## SANDRA D3.5.5 NAMING AND ADDRESSING

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Abbreviations

A/C  Aircraft
AAC  Airline Administrative Communication
ACARS  Aircraft Communication Addressing and Reporting System
ANSP  Aeronautical Service Provider
APC  Airline Passenger Communication
ATM  Air Traffic Management
ATN/IPS  Aeronautical Telecommunications Network / Internet Protocol Suite
ATN/OIS  Aeronautical Telecommunications Network / Open System Interconnection
ATS  Air Traffic Services
ATC  Air Traffic Control
AOC  Airline Operational Control
COTS  Commercial Off-The-Shelf
DNS  Domain Name System
DNSSEC  Security Extensions for the DNS
EC  European Commission
ECTL  Eurocontrol
FQDN  Fully Qualified Domain Name
IANA  Internet Assigned Numbers Authority
ICAO  International Civil Aviation Organization
IMR  Integrated Modular Radio
IPv6  Internet Protocol version 6
ISP  Internet Service Provider
LAN  Local Area Network
LIR  Local Internet Registry
NEMO  NEtwork MObility
NSAP  Network Service Access Point
PA  Provider-Aggregatable
PENS  Pan-European Network Services
PI  Provider-Independent
QoS  Quality of Service
RF  Radio Frequency
RIR  Regional Internet Registry
SESAR  Single European Sky ATM Research
SLA  Service Level Agreement
SP  Sub Project
SWIM  System Wide Information Management
TLD  Top Level Domain
VDL  Very High Frequency Data Link
WiMAX  Worldwide Interoperability Microwave Access
Executive Summary

One of the main objectives in SP3 is the specification of networking solutions allowing integration and interoperability at different levels with IPv6 as unification point. In particular, the interoperability and interworking of different data link technologies, of network and transport layer technologies and the integration of operational domains are envisaged here.

The main contribution of WP3.5 is on the specification of the integrated IPS network solution, including network management (Task 3.5.1), resource and QoS management (Task 3.5.2), mobility management (Task 3.5.3), multicasting (3.5.4) and specification of a naming and addressing scheme (Task 3.5.4).

This document discusses the issues of naming and IPv6 based addressing in an aeronautical communications environment. An addressing (Section 2) and a naming (Section 3) scheme are proposed. This schemes assign prefixes and names to both airborne and ground networks and to both safety and non-safety related networks.

Section 1 presents the context, the assumptions and the requirements linked to the Air Transport environment.

Section 2 is dedicated to addressing and summarizes the individual advantages and disadvantages of past proposals. The new addressing plan is described in Section 2.2.

Section 3 is dedicated to naming and summarizes the individual advantages and disadvantages of past proposals A more naming oriented discussion on the overall context and assumptions is provided too. The naming plan is described in Section 3.2. Considerations regarding the use of DNSSEC are also provided there.

The discussion on the DNS reverse tree, which is used for IP address lookups, is provided in Section 3.2.4.

The appendixes in Sections 6 and 7 provide a summary of related work on addressing and naming.
1 Assumptions

Both the addressing and the naming plans are defined taking certain assumptions into consideration. These assumptions are specified in this section.

The basic hypotheses, apart from what is specified in Sections 1.1 to 1.2.2, are as follows:

- The IP addressing plan is defined according to the relevant IPv6 protocol specifications from IETF.
- Only global unicast addressing is considered. Multicast is not considered within this document.
- It is assumed that safety-related (ATS/AOC) and non-safety related (AAC/APC) services have to be segregated into two disjoint address and naming spaces.
- The addressing plan for the ATN should follow a hierarchical structure in the form of Top-Level Organization – National Authority – Institution/Company – End-Site /Aircraft.
- The naming plan should reuse existing and established coding systems where possible to facilitate transition from the existing communication systems.

1.1 Overall Architecture

A basic concern which has to be addressed is whether provider-independent (PI) or provider-aggregatable (PA), addressing should be used used. In PA, addresses are assigned from a provider (e.g. a large company, telecom operator or service provider), whereas in PI, addresses are assigned by an Internet Registry. The disadvantage of PA over PI is that in case the user chooses to change provider, the IP addresses of all sub-systems have to be reconfigured to the newly assigned PA address space. PI is considered to have a negative impact as it decreases the possible level of aggregation in the routing tables. A more detailed discussion on PI vs PA can be found in [8].

