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NICC Document

VoIP Call Routeing between UK Networks

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Contents

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Foreword

This NICC Document (ND) has been produced by NICC IP Routeing TG.

Introduction

Communications Providers (CPs) in the UK are currently migrating or have already migrated to an all-IP network infrastructure. In parallel, Ofcom are considering the introduction of a common numbering database, which could be used to facilitate the introduction of STIR [i.1] technology, the direct routeing of traffic to ported numbers and eventually the removal of the concept of a range-holder network. This affords the opportunity to review the routeing of calls within and between UK networks.

Currently, calls are routed either according to the leading digits of the dialled number or, in some cases – notably calls to ported numbers – based on inserted prefix digits.

When number ranges are allocated to a CP, from that point onwards that CP acts as the 'Number Range Holder' for that range, which results in all calls being routed initially to the Range Holder, even if the destination numbers have been ported to another CP. This means that the Range Holder must onward route calls for destination numbers which have been ported away from them, which is an inefficient use of resources.

Interconnection is predominately on a bilateral basis between operators, with non-geographic and mobile calls handed over on a near-end-handover basis, and geographic calls handed over on a far-end-handover basis.

The adoption of IP technology means it is appropriate to review whether the current methods for routeing calls can be improved, and to review the feasibility of implementing change. It is assumed that Network Operators will seek to route calls as directly as possible to terminating networks, but that they will not be regulated to do so.

1 Scope

This document proposes a method for a more efficient routeing of IP calls between UK Network operators and discusses the factors and impacts which should be considered in doing so. The report is primarily intended to identify the technical aspects of this improved routeing but recognises that some changes to call routeing may have commercial consequences.

The following questions will be addressed:

- Should a common numbering database be adopted for call and message routeing?
- What should the “key” for routeing be?
- Should the near/far-end handover paradigm persist for different traffic types?
- How will portability be implemented?
- Should interconnection remain a bilateral exercise, or should there be alternate measures such as public peering points? If so, what standards are needed?
- How will calls be managed and routed in a more efficient way between Communications Providers?

2 Informative References

The following referenced documents offer complementary information to assist the reader to glean a wider knowledge and understanding of the topics covered in this document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

[1] STIR – A system defined as a series of *Requests for Comments* (RFC) documents by the IETF:
RFC 8224 - Authenticated Identity Management in the Session Initiation Protocol
RFC 8225 - PASSporT: Personal Assertion Token
RFC 8226 - Secure Telephone Identity Credentials: Certificates
RFC 8588 - Personal Assertion Token (PaSSporT) Extension for Signature-based Handling of Asserted information using toKENs (SHAKEN)

[2] RFC 4694 Number Portability Parameters for the "tel" URI
[3] NICC ND 1203 Geographic Number Portability
[4] NICC ND1207 Non-Geographic Number Portability
[5] NICC ND1208 Mobile Number Portability
[6] RFC 3261 SIP: Session Initiation Protocol
[7] Ofcom General Conditions of Entitlement

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Common Numbering Database	The generic function which holds reference mapping of telephone numbers to serving Communications Provider. The Common Numbering Database (CDB) is the general term for the authoritative database and all copies of it held locally by individual Communication Providers.
IP Routeing Capable	The capability of a network to query and upload data from/to a CDB in order to assist with more efficient routeing of telephone calls, and also able to interpret CDB related parameters received in signalling from an upstream network.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CDB	Common Numbering Database
CLI	Calling Line Identity
CP	Communications Provider
IETF	Internet Engineering Task Force
IP	Internet Protocol
NPDI	Number Portability database Dip Indicator
RN	Routeing Number
SHAKEN	Signature-based Handling of Asserted information using toKENs
SIP	Session Initiation Protocol
STIR	Secure Telephony Identification Revisited
URI	Uniform Resource Identifier

4 IP Call Routeing

4.1 Common Numbering Database

Today, each Communications Provider (CP) maintains their own routeing tables in their switches, intelligent network or numbering database, which hold information on which ranges they are the range holder for, and for all other number ranges information on to where they should route calls destined for those numbers. The disparate, decentralised nature of these repositories means that it is impracticable to hold synchronised routeing information on an individual number basis across all networks. It also complicates the number porting process; whilst only the donor, rangeholder (if different) and recipient networks need to update their routeing tables to port a number; synchronising this is complex. The number porting process currently allows that the port may complete by midnight on the day of porting, to ensure that all parties have updated their local databases.

