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Description of the DNS protocol usage
in IP based operators networks

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Contents

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Foreword

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Modal verbs terminology

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1 Scope

The present document describes different use cases for the usage of the DNS protocol (e.g. Service Location, NP/ENUM, address resolution) in IP based operators networks. The DNS base protocol itself is defined in RFC 1035 [i.16].

The present document describes the behaviour and details for DNS protocol usage in IP based operators networks, transport options for DNS messages, DNS protocol behaviour and configuration as well as options to make the usage of the DNS protocol more reliable (e.g. timer characteristics etc.).

The use cases described here and options to make the usage of the DNS protocol more reliable are principal ones for network operators and not intended to be exhaustive.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ICANN: "Internet Consensus Policy 2: Criteria for Establishment of New Regional Internet Registries".

[i.2] ETSI TS 182 028: "Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN); NGN integrated IPTV subsystem Architecture".

[i.3] IETF RFC 5966: "DNS Transport over TCP - Implementation Requirements".

[i.4] ETSI TS 124 229: "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; IP multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 (3GPP TS 24.229)".

[i.5] IETF RFC 3263: "Session Initiation Protocol (SIP): Locating SIP Servers".

[i.6] ETSI TR 184 003: "Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN); Portability of telephone numbers between operators for Next Generation Networks (NGNs)".

[i.7] IETF RFC 3761: "The E.164 to Uniform Resource Identifiers (URI) Dynamic Delegation Discovery System (DDDS) Application (ENUM)".

[i.8] ETSI TS 184 009: "Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN); Rules covering the use of TV URIs for the Identification of Television Channels".

[i.9] IETF RFC 2838: "Uniform Resource Identifiers for Television Broadcasts".

[i.10] IETF RFC 2396: "Uniform Resource Identifiers (URI): Generic Syntax".

[i.11] IETF RFC 2782: "A DNS RR for specifying the location of services (DNS SRV)".

[i.12] IETF RFC 3403: "Dynamic Delegation Discovery System (DDDS) Part Three: The Domain Name System (DNS) Database".

[i.13] IETF RFC 1034: "Domain names - concepts and facilities".

[i.14] IETF RFC 2317: "Classless IN-ADDR.ARPA delegation".

[i.15] IETF RFC 3596: "DNS Extensions to Support IP Version 6".

[i.16] IETF RFC 1035: "Domain names - implementation and specification".

3 Definitions and abbreviations

3.1 Definitions

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

access network provider: service provider that provides physical and IP connectivity to a user equipment (UE) via a fixed or mobile access

3.2 Abbreviations

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

AfriNIC	African Network Information Centre
APNIC	Asia Pacific Network Information Centre
ARIN	American Registry for Internet Numbers
IANA	Internet Assigned Numbers Authority
DDDS	Dynamic Delegation Discovery System
DNS	Domain Name System
ENUM	tElephone NUMber mapping
FQDN	Fully Qualified Domain Name
ICANN	Internet Corporation for Assigned Names and Numbers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPTV	Internet Protocol TeleVision
LACNIC	Latin America & Caribbean Network Information Centre
LIR	Local Internet Registry
NAPTR	Naming Authority Pointer
NGN	Next Generation Network
NP	Number Portability
OSI	Open System Interconnection
P-CSCF	Proxy-Call Session Control Function
PTR	Pointer
RIPE NCC	Réseaux IP Européens Network Coordination Centre
RIR	Regional Internet Registry
RR	Resource Record
S-CSCF	Serving-Call Session Control Function
SDP	Session Description Protocol

SIP	Session Initiation Protocol
SRV	Service
TCP	Transport Control Protocol
TV	Tele Vision
UDP	User Datagram Protocol
UE	User Equipment
URI	Uniform Resource Identifier

4 DNS use cases in IP based operators networks

4.1 Service discovery

4.1.1 Service access point discovery

Service discovery can be defined as a mechanism which provides to a client, given a type of service that the client is looking for, and a domain in which the service is located and the IP protocol version the client is using, one or several IP addresses of systems which offer the requested services.

EXAMPLE: As described in clause 9 of ETSI TS 124 229 [i.4] the User Equipment (UE) can employ the DNS to obtain the P-CSCF IP address(es). This can be done when the UE is using IPv6 or IPv4 as a DNS or SIP/RTP message transport protocol and is valid for different IP-Connectivity Access Network (IP-CAN) types. Usually the UE will use RFC 3263 [i.5] to locate the P-CSCF IP address as a Session Initiation Protocol (SIP) server.