We assume that ICAO will be capable of receiving a large IPv6 (PI) address block that can be distributed among the aeronautical community for ATS & AOC networks/systems.

We also assume that additional available address space might already have been allocated for other purposes. This address space is not affected by the proposed addressing plan outlined in this document.

We assume that the address space used for ATS, AOC and AAC follows the PI model. Address space for APC will instead be based on a PA model. This is valid for both airborne and ground networks.

Different networks are involved in the overall SANDRA architecture. The following figure is extracted from SANDRA Deliverable 3.2.1 [23].
Figure 1.1: Functional Architecture – Topology Level

Four levels of networks can be inferred from Figure 1.1:

1. Airborne network
2. Access networks
3. Network with air-ground routing convergence point
4. Networks with end-systems

These will be discussed in more detail in the following sections.
1.2 Operational Perspective & Requirements

The following diagrams show a typical scenario with traffic flows, involving typical network entities that are involved in the aircraft-ground message exchanges.

In line with architecture outlined in SANDRA Deliverable 3.2.1 [23], an aircraft needs to be accessible directly from ground (ATC) facilities through a Mobility Service Provider (MSP). The MSP will operate the home agents that are required by the mobility protocol, which is NEMO [7], [23].

Routing of traffic between different domains may be performed by a central network (such as PENS).

Each ground entity uses a Service Provider (SP) to access the ATN. The notion of service provider, within this context, refers to an access service provider [21].
When an aircraft connects at the airline hub, it needs to be integrated in the airline LAN (not shown in the figure).

3rd parties may communicate directly with the aircraft, but a preferred solution is that traffic, at least control data, goes through the airline.
Aircraft needs to access the Internet for AAC/APC through a MSP which may be different from the one used for safety-related communications (ATS/AOC).

Large airline may manage their own network by themselves and contract an operator for mobility service provision of their aircraft. For a medium sized airline, only one operator may provide mobility service provision.

For ATC communications with ground networks:
- Each country manages its own national ground network.
- Interconnection between countries is operated by a service provider e.g. SITA

**Operational Requirements**

- It is up to an airline to decide whether it provides mobility service provision by itself or whether this is performed by a dedicated mobility service provider. The addressing system shall support both scenarios.
- In case of airline changing its mobility service provider, the aircraft configuration changes should be limited to the aircraft's external interfaces only.
- The addressing system shall preserve flexibility, especially it shall be possible:
  - To have different MSPs between APC domain and other domains
  - The service provider on the APC side may not be aero-specific - the addressing system should allow this scenario.

The addressing system shall allow segregation between ATC and AOC/AAC, or between ATC/AOCs and some AOCs/AACs, at least by using different subnets.

It should be assumed that ATC/AOC traffic is not routable on the public Internet while AAC/APC traffic is routable on the Internet.

ATC traffic routing shall not have a dependency on airline ground network infrastructure.

There is a need to distinguish the aircraft-ground traffic from the ground-ground traffic, in order to allow all ATC traffic to be routed by service providers, without any involvement of the airline (that would impose burden on their infrastructure to meet the SLA requirements), and have all other ground-ground traffic potentially managed by another service provider.

At least 32 or 64 subnets should be available for an aircraft to leave flexibility to the aircraft manufacturer.
1.2.1 Airborne Network

The airborne addressing can be split into two parts: addresses for use within the airborne network and addresses for use on the egress interfaces (e.g. satellite link where the addresses are configured from the prefix owned by the operator of the access network). This section focuses on the addressing within the on-board network.

The airborne network consists of several IPv6 subnets. We assume that the minimum number of IPv6 subnets required for the network is four, in accordance to the ARINC 664 reference model [6] shown in Figure 1.5.

