An Approach to Call Routing in Softswitch based Telephony Networks

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Abstract – Call routing in a PSTN is normally performed with help of routing tables based on called numbers prefixes. Migration of the PSTN, circuit switched telephone network to the NGN (Next Generation Network), IP based layered network based on softswitch and media gateway components that emulates PSTN services, requires adaptation of the call routing mechanisms for new target network architecture. In the same time, it offers opportunity for use of new IP based technologies such as ENUM (Telephone Number Mapping) to fulfill the call routing function in the new network. This paper describes an approach for complementing traditional call routing methods with use of an ENUM based routing. At the end of transition period to the NGN, the ENUM based routing may eventually completely replace traditional call routing.

I. INTRODUCTION

Migration of a PSTN to a NGN and change of network architecture puts demands on new network components to support telephony functions known in the PSTN. On the one side, the PSTN replacement must be unnoticeable by end users and on the other side, the NGN components must support common PSTN functions, that were implemented in TDM exchanges, and adapt them to the new network architecture based on IP technologies and protocols. Call routing is such function that will need to be adapted to the following conditions: part of subscribers are still in the PSTN and part in the NGN hosted at AGWs (Access media Gateways) controlled by call servers (softswitches), there is interconnect over TGWs (Trunking media Gateways) between the PSTN part and the NGN part, interconnect (to other networks) is realized via IP interconnect over BGWs (Border media Gateways) besides TDM interconnect. Additionally, call control protocol between NGN call servers and at IP interconnect is SIP-I (Session Initiation Protocol [4] with encapsulated ISUP) and different types of media gateways (AGW, TGW and BGW) are controlled via media gateway control protocol (H.248) with appropriate profiles.

This paper, in chapter two, starts by discussing call routing in the PSTN and its aspects in the PSTN migration to the NGN. Chapter three explains possible approaches in implementing call routing in migrating networks, ones based on legacy PSTN methods and others more radical and based on IP technologies. Target call routing architecture in the NGN with support of ENUM system [1] is described in chapter four. Chapter five gives overview of new proposed enhancements to realize feature rich call routing in the NGN based on ENUM. Conclusions are given in chapter six.

II. BACKGROUND- CALL ROUTING IN PSTN AND MIGRATION TO NGN

Traditional call routing in the PSTN is largely dependant on number prefixes. Namely, each local exchange normally hosts subscribers with telephone numbers from number series with specific number prefixes (e.g. 10thousand number series 1230000-1239999, which has 123 as a number prefix). Therefore, routing tables in classic PSTN exchanges are built upon analysis of called number prefixes that result in specific routing to the target local exchanges e.g. via direct communication paths/routes (TDM trunks controlled by ISUP) or via transit layer (i.e. via routes over intermediate/transit exchange).

Additional complexity in PSTN call routing is introduced with regulatory services such as number portability and carrier selection. Specific routing solution is introduced for handling ported numbers as such numbers cannot be handled by number prefix based routing. Majority of such solutions, however, determine specific routing number associated with ported subscriber that is then handled much alike any other number prefix. Of course this is a simple view on call routing in the PSTN as routing cases/programs may be more complex and may be dependent on different input information such as origin information, incoming route direction, priority of a call etc. and as the result can give multiple paths/routes to the destination which selection is guided by different schemes (simple alternative routing or load sharing or time based scheme or some other) and depends on congestion of the previous route.