The advent of a Common Numbering Database (CDB) would mean that changes to a number's ownership would only need to be made in a single update transaction, and the latest data would be available to all CPs utilising it. This would not only greatly facilitate a better, faster number porting process, but could also be used to enable CLI verification services (STIR/SHAKEN) to confirm which numbers belong to which CPs, and also enable the direct routeing of calls to the network which owns a destination number rather than routeing via the legacy number range holder.

NICC has examined whether it would be possible to optimise routeing without a CDB. Annex A sets out a mechanism which is theoretically possible but presents significant technical risks.

Therefore, subject to a full cost and benefit analysis, a CDB is considered to be essential to bring efficient synchronised routeing information to multiple networks, and enable a better customer experience when changing CP.

Note: A separate study into the feasibility of using blockchain technology for a CDB is in progress, but the suitability of blockchain for this purpose is outside of the scope of this document. The benefits of using a CDB mentioned here are agnostic to the underlying technology of that database, or whether any query is to a real-time master of that database, or an off-line local copy.

4.2 IP Call Routeing Scheme

Assuming there is a CDB that specifies the terminating network for each individual number, then originating networks should query the database which will return a key which identifies the terminating network, so that if a direct route exists to that network it may be used as the most efficient path to the destination.

Networks that do not have access to the database may pass calls to a transit network that will make the query on their behalf and may choose to have a default transit network which performs that function.

A network which has migrated to IP and is capable of populating and querying a CDB for the purposes of sending and receiving directly routed traffic would be referred to as *IP Routeing*

Capable. When a network becomes IP Routeing Capable, it should populate the CDB with a routeing record for all of its numbers, i.e.:

a. Numbers which have been allocated to it and have not been exported to other networks
b. Numbers which have been imported from other networks

Numbers which are not hosted on IP Routeing Capable networks may still have entries in the CDB for administrative purposes, but these numbers will not have routeing records containing routeing keys. If a number is not routeable or if a number has simply not been populated in the database, there will be no routeing record, i.e. no routeing key will be returned.
An IP Routeing Capable network is also able to interpret CDB related parameters received in signalling from an upstream network.

4.2.1 Routeing Key

If the queried number resides on an IP Routeing Capable network, then the database will return a routeing key in the form of a Routeing Number (RN), as described in RFC4694 [i2].

The format for the RN would need to be standardised. RFC4694 describes RN in the tel URI, but this could be adapted to SIP URI (as described in RFC3261 Section 19.1.6 [i6]).

It is expected that the RN will be of the same format used today for routeing Ported Numbers between CPs to facilitate transition to the new routeing method and also ensure continued interoperability between IP Routeing Capable networks and legacy networks.

For geographic numbers this may be chosen to align with ND1203[i3] and for non-geographic numbers, with ND1207[i4]:
sip:+441234567890;npdi;rn=5XXXXX;rn-context=+44@ipaddress;user=phone

The mobile format could be chosen to align with that already defined in ND1208[i5].
sip:+447818012345;npdi;rn=+44799X818012345@ipaddress;user=phone

The RN would identify the terminating communications provider serving the number. As there are many relationship models for the assignment of numbers, this report is not prescriptive with regard to what constitutes a communications provider in this context, but it is assumed that RNs will be assigned to the same group of entities to which Ofcom would currently assign number ranges. On the whole, this would mean a RN represents a Public Electronic Communications Network, but there are scenarios where network provision has subsequently been outsourced to third parties; – this means that a single network would host multiple providers' RNs.

A central register would be kept of all RNs/RN prefixes (in the case of mobile), showing the provider which each RN is assigned to, and potentially the host network for that RN.

A network may choose to have multiple RNs, where different RNs identify different network nodes, or are potentially used for the accounting/charging of different traffic types – see Section 7. If a network hosts multiple communication providers, it may use a different set of RNs for each provider.