![Figure 1.5: ARINC 664 (ADN) reference model.](image)

In more detail, we assume that there will be:
- At least one subnet for the Aircraft Control Domain (ATS ATN/IPS & ATS SWIM)
- At least one subnet for the Airline Information Services Domain (AOC & AAC)
- At least one subnet for the Passenger Information and Entertainment Services Domain (APC)
- At least one subnet for the Passenger-Owned Devices Domain (APC)
With regard to the number of network nodes that have to be supported, we assume the following minimum numbers:

- 16 nodes for aircraft control domain, including 4 ATC ATN/IPS, 2 SWIM and 4 AOC
- 32 aircraft IT systems in the AOC/AAC domains
- 32 cabin systems in the AAC domain
- 2048 passenger devices in the APC domain

In the future, once all systems become intelligent, remotely controlled and thus connected (seats, lights, screens, seat-belt, i.e. the Internet of Things, many more IPv6 subnets could be contemplated. For example, it is perfectly reasonable that one small-size IPv6 subnet would be allocated per passenger for all multimedia equipments, and one per seat to control various body sensors. Here we note that separation between subnets doesn't infer independent cabling for each subnet as several IPv6 prefixes could be announced on each access technology (Ethernet, WiFi, Bluetooth, ...). This separation into various IPv6 prefixes could be used to segregate traffic for security or QoS purposes.

### 1.2.2 Ground Networks

We assume that networks carrying safety-related traffic use addresses allocated from different IPv6 prefixes than those carrying non-safety related services. In case a network supports both types of traffic, at least two different subnets will be necessary.

Access Networks can consist of satellites or terrestrial base stations. We assume that these networks make use of PA addressing. The addresses on the outgoing interfaces of the aircraft are configured from IPv6 prefixes advertised in the access networks.

Within the functional architecture, as shown in Figure 1.1, an air-ground routing convergence point aggregates the addresses of the mobile, on-board networks. Within the SANDRA network architecture, this convergence point is implemented by a NEMO home agent, as specified in the mobility management deliverable [7]. The home agent aggregates the PI addresses of the airborne networks. Additional PI and/or PA addresses are required for operating the home network itself.

The address planning of the networks containing the end-systems will depend on the number of end-systems. For this category, we therefore only provide recommendations for subnet sizes on organization level.
2 Addressing

This chapter describes an IPv6 based addressing plan for airborne and ground networks, covering ATS, AOC, AAC and APC services.

We first provide an overview of the “old” ATN/OSI and on the general IPv6 addressing structure, followed by a discussion on the advantages and disadvantages of related work, which is provided in the appendix (Section 6 on page 45).

Finally, we propose an addressing plan for both safety and non-safety related networks that attempts to address the deficiencies that have been observed within the related work.

2.1 General IP and ATN Addressing

In the following we provide a short introduction to the basic IPv6 and ATN/OSI addressing schemes.

IPv6 addresses are 128-bit identifiers for interfaces and sets of interfaces. There are three types of addresses: unicast, anycast, and multicast. This document defines the IPv6 unicast address format for use in aeronautical communications.

IPv6 unicast addresses are designed assuming that the Internet routing system makes forwarding decisions based on a "longest prefix match" algorithm on arbitrary bit boundaries and does not have any knowledge of the internal structure of IPv6 addresses. The structure in IPv6 addresses is for assignment and allocation.

2.1.1 IPv6 Global Unicast Address Format

The general format for IPv6 global unicast addresses as defined in "IP Version 6 Addressing Architecture" [1] is as follows:

|         n bits          |   m bits  |       128-n-m bits         |
+-------------------------+-----------+----------------------------+
| global routing prefix   | subnet ID |       interface ID         |
+-------------------------+-----------+----------------------------+

where the global routing prefix is a (typically hierarchically-structured) value assigned to a site (a cluster of subnets/links), the subnet ID is an identifier of a subnet within the site, and the interface ID is identifying a particular node within that subnet as defined in section 2.5.1 of [12].

The global routing prefix is designed to be structured hierarchically by the RIRs and ISPs in the PA address block case, of by the aeronautical organization in PI address block case. The subnet field is designed to be structured hierarchically by site administrators.