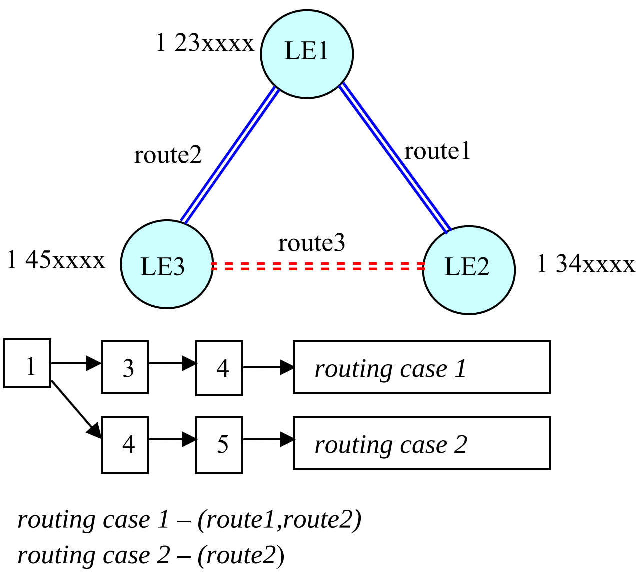

Figure 1: Simple view of PSTN routing

In example in Figure 1, specific number series are hosted at each local exchange. In the local exchange 1, the result of analysis of specific number prefixes of called numbers are different routing cases (or tables). The routing case 1 is specified for destination local exchange 2 and consists of direct route 1 to local exchange 2 and route 2 to local exchange 3 that will act as a transit node for routing to local exchange 2 (further via route 3). Routes are normally defined over specific TDM circuits associated to ISUP signalling.

The NGN represents departure from traditional network architecture largely based on TDM technology, and is built upon new, layered architecture and IP technology. There are dedicated functional elements in the NGN defined for interworking with the PSTN. According to the ETSI TISPAN functional model, the NGN consists of different 'application' subsystems built to support specific type of services and using common IP transport infrastructure: the PSTN/ISDN Emulation Subsystem (PES) for PSTN/ISDN services [2], the IP Multimedia subsystem for IP based multimedia services and others being recently defined (for IPTV) or future ones.

Scope of this paper is call routing in the softswitch based telephony networks or according to the ETSI TISPAN in the PES part of the NGN, that is based on softswitch principles, while the IMS is not directly considered although some of the methods and routing considerations made for the softswitch based architecture may be applicable to the IMS architecture as well.

During migration to the NGN, parts of the PSTN will in controllable and stepwise manner be moved into a set of call servers (softswitches) and media gateways. That means that part of subscribers previously hosted at local exchanges will move into a set of call servers and its physical lines reconnected to AGWs. Generally, it cannot be assumed that based on telephone number belonging to specific number prefix, a specific subscriber is associated with a specific call server. Namely, number portability needs to be supported as well in the NGN and that means that any subscriber number can be hosted at a particular call server. The hosting (destination) call server should be then identified from the called number at the granularity of a single number (or access line). A telephone number should be associated in the call server with a particular access line or port in an AGW controlled (via H.248) by the call server.

Further consideration related to call routing is to route a call appropriately with respect of where called number is located – in case calling subscriber is located in the NGN (IP network), but called in the PSTN (TDM network), route a call that only once pass IP/TDM border, and vice versa - in case calling subscriber is located in the PSTN (TDM network), but called in the NGN (IP network) to route a call that only once pass TDM/IP border. For both subscribers residing in the NGN, a call would need to be routed inside the NGN only (if possible) and for both subscribers residing in the PSTN, a call would need to be routed inside the PSTN (if possible). This principle should be followed in order to minimize transmission delays and eventual degradation of service.

Perhaps final consideration where call routing would require adaptation in a mixed NGN/PSTN or NGN environment is selection of a call server and appropriate media gateway (one of TGWs or BGWs) to be used for media transport at points of NGN/PSTN interconnection and at points of TDM or IP interconnection with other (operator) networks.

III. POSSIBLE APPROACHES FOR CALL ROUTING IN MIGRATING NETWORKS

There could be different approaches in realization of call routing in mixed NGN/PSTN environment when PSTN networks migrate to the NGN. Here are (not exclusive) possible approaches in fulfilling this task:

- minimal adaptation of existing PSTN routing mechanisms, based on number prefix and legacy number portability handling, to include SIP route and GW selection
- combination of existing PSTN routing methods with use of ENUM system/ routing database
- use of external routing database accessed by SIP interface (routing results returned via 3xx responses)
- new mechanism that enables dynamic exchange of routing data (e.g. via use of routing protocols supporting PSTN GW selection [3] or via extended, more generalized methods [9])

The two latter approaches would not be discussed further in this paper. The first approach is naturally deployed while the second approach is gaining ground in some large operator networks.