Alternatively, a new range of RNs could be introduced which would facilitate the parallel running of a new commercial regime for direct routeing alongside the existing commercial arrangements used for onward routeing.

The Number Porting database Dip Indicator (NPDI) is used to indicate that the CDB has been queried to prevent subsequent networks in the call path querying the database again. The NPDI will always be present following a database query to show that a query was performed, even in the case where there is no RN entry returned from the database.

4.2.2 Originating Network Actions

An IP Routeing Capable network, when originating a call, should query the dialled number in the CDB.
On receipt of the returned RN, the querying network should then select a route based on the RN:

a. If the querying network has a direct interconnect with the terminating (IP routeing enabled) network, it should route the call directly to the terminating network, including the RN and NPDI parameters.
b. If the querying network does not have a direct interconnect with the terminating network, it should select a transit network route and include the RN and NPDI parameters as above (if the signalling system allows).

When considering routeing based on RN, routeing tables would be populated locally, and it is a matter for individual CPs to develop the routeing for each RN based on information from Ofcom and the connections from the CP into the wider network.

If the originating network queries a number in the CDB and there is no routeing record for that number, it can conclude that the terminating network is not IP Routeing Capable, and therefore should route the call based on the destination number range, but with the NPDI set (if the signalling system allows).

4.2.3 Subsequent Network Actions

Subsequent IP Routeing Capable networks would first check whether the NPDI is set.

If the NPDI is not set, then the network would query the CDB and act on the response as set out in Section 4.2.2.

Where the NPDI is set, it should then check for the presence of an RN.

If present, it would then check that the received RN is assigned to them, and then:
a. If it is, then they handle the call based upon the content of the destination number. In the event that they did not host that destination number, then this is indicative of a data error hence the call should be failed to avoid circular routeing - other than if a scheme is put in place for temporary routeing of calls from donor to recipient networks.
b. If it is not, then route based on the RN towards the Terminating Network, or if the network does not have a route for that RN, they should fail the call.

If the RN is not present, it should then route based on the destination number, without performing a CDB query, but still passing on the received NPDI parameter.

5 Call Routeing Examples

5.1 Direct IP Routeing

Figure 1 shows a call from Originating Network A which has a SIP interconnect with Network D (which is IP Routeing Capable), where the destination number has been ported from Network C.

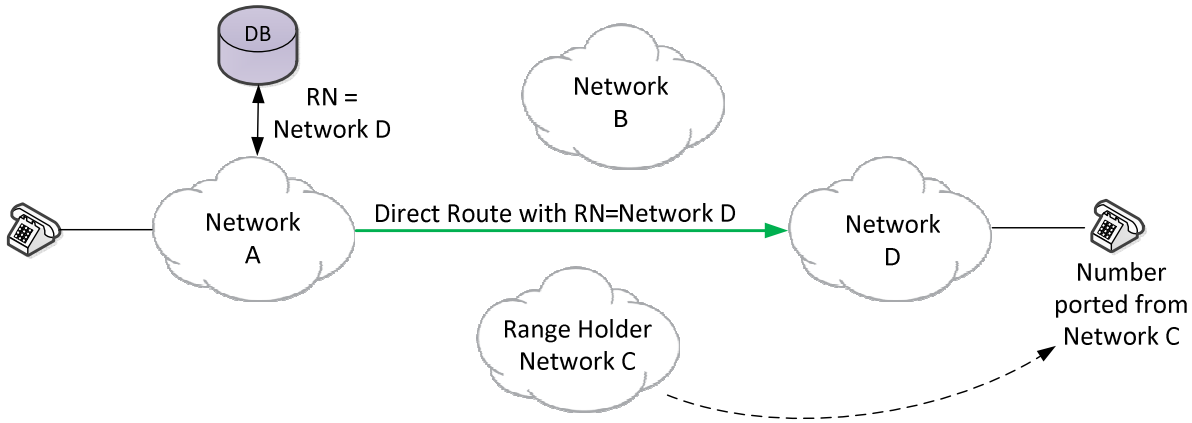

Figure 1: Direct Routeing between IP Routeing Capable Networks

Legacy routeing would have entailed the call being routed via Network C, which is the original range-holder for the destination. Here, the CDB lookup enables direct routeing to Network D, the new owner of the number which has been ported from Network C.