[1] also requires that all unicast addresses, except those that start with binary value 000, have Interface IDs that are 64 bits long and to be constructed in Modified EUI-64 format.
The format of global unicast address in this case is:

```
|         n bits          | 64-n bits |       64 bits              |
+-------------------------+-----------+----------------------------+
| global routing prefix   | subnet ID | interface ID               |
+-------------------------+-----------+----------------------------+
```

where the routing prefix is a value assigned to identify a site (a cluster of subnets/links), the subnet ID is an identifier of a subnet within the site, and the interface ID is a modified EUI-64 format as defined in [1]. In summary, the 64 first bits therefore identify the link (subnet) where a node is attached to and the last 64 bits uniquely identify the node on that link.

An example of the resulting format of global unicast address under the 2000::/3 prefix that is currently being delegated by the IANA and consistent with the recommendations in RFC 3177 [12] is:

```
| 3 | 45 bits | 16 bits | 64 bits |
+---+---------+--------+---------+
|001|global routing prefix| subnet ID | interface ID |
+---+---------------------+-----------+----------------------------+
```

### 2.1.2 Comparison of IPv6 address and ATN NSAP address

ICAO is the ultimate administrative authority of the ATN internetwork addressing plan and administers this plan through Sub-volume V of the Manual of Technical Provisions for the ATN (Doc 9705 -AN/956) [1]. That document defines and administers the ATN NSAP address syntax (i.e. field boundaries, field sizes and field formats), the ATN NSAP address semantics (i.e. the field content and interpretation), and the ATN NSAP address encoding procedures (i.e. the representation of the abstract field syntax and semantics). These addresses are for the “old” ATN/OSI.

Figure 2.1 shows the formats of the ATN NSAP address and the IPv6 unicast address, as recommended by [20]. The figure also shows a rough mapping of address fields that are similar between NSAP and IP.
Apart from the obvious reduction in size (from 20 bytes to 16 bytes), the following differences are worth noting:

- ARS refers to the 24 bit aircraft address.
- The SEL field in the NSAP address, used to identify either a network layer entity (such as the IDRP protocol machine) or a network service user within the context of a given ATN system, is not required in the IPv6 address. This functionality is realized in the ATN IPS via the TCP and UDP port numbers.
- The LOC and SYS fields have similar counterparts in the IPv6 address: the Subnet ID and the Interface ID, respectively. The size of the Interface ID is increased from 6 bytes in the NSAP address to 8 bytes in the IPv6 address.
- The ICAO IPv6 global prefix for aviation, obtained from IANA, is similar to the AFI and IDI fields in the NSAP address. At the time of this writing, the size of this prefix has not been determined yet, although the expectation is that it will be in the range of a /16.
- Given the smaller size of the IPv6 address and the larger Interface ID field, the functionality of the VER, ADM and ARS fields must fit into a considerably smaller block (4 bytes, instead of 8 bytes).

### 2.2 Proposed Addressing Scheme (DLR, SITA, INRIA)

#### 2.2.1 Advantages/ Disadvantages of individual proposals

Summaries of previous addressing proposals are provided in Section 6.

The proposed addressing plan in Section 6.1.1 (Option 1) provides the following advantages:
- The format allows for aggregation, both on the inter-domain and the intra-domain level
- Reasonable number of bits to split address block among different organizations and sites

The disadvantages are:
- Requires a continuous /22 address block for ICAO from IANA or one of the RIRs
Due to the TT field, ATS/AOC/AAC and APC are already split in the front part of the prefix. A 16bit long subnet prefix for A/C is therefore probably a wasteful allocation, as it is per service class.

Neutral:
- A subnet ID length of 16 is probably reasonable for ground-ground addresses.

Option 2 in Section 6.1.1 is similar with the additional disadvantage that using 24bits for identifying aircraft implies losing a significant number of bits.

The WG-I proposed addressing plan (Section 6.1.2) has the following advantages:
- No need for ICAO to request a large address block. Aeronautical providers directly receive address space from RIRs like ARIN, RIPE, etc.

The disadvantages are:
- Aggregation only possible on inter-domain level, but not for intra-domain (ICAO 24bit aircraft address is encoded on a per-country basis).
- Fragmented aeronautical address space. All address blocks are “dynamically” allocated from the global Internet address space for every service-provider.
- Potential general security issues, as separation from public Internet is more cumbersome.