4.1.2 Locating service capabilities

The DNS protocol and infrastructure can be used to locate service capabilities in a DNS domain. In general there are 2 possibilities applicable:

- querying a FQDN which indicates service capabilities; or
- querying a distinct RR type and obtain the service capabilities from the answer.

In the first case the DNS client forms a FQDN which labels associate distinct service capabilities (e.g. SRV RFC 2782 [i.11]). On a try and fail basis the DNS is queried with this FQDN in the query section. When there is a RR delivered this service (DNS response code 0 - no error) is available in the DNS domain. When there is a negative answer (DNS response code 3 - NX Domain) this service does not exist in that domain. The application which triggers the DNS client can try to form a new FQDN which labels associate a similar service and sends a new DNS query with another FQDN in the query section. When there is no positive answer the application can try another FQDN or can stop using the DNS for service location for this current process.

In the second case the queried DNS Resource Records contain in their data section information regarding the available services for the domain. Therefore the DNS delivers typically several DNS RRs. So the DNS client can analyse this answer and select the best matching RR for the further processing of the communication service. A typical example for such a kind of service location is ENUM. The services field within the NAPTR RR [i.12] contains a character-string that specifies the service parameters applicable to the queried FQDN.

4.2 IP Address resolution

The impetus for the development of the domain system in the 1980's was the growth in the Internet. In the early days of the Internet the mapping of hostnames to IP addresses was provided in a single file (HOSTS.TXT) which was distributed via File Transfer Protocol by all hosts. This has now been replaced by the DNS. Whereas today the DNS provides possibilities for managing more than 100 different Resource Record types (http://www.iana.org/assignments/dns-parameters), the mapping of hostnames to IPv4 (DNS Resource Record Type 1) and IPv6 addresses (DNS Resource Record Type 28) is still a key functionality of the DNS. It should be mentioned that the queried resource record type is independent of DNS transport protocol.

A DNS client can:

- query an IPv4 address of a given FQDN by using IPv4 or IPv6 transport; and

- query an IPv6 address of a given FQDN by using IPv6 or IPv4 transport.

Resolving an IPv4/IPv6 address for a given/configured FQDN instead of configuring static IP addresses reduces the necessity of configuration on DNS client side.

4.3 Load sharing and load balancing

The basic idea of DNS load sharing is to associate several resource records with a single domain name. When the DNS responds to a request, it returns the whole list of resource records to the client. The resource records are then used in a round-robin or load-sharing fashion, thus providing some form of load balancing.

Four types of DNS load sharing techniques are possible:

- Load Sharing with round-robin DNS
- DNS views a.k.a. Split DNS
- Parsing and analyzing fields of the DNS query and calculating an answer
- DNS resource records with fields for priority indication

Load sharing with round-robin DNS

In its simplest implementation round-robin DNS works by responding to DNS requests not only with a single IP address, but a list of IP addresses of several servers that host identical services. The order in which IP addresses from the list are returned is the basis for the term round-robin. With each DNS response, the IP address sequence in the list is permuted. Usually, basic IP clients attempt connections with the first address returned from a DNS query so that on different connection attempts clients would receive service from different servers, thus distributing the overall load among servers.

DNS views

Setting up different views, or visibility, of the DNS space to internal and external resolvers is usually referred to as a Split DNS setup. This mechanism can also be used in order to distribute load on servers.
Due to the configuration of different views for different IP source address ranges on an authoritative DNS server, the authoritative DNS server will provide to each DNS client dependent on the IP address of the DNS client a preconfigured response. The figure 1 provides an overview on how an authoritative DNS server can process and answer a DNS query based on the source address of the query packet of the DNS client.