5.2 Transit IP Routeing

Figure 2 shows the case a call from Originating Network A which has does not have a SIP interconnect with Network D (which is IP Routeing Capable), where the destination number has been ported from Network C.

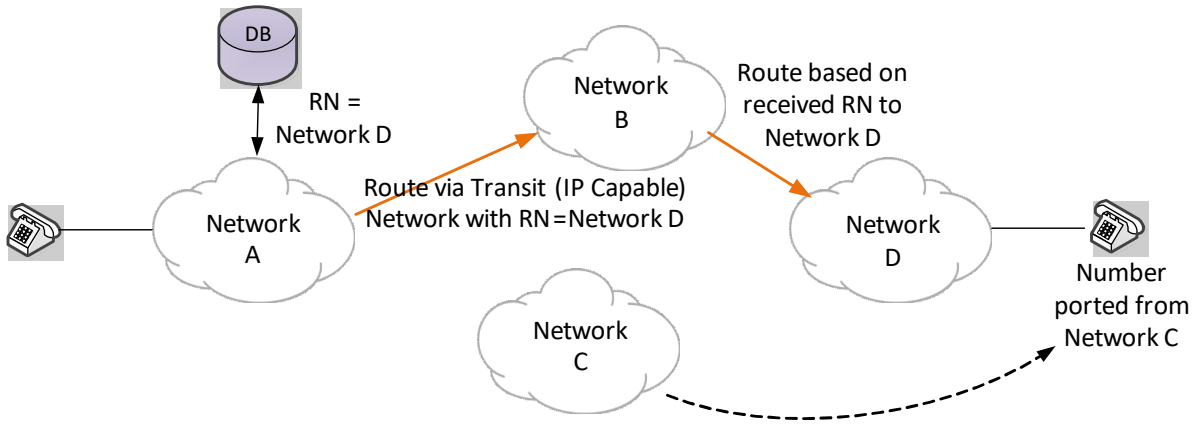

Figure 2: Indirect IP routeing between IP capable networks

In the example shown in Figure 2, Network A uses a transit IP Routeing Capable network B. Network B routes the call on to Network D based on the RN received from Network A and does not need to analyse the destination number or perform a database lookup itself.

5.3 Routeing to a network which is not IP Routeing Capable

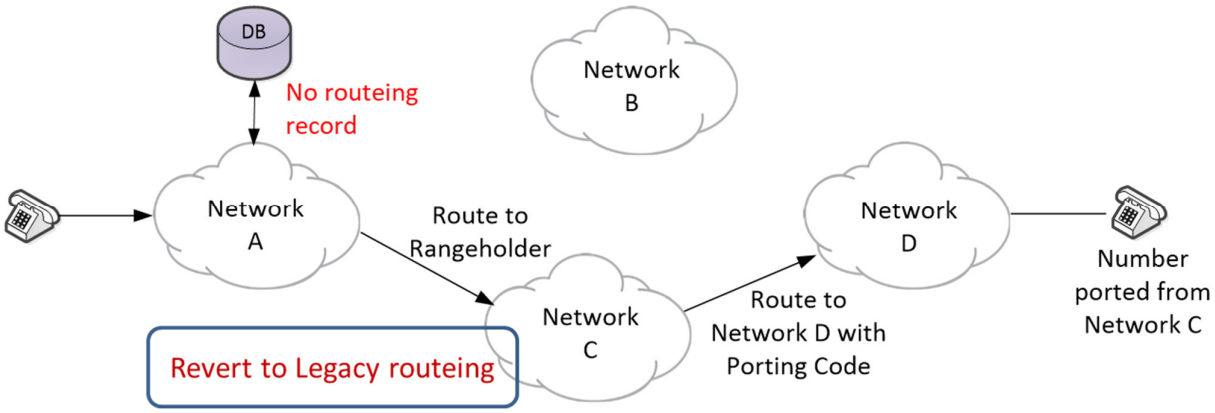

Figure 3: Routeing to a network which is not IP Routeing Capable

In the example shown in Figure 3, Network A looks up the destination number in the CDB and finds no routeing record there. Thus, Network A concludes that the terminating network is not IP Routeing Capable and reverts to legacy routeing techniques by routeing the call to the range-holder network (C). Network C knows that the number has been ported away to Network D and routes the call to Network D with a prefixed porting code.