The first approach to reuse existing PSTN routing mechanisms and make only necessary adaptations implies that the called number analysis in call servers is still structured based on number prefixes. That means that NGN call servers retain approach to host specific subscriber number series (number prefixes). However, some routing tables include routing results/alternatives leading over SIP routes to the target NGN nodes (call servers) that hosts subscriber number series migrated from the PSTN and some routing tables include routing results/alternatives leading over ISUP routes to the PSTN nodes that hosts not-migrated subscriber number series. ISUP routes should be associated with specific TDM circuits at TGWs controlled by a call server. PSTN nodes will have part of ISUP routes redefined or replaced (from local exchange destinations to call server destinations).

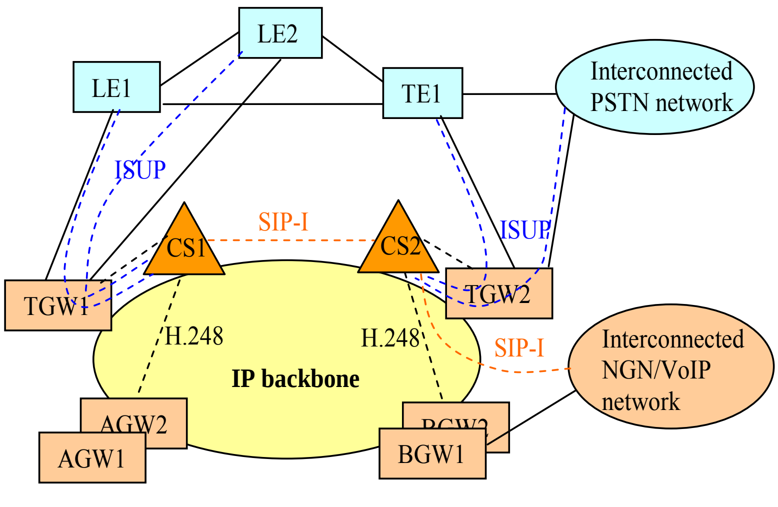

Figure 2: Migrating PSTN network and NGN network architecture

Prerequisite is that migration is done per subscriber number series (or per number prefixes) – e.g. that all subscribers with prefix 123 is moved from the PSTN local exchange to the NGN call server. Otherwise, there would be migrating number series - those that are not completely migrated to the NGN (i.e. those in which part of subscribers are connected to call servers but other part is still connected to PSTN exchanges). In such situation, if only part of subscribers belonging to a certain number prefix is moved, there would be cases where a call is onward routed, i.e. pass through (migrating) nodes where subscribers are not anymore (calls from PSTN) or yet (calls from NGN) hosted. This is similar to calls to ported subscribers in networks where the number portability solution is based on passing of calls through a donor exchange. There should be as well additional configuration to recognize moved subscribers at migrating nodes and perform routing to new destination/hosting nodes. However, in such scenario a number portability solution and its database may help but it must be additionally configured and populated with all numbers from migrating number series and additional routing numbers for NGN call servers. Regarding general number portability, then these solutions are retained as in the PSTN with possibility to support IP transport via signaling gateways in case of IN based solutions.

When comes to a GW selection, a TGW is selected via selection of an associated ISUP route while an AGW at which subscriber is hosted is selected based on association of a subscriber number with specific AGW and its port (access line). These associations are provisioned in the call server. In case of IP interconnect and BGWs, a BGW is selected based on association of specific BGWs with specific SIP interconnect route. There may be also SIP transit scenarios (e.g. due to some services) inside (operator) NGN network in which case call servers may perform only call signaling function without seizing any media gateway node in the bearer network or due to service complexity may seize a media server in the bearer network to perform complex media functions.

In the second approach, call routing in migrating networks is supported by ENUM. ENUM is the system that uses the Domain Name System (DNS) for storage of E.164 numbers and identification of available services connected to these numbers by use of NAPTR resource records containing specific service identifiers. For example, it can contain specific SIP Uniform Resource Identifier (URI) that can identify a host /call server accessible via SIP signalling to which related E.164 number is connected. As ENUM in this case is to be used for call routing by an operator network, then the class of implementation is private (also called infrastructure ENUM[7], unlike public or end user ENUM). ENUM inherently supports routing per individual numbering resource and to disperse targets. Thus it enables facility to host numbering resources belonging to the same numbering series at different call servers. Call servers may, with appropriate provisioning support, host any subscriber number from numbering portion assigned to the operator or from set of ported in subscriber numbers. In order to apply ENUM for call routing, B-number analysis should include triggers for launching ENUM queries for selected (or even all) numbering prefixes directly or after lookup to database of hosted subscriber numbers has been done.