Neutral:
- Provider-dependant addressing.

The two proposals from Section 6.1.3 have the following advantages:
- The address block that has to be requested by ICAO is relatively small, at least when compared to the /16 from Section 11.4.
- Size of the prefix is in relation to the current and probable future number of aircraft.
- Allows for aggregation, both on the inter and the intra-domain level.

Neutral:
- ICAO 24bit aircraft number is not used as an identifier.
2.2.2 Proposed SANDRA Addressing Plan

The final SANDRA addressing plan is provided below. We follow RFC 6177 [18] which obsoletes RFC 3177 [12], with the result that we do not follow the assignment strategy of /48s for sites and enterprises.

2.2.2.1 Common ICAO Prefix (PI) for Airborne and Ground Networks

We assume that ICAO will be capable of receiving a /22 IPv6 address block for distribution among aeronautical stakeholders. This overall address block is split into two subspaces (50-50 split) for each safety and non-safety related services. These sub-spaces are then split, based on a 50-50 ratio, into ground and airborne address subspaces.

This overall prefix structure looks as follows and covers ATS, AOC (safety related) and AAC, APC (non-safety related):

<table>
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<tr>
<th>Abbreviation</th>
<th>Prefix Length</th>
<th>Bits</th>
<th>Addressable entities</th>
<th>Explanation</th>
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<tr>
<td>Global ICAO prefix</td>
<td>/22</td>
<td>22</td>
<td>-</td>
<td>Assumption is that ICAO receives a /22 prefix.</td>
</tr>
<tr>
<td>Reserved</td>
<td>/24</td>
<td>2</td>
<td>-</td>
<td>Spares in case the split for safety vs non-safety and airborne vs ground networks proofs to be inadequate.</td>
</tr>
<tr>
<td>ICAO managed – Safety vs non-safety</td>
<td>/25</td>
<td>1</td>
<td>-</td>
<td>Differentiation between safety and non-safety related services</td>
</tr>
<tr>
<td>ICAO managed – ground vs airborne</td>
<td>/26</td>
<td>1</td>
<td>-</td>
<td>Differentiation between airborne and ground systems Equivalent to VER in NSAP</td>
</tr>
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Reserved fields are set to all zeros. In the example above, this would be “00”, which reserves 75% of the overall address space.

The proposal has the following advantages/disadvantages:

- Segregation between safety and non-safety related services at a high level (ICAO managed – safety vs non-safety related) allows to still perform aggregation in public Internet and the ATN.
- Differentiation between airborne and ground networks
- Reserved bits to account for future modifications in case the proposed format proofs to be not adequate enough.

How the /26 prefixes for airborne and ground networks are structured is presented in the following.
2.2.2.2 Airborne Addressing (PI)

The following table presents the address plan for airborne networks, based on the /26 ICAO prefix as outlined in the previous section.

<table>
<thead>
<tr>
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<th>Bits</th>
<th>Addressable entities</th>
<th>Explanation</th>
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<td>/26</td>
<td>26</td>
<td>-</td>
<td>Address allocation for airborne networks.</td>
</tr>
<tr>
<td>Reserved</td>
<td>/30</td>
<td>4</td>
<td>-</td>
<td>Spares in case the operator-aircraft-subnet ratio has to be modified.</td>
</tr>
<tr>
<td>Operator-specific</td>
<td>/43</td>
<td>13</td>
<td>8.192</td>
<td>This field refers to airlines and further organisations in need of mobile network prefixes or mobile addresses.</td>
</tr>
<tr>
<td>A/C-specific</td>
<td>/55</td>
<td>12</td>
<td>4.096</td>
<td>The number of aircraft for an organization Equivalent to ARS in NSAP</td>
</tr>
<tr>
<td>Subnet</td>
<td>/64</td>
<td>9</td>
<td>512</td>
<td>The number of sub-networks per aircraft Equivalent to LOC in NSAP</td>
</tr>
</tbody>
</table>

This proposal has the following advantages/disadvantages:

- High number of subnets - so high flexibility on aircraft.
- A sufficiently large number of supported aircraft per organization
- Discrimination by organization/airline: providers will advertise airlines and not aircraft. This provides aggregation and therefore reduces the size of the routing tables.
- It is possible to have multiple MSPs for the same aircraft or airline
- Reserved bits to account for future modifications in case the proposed format proofs to be not adequate enough.