5.4 Single Query per Call

The question could be asked as to why only the first Network in a call flow should query the CDB.

Consider the case where Network A originates a call to a number that it has exported to Network C, but there is no direct route between them. Network A queries the CDB which returns the RN of Network C, but as there is no direct route to C, it routes the call to transit Network B. (See Figure 4)

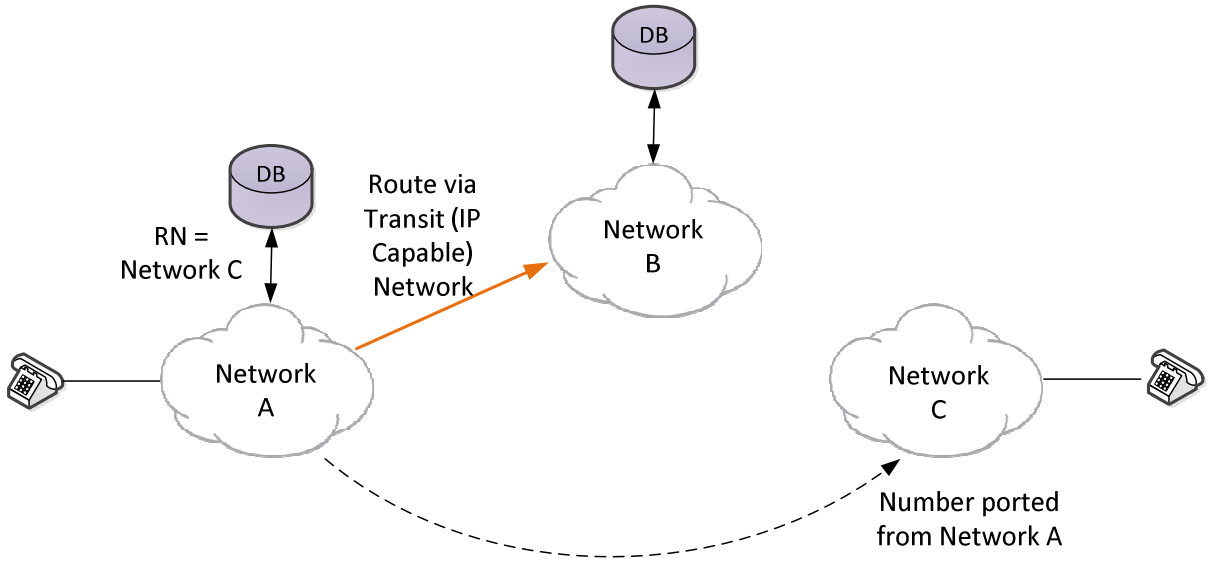

Figure 4: Multiple queries per call

If on receiving the call from Network A, Network B ignores the NPDI and performs a look-up to its own local copy of the CDB, the database *should* also return the RN of Network C. The risk with this approach is that Network B's database copy could be lagging behind that of Network A, and may still return a RN of Network A. The result would be that Network B routes the call back to Network A, and circular routeing would occur. (See Figure 5)

