity.

5. For each NAPTR object on the list, the ENUM-SIP Addressing Server MUST:

   - If there is no Egress Route associated the NAPTR object, then build a single NAPTR RR with parameters that are set to the value of the equivalent fields in the NAPTR object.
   - If there is one or more Egress Routes associated with the NAPTR object, then for each Egress Route that has a Svcs data element that matches the NAPTR object Svcs data element, build a NAPTR RR as follows:
     - Set the REGEX field in the NAPTR RR to the regular expression resulting from the application of the Egress Route RegexRewriteRule to the NAPTR object Regex data element.
     - Set the remaining NAPTR RR fields to the value of the equivalent data elements in the NAPTR object.

Note: The ESPP data model enables a NAPTR object to be associated with multiple Egress Routes in a couple of different ways. First, multiple Egress Route can reference the same Route, which in turn references a NAPTR object. Second, multiple Routes, each having a unique Egress Route, can point to the same NAPTR object. In these situations, the ENUM-SIP Addressing Server generates a NAPTR RR for each NAPTR / Egress-Route pair.

At this point the ENUM-SIP Addressing Server has generated a list of NAPTR RRs corresponding to the indirectly linked NAPTRs. If the original query identified a Public Identity object, then the ENUM-SIP Addressing Server MUST add to this list any NAPTR RR entries corresponding to directly linked NAPTRs.

If the ENUM-SIP Addressing Server receives a resolution request that identifies a Public Identity which is linked to one or more additional Public Identities via a Private Identity, then the ENUM-SIP Addressing Server MUST add to the list any NAPTRs linked to these additional Public Identities, using the procedure described above in this section.

6.1.4 Common Routing Function Requirements

This section describes the Routing Function requirements that are common to both ENUM and SIP address resolution queries (i.e., common to pkt-esrv-1 and pkt-esrv-2 interfaces). A Routing Function that claims compliance with this specification MUST support the procedures described in this section.

Once the Routing Function has updated the SIP request with the routing information from the selected routing address, it forwards the request to the next hop based on local policy (e.g., using the procedures defined in [RFC 3263]). If the Routing Function is unable to determine the next hop for the selected route, or if the request fails due an error response or no response, then the Routing Function MUST retry the request using the next highest priority routing address from the list of addresses returned by the ENUM-SIP Addressing Server, until either the list is exhausted or there is a successful response from the next hop.

6.2 Transport

The ENUM-SIP Addressing Server that supports pkt-esrv-2 MUST support both TCP and UDP on that interface.

The Routing Function that supports pkt-esrv-2 MUST support both TCP and UDP on that interface.

The transport requirements associated with pkt-esrv-1 are specified in the ENUM and DNS RFCs normatively referenced elsewhere in this document.

6.3 Interface Failure Detection and Recovery

A Routing Function that supports pkt-esrv-2 MUST periodically send an OPTIONS request with a Max-Forwards header field set to '0' via pkt-esrv-2, to detect the availability of the ENUM-SIP Addressing Server. The ping rate is based on local policy (typically every 5 seconds). If the Routing Function fails to receive a response to an OPTIONS request, then it will consider the non-responding pkt-esrv-2 interface to have failed, and MUST refrain from using the interface to route new dialog-initiating requests. In the meantime, the Routing Function MUST continue to send periodic OPTIONS pings via the failed interface in order to detect when it has been restored and is available for service.

On receiving an OPTIONS request with a Max-Forwards header field containing the value '0', the ENUM-SIP Addressing Server MUST respond with a 483 (Too Many Hops) response message.

6.4 Security

6.4.1 Security Procedures for the SIP Interface

An ENUM-SIP Addressing Server that supports pkt-esrv-2 MUST comply with the requirements applicable to the pkt-s16 interface as specified in the PacketCable Security Specification [SEC1.5].

A Routing Function that supports pkt-esrv-2 MUST comply with the requirements applicable to the pkt-s16 interface as specified in the PacketCable Security Specification [SEC1.5].

6.4.2 Security Procedures for the ENUM Interface

The security requirements for the pkt-esrv-1 reference point are not covered in this version of the document.

Annex A ENUM Client Requirements

This Annex describes the Routing Function requirements specific to support of the ENUM Client that terminates the pkt-esrv-1 reference point at the Routing Function. A Routing Function that supports pkt-esrv-1 MUST support the ENUM Client requirements in this Annex.

A.1 Introduction

The PacketCable ENUM Client is responsible for taking as an input an E.164 phone number (with country code) (e.g., +1-301-555-1212), an optional service selector, an optional database selector and an optional count of desired URIs and returning one or more URIs. The service selector is used by the ENUM Client for filtering NAPTR responses as described in Section A.2.1. The database selector is used by the ENUM Client to identify the portion of the DNS Tree where the ENUM data resides, its use is described in Section A.1.3.

A.1.1 General

This section describes the ENUM requirements necessary for usage by CMS, MGC, S-CSCF, and other PacketCable component implementations. ENUM is defined in [RFC 3761] and unless otherwise prescribed below, is required for the implementation of a PacketCable ENUM Client [hereinafter "Client"].