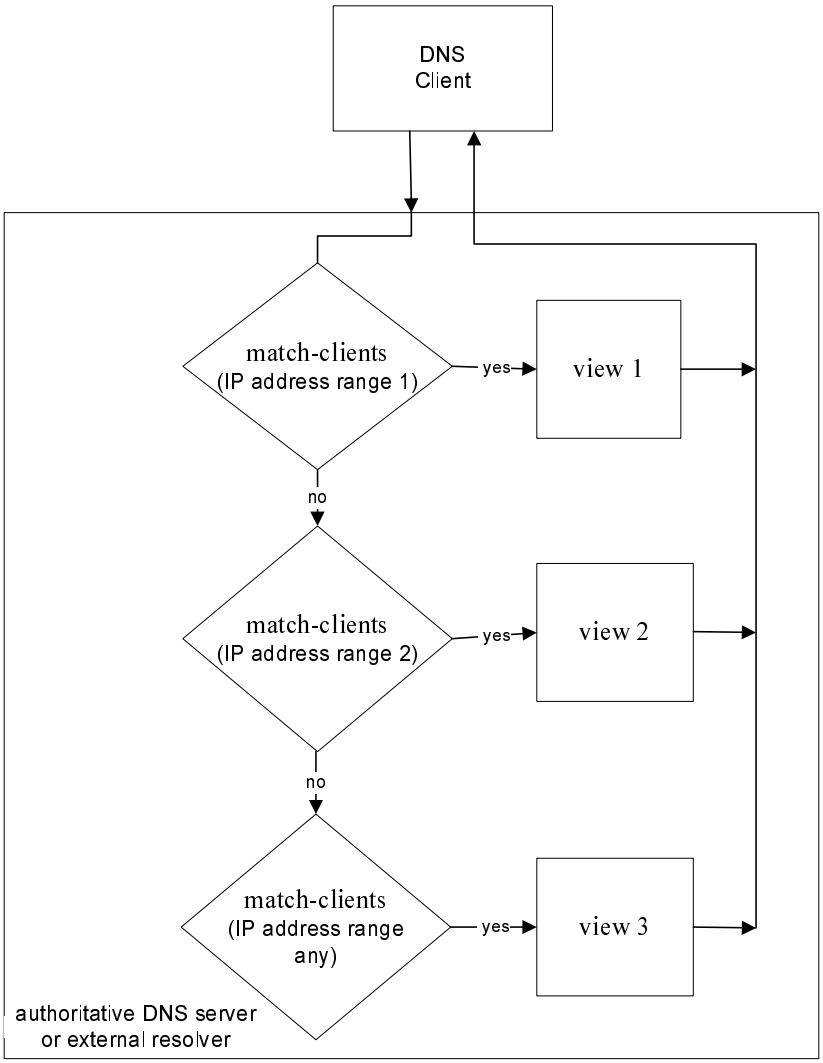

Figure 1: Processing of a DNS answer based on the IP address of the DNS client

Parsing and analyzing fields of the DNS query and calculating an answer

Similar to the split DNS approach where different DNS clients will be served with different answers based on a more or less static configuration it is possible to parse all or selected fields of a DNS query and calculate a DNS answer on demand based on distinct characteristics of the content of these fields. A typical use case here is the realization of DNS reverse mapping.

DNS resource records with fields for priority indication

Some resource record types contain in their data format fields which mandate the client to prioritize these RRs. Examples are the fields priority and weight within the SRV RR [i.11] or the fields order and preference within the NAPTR RR [i.12].

4.4 Number portability real time operational database

As described in ETSI TR 184 003 [i.6] DNS/ENUM is an option to provide Telephone Number Portability functionalities in NGN. Number Portability (NP) refers here only to the E.164 number part of the user's public identifier that, in NGN, can be represented with either a tel URI or a SIP URI (the user part of SIP URI) with the parameter "user=phone". ENUM itself is standardized in [i.7] and uses DNS protocol functionalities and mechanism.

4.5 Indicating security association

The DNS reverse mapping provides a capability to map an IP address to a hostname, whereas the authoritative rights for managing the DNS zone for the IP address will be delegated to the Local Internet Registry that assigns and allocates address space to its customers, telecom and enterprise organisations, as well as academic institutions.

By comparing the FQDN in the DNS reverse domain with a FQDN which is provided on an application layer a party can achieve a basic level of trust in order to prevent IP spoofing. This can be used as a part of a security or abuse-prevention policy.

As described in ETSI TS 124 229 [i.4] the FQDN can be used in the hostport parameter of different SIP header fields (e.g. Contact header field, in the sent-by field, in the Via header field). The receiver of this information (e.g. P-CSCF) can retrieve via a DNS reverse lookup this FQDN. In the case that both FQDNs are identical, the service provider can assume a binding between the network service provider (which manages the DNS domain) and the client.