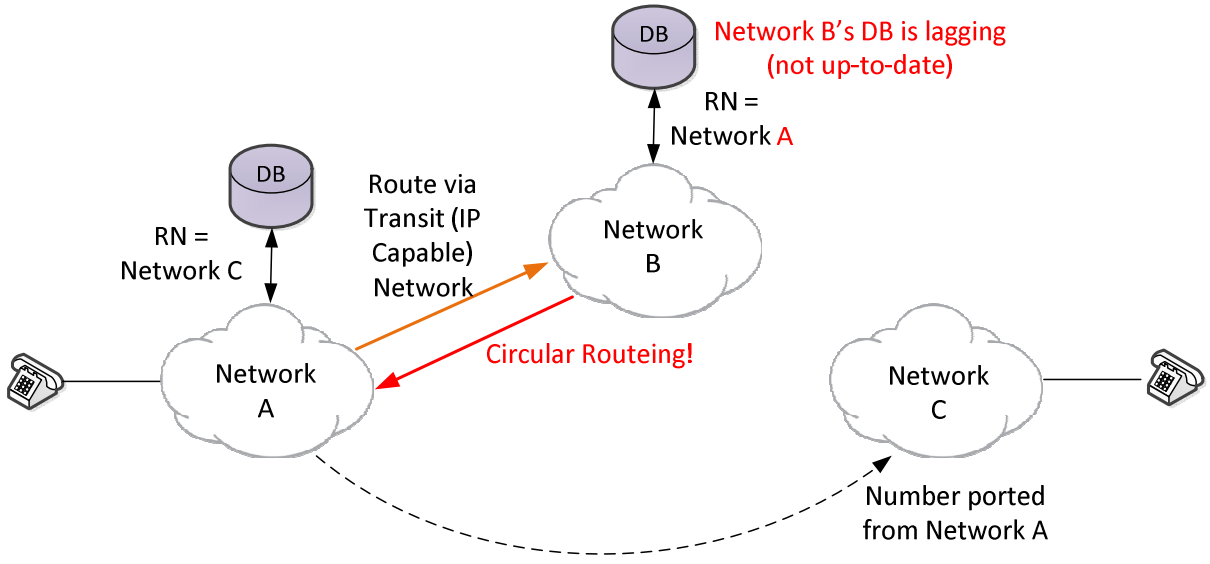

Figure 5: Circular Routeing caused by multiple database queries

6 Leveraging a CDB to Enhance Mobile SMS Routeing

Today, originating SMS Service Centres (SMS-SC) locate the correct destination Visitor Location Register (VLR) for SMS delivery by sending a request to the rangeholder Signalling Relay Function (SRF), which depending upon whether the destination number is ported, redirects the request to its own or the recipient network Home Location Register (HLR). The HLR responds with the identity of the VLR to the originating SMS-SC, which then uses it to route the underlying SMSs directly.

"Recipient trap", which is universally adopted among the main UK mobile networks, enhances this approach by the originating network routeing all outbound messages via its own SRF, which contains a record of numbers that it has imported and traps messages to them – thus meaning that signalling associated with calls & SMSs originated on the recipient network do not route via the rangeholder network.

By incorporating the contents of the CDB into the originator's SRF so that it contains data about all ported mobile numbers rather than those just imported to its network, it means that the originator's SRF could route all signalling associated with both calls and SMSs directly to the relevant recipient network.

Note that similar considerations apply for MMS Services.

7 Node and Service Considerations

Section 4.2.1 touched on the possibility of having multiple RNs per network. Here we consider the benefits of multiple RNs in more depth.

7.1 The Near or Far End Call Handover Paradigm

A called number can be determined as a geographic or non-geographic number based on the leading digits of that number.

7.1.1 Geographic Call Termination

There is a live regulatory debate about interconnect charging. There could potentially be a shift in the way regulated termination rates are applied from today's model where regulated rates only apply at pre-specified terminating nodes, to a flat-rate model where regulated termination rates apply at any delivery point/node. This in turn could lead to a change in paradigm so that calls are routed over the nearest point of handover to origination, rather than delivered at the handover nearest to the terminating user.

Notwithstanding any benefits in charging arrangements, there may be other benefits to delivering these calls to the correct terminating node.
Consider an example of two networks, Network A having two nodes and Network B having 10 nodes -

- There is good connectivity between the two networks for resilience purposes, meaning each of A's nodes are connected to 5 of B's nodes.
- If A queried the database and just received an answer of "B", then this would be sufficient to get the call to the correct terminating network and, with flat rate charging, that would be sufficient from a commercial standpoint.
- However, network A would choose the wrong node in 90% of cases, when it could have targeted the correct node in 50% of cases without using any additional assets in its own network.
- So, without identification of the terminating node, we are engineering in a series of unnecessary double hops, which ultimately have a cost and represent an increased chance of call failure.

As such there is a strong argument for providing the terminating node information within the RN for geographic numbers.