Furthermore, with use of ENUM, B-number analysis and routing tables in call servers may be simplified and can depart from strict structure per numbering prefixes allowing more general, flat and simplified analysis.

Regarding number portability, as ENUM ensures per individual number granularity, it is perfectly suitable for collapsing existing number portability solutions/database (especially those based on all call query) into ENUM database or replacing such solutions. With application of ENUM for call routing, it is now possible to uniformly cover routing for all subscribers – non-ported as well as ported subscribers and with a single query per call.

With use of ENUM based routing, migration can be done per subscriber number series/prefixes, but it is not necessary. ENUM can as well be applied for migrating number series. For this purpose, all numbers belonging to migrating series are populated in ENUM, those hosted in the NGN with SIP URIs targeting call servers and those hosted in the PSTN with SIP URIs targeting the PSTN. For those SIP URIs that targets PSTN, a call server will directly route calls over ISUP routes and TGWs to the PSTN (without passing through migrating node) . However, for calls in other direction – originating from the PSTN, passing through other exchange may happen if eventually a number portability solution is not deployed for subscribers migrated to the NGN.

IV. TARGET CALL ROUTING ARCHITECTURE IN NGN BASED ON ENUM

In the target NGN environment, call routing will be performed based on received routing information from the ENUM database for each call, originated in the call server or coming over interconnect routes, that is not terminating at the call server (on all call ENUM query basis). Received routing information include destination service provider (e.g. its domain name) and/or call server (e.g. its host name) to which call signalling should be delivered and media/transport gateway to be used for media transport (e.g. its host name or other relevant identifiers). Media gateway information may include identifiers of finer granularity at specific media gateway – e.g. specific trunk group (group of TDM circuits at a TGW) or specific gateway interface or realm (in a BGW).

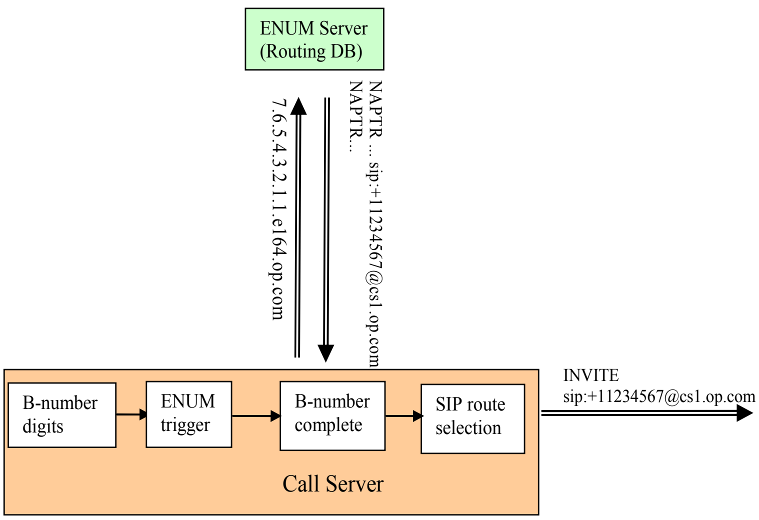

Figure 3: ENUM based call routing

Figure 3 shows principle handling when using ENUM for call routing. In the called (B-)number analysis, an ENUM trigger can be specified for particular number prefixes (or even practically on all call query basis) that will, after reception of a complete B-number, result in launching ENUM(DNS) query with a B-number based domain to an ENUM server acting as the routing database. The ENUM server will return one or more routing alternatives in the form of NAPTR resource records with specific destination/point of interconnect addresses (e.g. SIP URIs). The call server will match a routing alternative (the most preferred if more than one returned) with specific SIP route/destination and route a call using configured IP addresses of destinations or determining IP address (and transport, port) of destination server by using DNS procedures [5].