4.6 Identification/locating television channels

ETSI TS 184 009 [i.8] provides rules for the identification ("naming") of television channels using the TV URI within a NGN integrated IPTV subsystem Architecture [i.2].

Due to the usage of Uniform Resource Identifiers for Television Broadcasts [i.9] and RFC 2396 [i.10] the usage of the DNS is mandated. ETSI TS 184 009 [i.8] itself describes several options for the harmonization of TV URIs. In any case the usage of DNS styled identifiers is related to the natural hierarchy of such a solution.

4.7 Identification of IP Connectivity Service Provider

4.7.1 DNS reverse mapping

With the so called DNS reverse mapping the DNS provides a capability to map an IPv4 or IPv6 address to an FQDN. This is described in RFC 2317 [i.14] for IPv4 addresses and in RFC 3596 [i.15] for IPv6 addresses.

Table 1 represents an example of mapping relations between IP addresses and hostnames. For the mapping of an IP address to a hostname a PTR (Pointer) resource record is used. The PTR-RR represents a FQDN. For the mapping of the FQDN of the PTR-RR to the IP address an A-RR respectively AAAA-RR are used.

Table 1: Example for mapping relations between IP addresses and DNS names

Reverse Domain	PTR-RR	IP address
1.2.0.192.in-addr.arpa.	Host1-IPv4. test-nat-1. example.com.	192.0.2.1
1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0. 0.0.0.0.0.0.0.0.8.b.d.1.0.0.2. IP6.ARPA.	Host1-IPv6. test-nat-1. example.com.	2001:DB80:0000:0000: 0000:0000:0000:0001

4.7.2 Identification of Access Network Provider

The global registry for the IPv4 and IPv6 address space is maintained by IANA. The IANA maintains a high-level registry of IP addresses and differentiates the global IPv4 and IPv6 address space in 3 parts:

- IP addresses that have been allocated to a RIR or other user;
- those that are reserved for a special use; and
- those that have not yet been allocated by the IANA and are reserved for future allocation and use.

For the use case identification of an access network provider based on the IP address only the IP addresses that have been allocated to a RIR are relevant.

The IANA maintains a high-level registry of IP addresses. It works with the Regional Internet Registries (RIRs) to distribute the large blocks of IP addresses among the RIRs. There are currently five RIRs, distributed around the world:

- AfriNIC (African Network Information Centre) for Africa and parts of the Indian Ocean
- APNIC (Asia Pacific Network Information Centre) for Asia/Pacific Region

- ARIN (American Registry for Internet Numbers) North America and parts of the Caribbean
- LACNIC (Latin America & Caribbean Network Information Centre) for Latin America and parts of the Caribbean
- RIPE NCC (Réseaux IP Européens Network Coordination Centre) for Europe, the Middle East and Central Asia)

The RIRs are the organizations that actually allocate IP addresses to Local Internet Registries. These allocations are in smaller blocks of addresses.

According to chapter 5 of [i.1] the RIRs are expected to have technical expertise to meet the specific technical requirements including provisioning of DNS servers to support reverse DNS delegation. This ensures that at least the RIRs are providing reverse DNS capabilities.

The RIRs are using different policies to provide IP addresses to Local Internet Registries. There is no common requirement available that mandates all Local Internet Registries to support DNS reverse mapping.

So the DNS reverse mapping does not cover the whole IP addresses that have been allocated to LIR and can therefore not be used to identify an access network provider on a global level.

Nevertheless the DNS reverse mapping mechanism can be used due to bilateral and multilateral agreements between service and access network providers to identify the access network provider of an IP address.

5 DNS functionalities within IP based operators networks

5.1 DNS topology

As described in RFC 1034 [i.13] the DNS has three major components:

- the domain name space and resource records;
- name servers; and
- DNS stub resolver and DNS resolver.

Figure 2 shows an end-to-end topology of DNS components and the application part.