7.1.2 Non-geographic Call Termination

Calls to non-geographic numbers are charged at different rates on an individual number basis, depending on the service provided to the user when calling each number, and are not representative of the handover point to the next network. Therefore, each network routeing non-geographic calls has to analyse the destination numbers in order to apply the correct rating and charging to the calls. Hence, for non-geographic numbers, there is merit in a separate RN being used to indicate that a different charging regime prevails.

So, whilst it would be superfluous to use a RN for each individual Service Charge level on 08/09, it is logical to have a specific RN for each network that indicates that the call is to a non-geographic number (signifying that networks should use the destination number to determine the interconnect charge applicable). A possible alternative for consideration would be to use the 'cic' parameter for non-geographic numbers, as described in RFC 4694 [2].

It is proposed that there should be a maximum number of RNs for each CP that identify geographic calls (N x according to the node considerations above), plus 03, 07 and 08/09. An alternative approach might be that there are a set of RNs for geographic nodes, and just a single one for everything else, indicating the need to examine the destination number to determine how to account.

8 Carrier of Last Resort

Ofcom General Condition B4.2[7] requires all telecoms providers to ensure that end-users can access all telephone numbers in the European Union (including UK numbers in the National Telephone Numbering Plan), where technically and economically feasible. Though this requirement is for all CPs, at the time of publication of this report there is one CP which is subject to a specific access condition (i.e. the End-to-End (E2E) Condition) which in practise means that other CPs can use that CP as the 'carrier of last resort' to route calls to when the originating CP does not have an interconnect to the terminating network or does not know how to reach the terminating network.

If the E2E Condition were to be removed by Ofcom, CPs may not know which onward networks they can use to reach every destination. The RN returned by the CDB would, on its own, not help in

this regard as it would identify the terminating network without giving any information on how to reach it.

A potential way forward may be for small networks (e.g. those interconnected to fewer than N networks) to have a means of publishing the transit networks to which they connect. This could be in the form of a simple register stored centrally, for example in the register of assigned RNs. This would then allow originating networks to target their transit network of choice.

9 Bi-Lateral Interconnect versus Peering Points

While it is accepted that originating operators need to be able to route traffic to all terminating operators, it is expected that routeing will continue to be over bi-lateral interconnects, either directly to the terminating network or via a transit network.
The concept of telephony peering points is contrary to the current needs of CPs to:

- secure their networks from attack
- be able to charge for individual calls based on destination and duration
- only route calls from customers who have signed up to a charging agreement
- maintain regulatory compliance – being responsible for emergency location information and which numbers call originators have the rights to use for Calling Line Identification.

In the UK there are already plenty of transit Communications Providers who effectively act as peering points for customers who sign into contractual agreements with them, and will transit all of their calls from multiple points of interconnect, on towards the terminating networks either directly or through subsequent transit carriers.

10 Porting

The adoption of a CDB and IP call routeing scheme, as described in section 4, facilitates the eventual demise of the concept of default number range holder. This would evolve over a period of time as all numbers are allocated to CPs in the CDB, and re-allocated either individually or in bulk to gaining CPs where a number or numbers are ported.

Though the scheme for routeing is vital to the successful end-state, the process that CPs need to adopt to port numbers, and the associated timescales for porting, will be dependent on the CDB structure and the ability of individual CPs to update the database and consume the data as near to real time as possible. These aspects are outside of the scope of this document which is concerned with the technical feasibility of routeing calls as efficiently as possible once that data has been populated.

10.1 Routeing of Calls During the Porting Window

Today, numbers which are in the process of being ported from a donor network to a gaining network could be subject to outages during the porting window until the routeing tables of the CPs involved in the porting process are all up to date. Such outages are minimised as the routeing of

calls is only determined by the routeing being changed in the rangeholder, recipient network and, to a limited extent, the donor network. In contrast, in a CDB environment, calls will not be universally routed correctly until all originating networks have synchronised their routeing tables with the CDB.

To mitigate this, it is advised that during a suitable porting window – for example on the day of the port - IP Routeing Capable donor networks would onward route any calls destined for numbers which they have ported out to the recipient network. This would mean that if originating networks with an outdated copy of the CDB sent the call to the donor network, then the call would route to the recipient network, albeit not in the most efficient manner. Note that this differs from the situation today, where it is the rangeholder (rather than donor) network which onward routes calls.