ENUM mechanism as currently standardized is not enough flexible in specifying and possible handling of routing alternatives. Routing alternatives can practically be specified only in a sequential alternative way with priority scheme (i.e. order and preference field in NAPTR resource records) lacking support for other types of schemes for choosing routing alternatives. There should be necessary enhancements in order to support such additional schemes (see next chapter).

There are two general domains of routing:

- inside own (operator) network to the terminating node (i.e. via target SIP URI finding the call server where a subscriber is connected or is acting as the PSTN gateway node if a subscriber is still connected in remaining PSTN islands)
- to other (operator) network to the point of inter-connect (i.e. via SIP URI of the interconnected operator network with additional means of identifying the interconnect node in the own network and the route/trunk at the interconnect node to other network). Routing to other network may be arranged via direct interconnect points to that network or indirectly via other transiting networks in case of no direct interconnect points to that network. The route/trunk at the interconnect node to transit network should be determined for interconnect case via transit network.

In case of call routing to a target call server inside own network, the specific AGW needs to be selected where actual called subscriber is physically connected. Selection of AGW is done implicitly via selection of target call server based on called number as there is configuration done in a call server that associates a hosted subscriber number with a particular AGW. Therefore explicit identification of an AGW is not needed in ENUM.

Interconnect can be realized as IP interconnect as well as TDM interconnect in migration period for interconnected networks from the PSTN/TDM to the NGN/IP network. The problem of selecting the point of interconnect includes determination of trunk group (TDM circuits) at the PSTN (Trunking) GW in case of TDM interconnect and determination of specific border interface at the (Session) Border GW. In layered NGN architecture this boils down to selection of specific group of TDM circuits at a Trunking media GW (TGW) and associated ISUP route(s) toward next TDM exchange (TDM interconnect) or specific logical interfaces or IP realms at a Border media GW (BGW) and associated SIP(SIP-I) route(s) toward next call server (IP interconnect).

ENUM routing database enables selection of target node or point of interconnects directly or via intermediate nodes. Addition of routing parameters in destination address identifier (i.e. SIP/tel URI) that identifies specific route enables steering of routing directly over next-hop or intermediate-node and avoids repetition of call processing related to number and routing analysis in next-hop or intermediate-node. This node based on received routing parameters directly determines the outgoing route and the interface(s) to interconnected network.

Routing Scenario	ENUM Routing Information (URI)
Target node (call server) in own network	sip:+1123456@cs1.operator.com;user=phone
Target node in PSTN islands	sip:+1134567;trgrp=isupTE1-1;trunk-context= cs2.operator.com@cs2.operator.com;user=phone ?route=cs2.operator.com
IP Interconnect	sip:+17654321@otheroperator.com; bgrp=extif11.bgw1;border-context=cs2.operator. com; user=phone?route=cs2.operator.com
TDM Interconnect	sip:+19876543;trgrp=otherop11;trunk-context= cs2.operator.com@cs2.operator.com;user=phone ?route=cs2.operator.com

Table 1: Routing data in ENUM (SIP URIs) that identifies target or intermediate nodes (dependent on call routing scenario)

Note that today only trunk group is officially defined in IETF [6]. However, this paper's proposal is to use new SIP URI parameters (bgrp, border-context) to identify specific border node(s) and interface(s) in case of IP interconnect scenarios (alternative could be to reuse trunk group parameter – i.e. extend application of trunk groups to IP interfaces).

Possibility to steer calls through the own network to the specific point of interconnect will be necessary requirement to fulfill present and future interconnect agreements with other operators. Therefore, feature to select interconnect points at finer granularity is obvious advantage in fulfilling this requirement.

V. ENHANCED ENUM ROUTING METHOD

ENUM enables alternative routing based on order/ preference of routing alternatives specified as NAPTR resource records. However, this is simple sequential alternative routing without support for load sharing or more complex alternative routing scheme. This may be overcame with extensions to the NAPTR specification that would support load sharing and other schemes (e.g. weights may be introduced similar as in SRV resource records to enable load sharing).