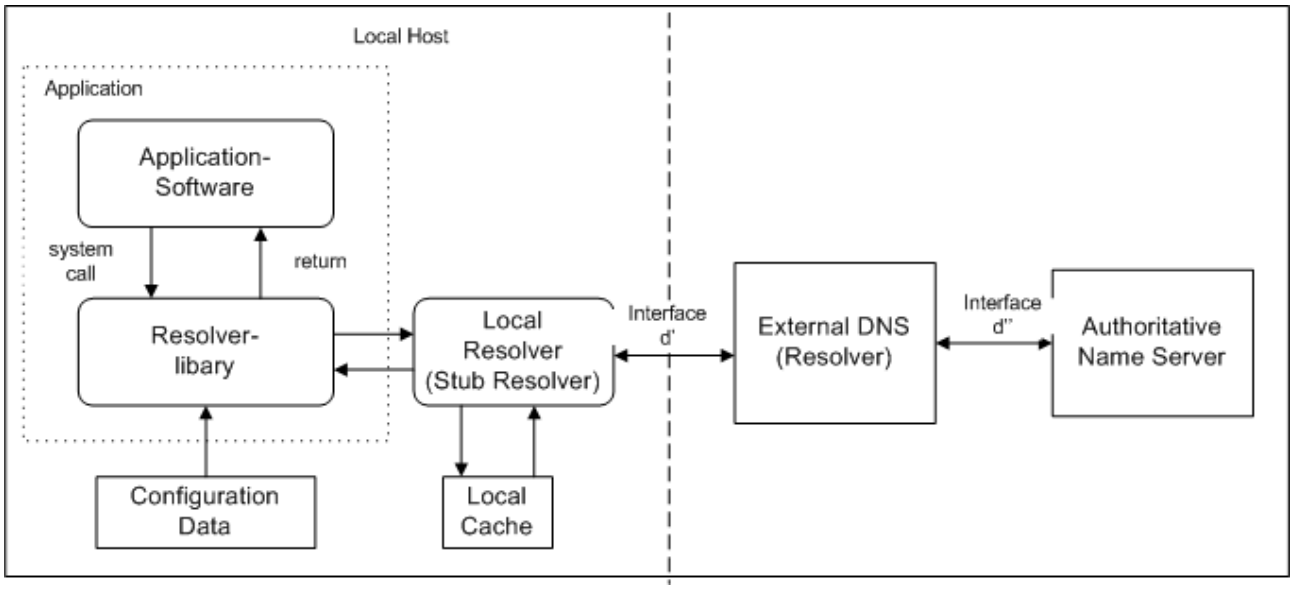

Figure 2: Topology of DNS components

A system (e.g. S-CSCF) which is using DNS functionalities needs on the local host at least a DNS resolver library and a local DNS resolver implementation. As interface to the external DNS (e.g. a DNS resolver) acts the d' interface.

The external DNS resolver interacts with the authoritative nameserver by using the d" interface.

5.2 DNS resolver

A DNS resolver is a local agent which retrieves information associated with a domain name. The retrieving of information can be triggered by a local application or the receiving of a DNS query from another DNS resolver (typically from a DNS stub-resolver). The requested information can be obtained by querying an authoritative DNS server or a lookup of cached DNS data. In order to process a query the DNS resolver asks a known authoritative DNS server for the information; in return, the DNS resolver either receives the desired information or a referral to another authoritative DNS server. Due to querying referrals, DNS resolvers learn the identities and contents of other authoritative DNS servers until the authoritative DNS server which is responsible for the domain name associated to the query replies to it. This process is also called recursive name resolution.

A DNS resolver can cache the data which are obtained during the recursive name resolution. Therefore in the case of repeated access these data are immediately available, without querying an authoritative DNS server.

5.3 DNS stub resolver

One option for implementing a resolver is to move the resolution function out of the local machine and into a name server which supports recursive queries. All that the remaining stub needs is a list of DNS resolver addresses that will perform the recursive requests. Usually a configuration file contains this information.

A stub resolver is typically a system routine that is directly accessible from user programs; hence no protocol is necessary between the resolver and the user programs.

5.4 Authoritative DNS server

An authoritative DNS server holds information about the domain tree's structure and the related set of information. In general a particular name server has complete information about a subset of the domain space, and points to other name servers that can be used to lead to information from other parts of the domain tree. Name servers know the parts of the domain tree for which they have complete information; a name server is said to be "authoritative" for these parts of the name space.