11 Conclusions and Next Steps

This report concludes that, given the advances in switching technology that modern telephony networks exhibit, a more efficient method for call routeing is feasible in conjunction with a CDB solution. Such a database would hold routeing records which identify the destination networks (or even nodes) for all numbers, enabling a querying network to route as directly as their interconnect model affords to the destination network. In order that networks know how to reach all destination networks/nodes, it is anticipated that a central register of networks and their primary interconnects should be available.

The signalling of the destination network could be realised across network to network interfaces by making use of existing SIP parameters, which would limit the need for subsequent networks in the call flow to re-query the database and would also limit the risk of circular routeing.

The transition to a new IP call routeing scheme is not without challenges, as it is expected that different networks will adopt the new scheme at different times. Therefore, consideration has been made for routeing between IP Routeing Capable and non-IP Routeing Capable networks.

The next steps towards achieving the objective of efficient call routeing are to feed in requirements to a cost and benefits analysis of CDB solutions which would be capable of supporting the scale, speed, and robustness required to support the demands of call routeing and number porting.

Annex A: Alternative proposals for IP Call Routeing without a Common Numbering Database

A.1 Self-Learning Method

As an alternative to a reliance on a CDB for IP Call Routeing, a mechanism could be possible for CPs' routeing tables to be self-learning. After initial routeing data population, CPs would route calls to the notional range-holder networks based on the destination number.

Where a number is ported, the donor CP would reject any received call to that number with a 3xx class response, supplying the routing information for the new (gaining) recipient network. The originating network would then retry the call using the updated routing information.

On receipt of a **SIP 301 Moved Permanently** response, the call originator would update their database to reflect the new routing information so that subsequent calls would not route to the notional rangeholder network.

A.1.1 Advantages of a Self-Learning method:

Eliminating the need for a CDB is a significant advantage, due to the potential cost and complexity of setting up a database with the capacity, security and resilience required for such a critical purpose. The governance, ownership, and ongoing operation of a CDB are not trivial matters.
Routeing would be instantly improved, as this mechanism would eliminate all need to trombone calls, even immediately after a number is ported.
Networks would be self-learning, updating themselves whenever they send a call to a number which has ported.

A.1.2 Disadvantages of a Self-Learning method:

CPs would need to update their network software, as some form of feedback mechanism from the switching equipment to the database would be required which is not generally a feature today.

The routeing information for each number would be stored independently on every CP. It would not be updated until a customer on that CP attempts to call the number. If a number is ported multiple times, there may end up being different routeings stored by different CPs. A number that is ported repeatedly, but rarely called, may result in networks receiving more than one 3xx redirect before the call arrives at its destination.

A mechanism to add an initial routeing choice for newly issued numbers would be needed. With a CDB, the issuing body (Ofcom) would add the numbers to the CDB, and all CPs would pick this up with their next update. Without a CDB a separate mechanism would be needed to add new numbers to all CPs routeing tables. There would be no central list of which numbers belong to which network, so an external list of the notional range-holders for each number range would need to be

maintained by Ofcom. A new entrant to the market would rely on this list for initial population of their routeing database.

There would need to be strict security protocols applied, as this method would require CPs to trust routeing information received over the signalling layer, and to handle 3xx responses received from external parties, which is not currently the case. Otherwise a bad actor or an administrative error would have the potential to inject an incorrect 3xx response at any time and could permanently reroute a number. As such, some form of roll-back mechanism would be required to recover from bad information.

A process would be required for the re-allocation of numbers from a CP who ceases trading.

A.2 Temporary Redirect Method

There is also a possibility of making use of **SIP 302 Moved Temporarily** for routeing calls to ported numbers during the porting window, to re-direct calls to the gaining CP.

If no Expires value is given with a 302 Moved Temporarily, then the new routeing information for a number MUST NOT be cached, so all further requests to this number will be also sent to the donor, until the originator updates their database to reflect the port.

History

Document history		
Version	Date	Milestone
1.1.1	2nd July 2020	Initial publication on the NICC public site