The processing of the final output of an ENUM lookup up (e.g., a SIP or Tel URI) is outside the scope of this document.

The Client MUST be in accordance with the following ENUM related RFCs: [RFC 3761], [RFC 3764], [RFC 4415], and [RFC 3402] except as noted in the following sections.

A.1.2 DNS Resolver Requirements

The Client MUST implement a "stub" resolver as defined in [RFC 1034]. The Client SHOULD implement a 'full' resolver per [RFC 1034]. If the Client implements a full resolver, it MUST be configurable to act as a stub resolver - e.g., all ENUM queries are forwarded to an external resolver.

Since the data used for ENUM can reside in a DNS system that is partially or totally independent of an operator's DNS system used for other applications (e.g., email, web, etc) the ENUM Client may need to be configured accordingly. As such, the ENUM Client resolver MUST be capable of being configured to forward ENUM queries to an external DNS Server which may differ from the DNS Server used by other applications or processes on the system on which the Client resides.

A.1.3 Database Selector

The default database selector [RFC 3761] default database - "e164.arpa". For the purposes of this specification, step 4 is modified to read as follows:

```
4. Append the database selector string (or if unspecified), the default string
   ".e164.arpa" to the end.
   Example: "8.4.1.0.6.4.9.7.0.2.4.4.e164.arpa" or
   "2.1.2.1.5.5.5.1.0.3.1.enum.mso.net"
```

Valid database selectors MUST be specified using the recommended syntax from [RFC 1034], i.e., labels consist only of letters, digits and hyphens. The Client MUST NOT send queries with database selectors which violate this syntax.

A.2 NAPTR

A.2.1 Service Field

A service selector matches any service field that begins with that string, e.g., "E2U" matches any service field beginning with "E2U". "" (blank) matches any service field.

The default selector for the service field is "E2U". Other possible values for the service field selector that can be requested of the Client include "E2U+voice:tel" and "E2U+SIP". During ENUM processing, the Client MUST silently ignore returned NAPTR records where the selector does not match the service field.

The Client MUST be able to receive and process the "E2U+SIP" NAPTR service records as defined in [RFC 3764].

The Client SHOULD be able to receive and process the "E2U+voice:tel" NAPTR service records as defined in [RFC 4415].

The Client processing of NAPTR records with other service types is outside the current version of this specification.

A.2.2 Case Insensitivity

For the purposes of selecting and matching records, the Client MUST match with the Service and Flags fields of the NAPTR records in a case-insensitive manner, e.g., "E2U+SIP", "E2u+sIP" and "e2u+sip" are all values which indicate an ENUM SIP NAPTR record.

The Client MUST do a case insensitive match with the left hand side of the NAPTR Regular Expression.

Case insensitivity is defined only with respect to the 26 uppercase and 26 lower case alphabetic characters of the ASCII character set (e.g., A-Z and a-z) - "A" is equivalent to "a", etc. All other characters, regardless of character set, require an exact match.

A.2.3 Regular Expression Delimiters

The Client MUST be able to process the regular expression field of the NAPTR record for any valid delimiter as defined in [RFC 3402]. While the preferred delimiter is the exclamation point (!), this specification does not impose requirements on the servers which serve the NAPTR records and Clients should be prepared to process any valid delimiter they receive. The Client MUST ignore NAPTR records which contain malformed regular expressions. When ignoring malformed NAPTR records the Client MUST continue processing with the next available NAPTR record if any.

A.2.4 Non-Terminal NAPTR Records

At this time, PacketCable only supports NAPTR records with a flag field of "U". The flag indicates a "terminal" or final lookup record with the result being a URI. Clients MUST silently ignore any NAPTR record which contains a flag field with any value other than "U" (or its lower case equivalent "u").

A.2.5 Handling Multiple URIs

Differing from [RFC 3761], the Client MAY return multiple URIs. Unless specified by the application, the Client MUST assume the number of desired URIs is 1. Consistent with [RFC 3402], when presented with multiple returned NAPTR records which match the service selector, the Client MUST follow this procedure:

1. Remove from consideration all non-terminal NAPTR records.

2. Sort the NAPTR records first by the "Order" field, and then by the "Preference" field within the "Order". The sort order for two records with identical Order and Preference fields is undefined and may be ordered any way the Client application desires.
3. If there are more than ten NAPTR records remaining, remove the excess records at the bottom of the sorted list.
4. In sort order, attempt to match (see [RFC 3402]) each NAPTR record. If the match is successful, and the returned string is a valid URI, add that URI to the result set along with the NAPTR's associated Order, Preference and Service fields.
5. Repeat step 4 until the end of the list is reached or until the number of desired URIs is produced. In no event shall the Client produce more than five URIs.
6. Return the result set of URIs along with their associated Service, Order, and Preference fields.

A.2.6 EDNS0 Support

The Client MUST implement EDNS0 as defined by [RFC 2671]. Clients MUST include an EDNS0 OPT record in any UDP DNS request they send. The Client SHOULD set the OPT record to indicate a Sender UDP Payload Size of at least 4096 octets, which, in turn, implies that the Client must be able to receive and process a UDP payload of at least 4096 octets.

Appendix I Acknowledgements

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