5.5 DNS protocol format

The DNS protocol is specified in [i.16]. Per definition the domain name system is a mixture of functions and data types, some of which are experimental. The official protocol parts include standard queries, responses and the Internet class RR data formats (e.g. A-RR, AAAA-RR).

5.6 The d' interface

Table 2 lists the protocol requirements of the different OSI layers for the d' interface.

Table 2: Requirements for the d' interface

OSI Layer	Protocol Requirements
Physical Layer	no special requirements
Link Layer	no special requirements
Network Layer	IPv4 and/or IPv6
Transport Layer	UDP and/or TCP
Application Layer	DNS

In the case that the usage of several protocols on an OSI layer is possible a bilateral agreement about the common used protocol on each OSI layer is necessary.

The interface itself can be shared with other applications or can be dedicated for using the DNS protocol only.

5.7 The d'' interface

Table 3 lists the protocol requirements of the different OSI layers for the d' interface.

Table 3: Requirements for the d'' interface

OSI Layer	Protocol Requirements
Physical Layer	no special requirements
Link Layer	no special requirements
Network Layer	IPv4 and/or IPv6
Transport Layer	UDP and/or TCP
Application Layer	DNS

In the case that the usage of several protocols on an OSI layer is possible a bilateral agreement about the common used protocol on each OSI layer is necessary.

Because the interface resides on the DNS system it is recommended to use the interface for the DNS protocol only.

6 Options to make the DNS usage more scalable and reliable

6.1 Optimization options

In order to provide a guaranteed service level within IP based operators networks there are measures needed to improve the Internet based DNS technology. In order to provide an efficient scaling of DNS systems within IP based operators networks optimizations are needed.

Optimizations can be reached due to:

- simplification of the network architecture;
- reducing the amount of messages to answer a DNS query; and
- self-recognizing of network or DNS failures.

Simplification of the network architecture means reducing the amount of network elements which lead to a reduction of the amount of messages to answer a DNS query.

A reduction of the amount of messages to answer a DNS query can be reached by means of DNS queries to an authoritative DNS server on the lower hierarchical level. Another opportunity would be to cache DNS answers and using cached data for answering DNS queries.

A useful self-recognition of networks and DNS failures can be reached by using on a DNS client an answer timer. When the DNS client does not receive an answer and the timer expires, this will trigger an action on the DNS client (e.g. resend the query to another DNS server).

6.2 DNS stub resolver

A DNS stub resolver can support the optimization of the IP based operators networks DNS in:

- simplification of the network architecture; and
- self-recognition of network or DNS failures.

A DNS stub resolver could make a DNS resolver within a IP based operator network architecture needless. This can be achieved via a domain specific configuration of the responsible authoritative DNS server.

Figure 3 provides an overview of how a local resolver can select the usage of an external DNS resolver based on the domain. A useful application could be that an S-CSCF sends ENUM queries e.g. for a root domain e164.private-infra.example.org. to another external DNS resolver that queries for a root domain for the IP based operator network infrastructure e.g. ngn.private-infra.example.org.