Besides selection of breakout node or target node in the control plane on call signaling level (i.e. call server), and user plane node (i.e. media gateway) based on destination information – called number, routing capabilities should as well support selection of these nodes based on some additional criteria. Such criteria can include origin/source information, calling subscriber identity, call priority, type of calling subscriber or even some other routing attributes. One of additional basic criteria could include geographical location and distance from originating subscriber or media gateway where originating subscriber is connected. However, in order to support such selection, ENUM used as the routing method should be enhanced with capabilities to include additional attributes as part of specification of routing alternatives (e.g. NAPTR resource records) as well to include additional attributes as part of standard ENUM queries. Based on the routing attributes values received in ENUM query, ENUM routing database will return different set of routing alternatives results. This puts requirements on ENUM(DNS) servers to support more complex provisioning of ENUM resource records, flexibility in selecting records and storage capabilities for increased number of records. Additionally, related information should be as well propagated at the call signaling level in the appropriate information elements. These can be fulfilled via URI extensions – new URI parameters holding such information, NAPTR resource records extensions and extensions to the DNS/ENUM query mechanism to include additional information in ENUM queries.

Recommended approach would be to specify and standardize (in IETF) set of such information elements to enable industry wide implementations of enhanced call routing capabilities based on IP technologies (ENUM and SIP). Similar, but only initial approach has been done already to enable possibility to select specific trunk group at a PSTN gateway node (see previous chapter, [6])

Further, more advanced enhancements to the routing methods is possibility to perform routing based on some dynamic routing attributes (e.g. such as load level of routing targets). Such data and other general routing attributes could be even dynamically supplied or exchanged (e.g. partial update like changing load factor or complete change or update of routing alternatives) via DNS update or other mechanisms (like [3] or [9]).

There are at least the following two main possible approaches in inclusion of additional attributes as part of ENUM query which can determine different routing results based on different attribute values:

- First, to prefix number based domain name with the routing attribute value (e.g. origin information) to which the routing result is dependent.
- Second, to use extension of DNS (EDNS0) to carry the routing attribute as part of an ENUM query in extended part/parameters of the DNS(ENUM) query message.

In the first approach, for example, origin information may be based directly on some real geographical data or may just resemble some geographical areas (i.e. 0 – Zagreb Donji Grad , 1- Novi Zagreb, …, 255- Dubrovnik) where an originating node is located (e.g. an AGW of originating subscriber, a TGW for incoming TDM call entering the NGN or a BGW for incoming interconnect call entering the NGN). The origin information (0-255) is appended as a prefix to the E.164 number domain (7.5.6.4.3.2.1.1.e164.operator.com), i.e. 255.7.6.5.4.3.2. 1.1.e164.operator.com and a DNS/ ENUM query is launched for such domain. Different results (NAPTRs) may be returned for different origin information for that E.164 number. However, this approach may end in a large number of proprietary implementations.

In the second approach, such additional information is carried in ENUM (DNS) query in additional information part of the message using specific record information. This approach is more aligned with standard way of dealing with extension and transfer of additional information in DNS/ENUM query messages and support freedom of supporting different format of information not limited to domain name rules. Currently this approach in promoted inside IETF ENUM Working Group in draft specification for supplying source URI as origin information in the ENUM query [8] .

VI. CONCLUSION

ENUM can act as a strong enabler for hosting any subscriber number on any call server removing limitation of hosting only specific number series at particular call server. It inherently supports portability of subscribers and thus enables straightforward implementation of number portability in the NGN environment. ENUM acting as general routing database as well as a NP database can, with all call query approach, in a single query support number portability and target routing information in the query result eliminating need for multiple queries.

ENUM facilitates simple routing logic in a call server based on received routing alternatives (SIP URIs) without need to hold specific routing tables and enables direct routing without call routing processing in next-hop nodes for interconnected destination. Use of ENUM can additionally simplify analysis and call control functions in call servers. Implementation of centralized logic of routing for whole network with support of ENUM would benefit from use of centralized procedures (i.e. supported by OSS) for provisioning of subscribers in call servers and routing data in ENUM based routing database.

Main disadvantage with use of ENUM is introduction of completely new infrastructure for routing, but as ENUM is based on DNS, DNS infrastructure would normally be part of any NGN (though ENUM puts more demands on DNS infrastructure).

Although ENUM has a number of strong advantages, further standardization steps and enhancements to the ENUM specifications and standards are needed in order to turn ENUM into full fledged and powerful routing solution for the NGN.

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