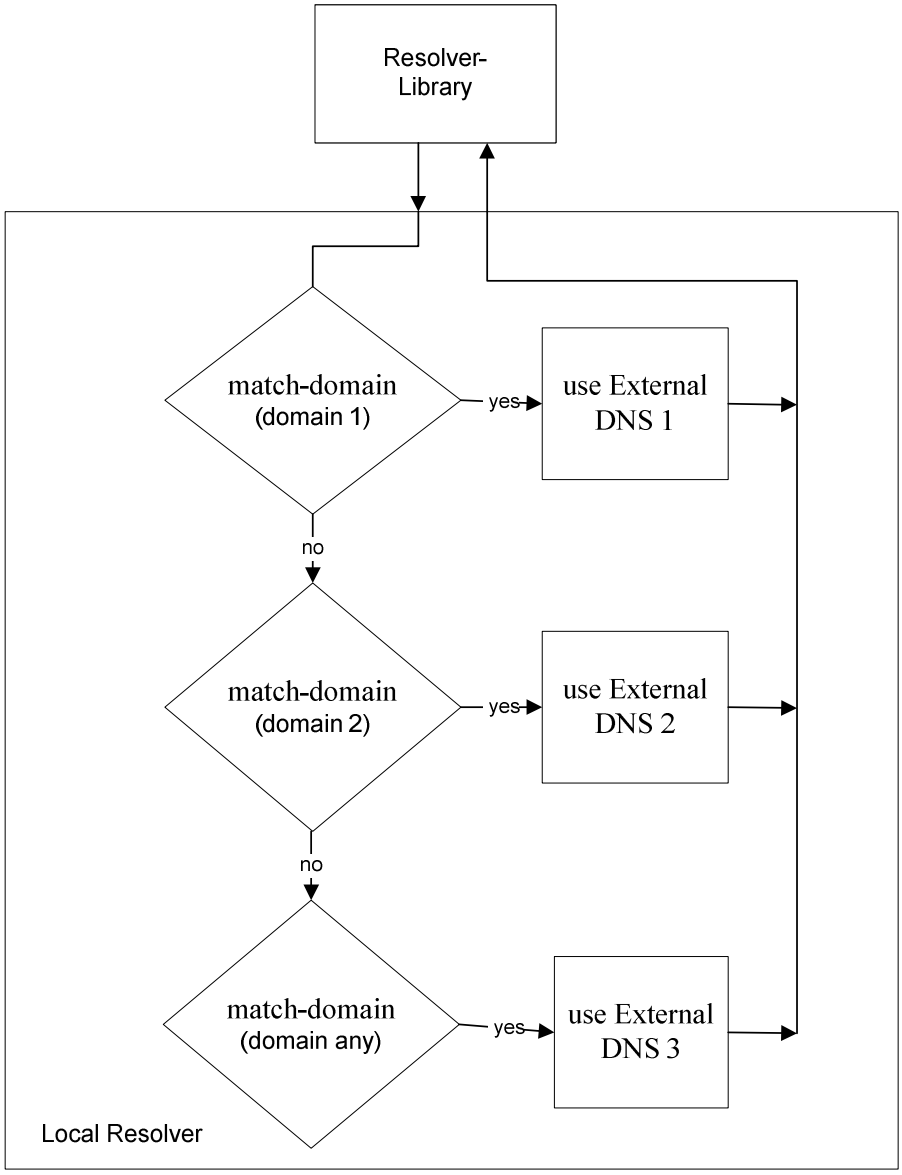

Figure 3: Domain based usage of external DNS resolver

6.3 DNS resolver

Within the Internet architecture a DNS resolver builds a proxy functionality between a large amount of DNS clients and a relatively small amount of authoritative DNS servers.

This proxy functionality leads to a doubling of DNS messages and therefore a doubling of the likelihood of packet loss.

In order to fulfil this proxy functionality the DNS resolver acts as a client in the communication to the authoritative DNS server.

Nevertheless, in order to support the optimization of the IP based operator network DNS due to self-recognizing of network or DNS failures, the DNS resolver could possess a mechanism which triggers a resending of a DNS query in a configurable interval.

An advantage of the proxy functionality is that this functionality can be coupled with a caching mechanism in order to reduce the load on the authoritative name server as well as to reduce the amount of messages.

6.4 Authoritative DNS server

A DNS stub resolver can support the optimization of an IP based operator network DNS in:

- Reducing the amount of messages to answer a DNS query.

This can be achieved by using the additional answer section within a DNS answer packet.

The additional answer section could contain information which would be queried after receiving the DNS answer. With providing this information in a first DNS response message, the sending of a subsequent DNS query can be avoided.

6.5 DNS transport

DNS as based on IP as Layer 3 protocol, can use TCP and UDP as transport protocols.

In accordance to RFC 5966 [i.3]:

- Authoritative server implementations are expected to support UDP and TCP.
- Recursive server (or forwarder) implementations are expected to support UDP and TCP.
- Stub resolver implementations are expected to support UDP and TCP.

However the usage of TCP could lead to performance and scaling issues in comparison to the usage of UDP.
RFC 5966 [i.3] describes the motivation and reasons for the usage for TCP transport for DNS messages.

In an operator controlled IP based network environment these reasons could be neutralized, so that exclusive usage of UDP be possible.

In an IP based operator network DNS is used as signalling protocol (similar to SIP). Therefore it is recommended to handle DNS traffic here in a Class of Service which provides a low packet loss characteristic. In an Internet environment it is recommended to transport DNS traffic in the internet class/best effort.

History

Document history		
V1.1.1	May 2015	Publication