The way prefixes will be allocated can vary:

- Sequential assignment
- Encode specific IDs within the individual prefix portion.

Additional discussions might be required at a later stage.
2.2.2.3 Ground Networks Addressing (PI)

The following table presents the address plan for ground networks, based on the /26 ICAO prefix as outlined in Section 2.2.2.1.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Prefix Length</th>
<th>Bits</th>
<th>Addressable entities</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common ICAO Ground</td>
<td>/26</td>
<td>26</td>
<td>-</td>
<td>Address allocation for ground networks.</td>
</tr>
<tr>
<td>Prefix</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reserved</td>
<td>/28</td>
<td>2</td>
<td>-</td>
<td>Spares in case the SPR allocation proofs to be not adequate enough.</td>
</tr>
<tr>
<td>SPR specific</td>
<td>/32</td>
<td>4</td>
<td>16</td>
<td>Used to distribute the address space among regions and large service providers (Europe, Asia, etc and SITA, ARINC, etc.). Each region of major SP will be affected a 4 bit value associated to the /26 ICAO prefix</td>
</tr>
<tr>
<td>ORG specific</td>
<td>/43</td>
<td>11</td>
<td>2.048</td>
<td>This field refers to airlines and other organisations in need of ground network addresses (end-systems, access networks, etc.). Each organization will be affected an 11 bit value associated to the /26 ICAO prefix and SPR specific field</td>
</tr>
<tr>
<td>Reserved</td>
<td>/45</td>
<td>2</td>
<td>-</td>
<td>Spares for rearranging the site/subnet ratio.</td>
</tr>
<tr>
<td>Site</td>
<td>/55</td>
<td>10</td>
<td>1.024</td>
<td>The number of sites supported for each service provider.</td>
</tr>
<tr>
<td>Subnet</td>
<td>/64</td>
<td>9</td>
<td>512</td>
<td>The number of subnetworks.</td>
</tr>
</tbody>
</table>

This proposal has the following advantages/disadvantages:
- A sufficiently large number of supported organizations
- Aggregation is even on the level of ICAO regions and large service providers.
- Reserved bits to account for future modifications in case the proposed format proofs to be not adequate enough.

Note: SPR-specific, ORG-specific: these fields, for a given organization, may vary depending on the ICAO /26 prefix. As they will probably be assigned by ICAO sequentially, the SPR-specific field for a given service provider for a /26 safety ICAO prefix and /26 non safety ICAO prefix may be different if the request for allocation are submitted at different times.

The way prefixes will be allocated can vary:
- Sequential assignment
- Or
2.2.2.4 Airborne Addressing (PA) for APC

Addressing for APC is based on a PA model. This address block is already included in the overall ICAO allocation for airborne networks presented in Section 2.2.2.2.

In case a service provider might not want to request address space from ICAO but instead prefers to file a request with a “normal” Regional Internet Registry, we provide a recommended address format that should serve as a guideline for this allocation.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Prefix Length</th>
<th>Bits</th>
<th>Addressable entities</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility Service Provider Prefix</td>
<td>/32</td>
<td>-</td>
<td></td>
<td>Prefix for Mobility Service Provider</td>
</tr>
<tr>
<td>Provider Specific</td>
<td>/33</td>
<td>1</td>
<td>8.192</td>
<td>Differentiation for APC domain: passenger owned devices and airline owned devices</td>
</tr>
<tr>
<td>Reserved</td>
<td>/43</td>
<td>10</td>
<td>-</td>
<td>Spares to provide more differentiation on services (Provider specific field) or to increase the number of aircraft (A/C field)</td>
</tr>
<tr>
<td>A/C</td>
<td>/55</td>
<td>12</td>
<td>4.096</td>
<td>The number of aircraft for an organization Equivalent to ARS in NSAP</td>
</tr>
<tr>
<td>Subnet</td>
<td>/64</td>
<td>9</td>
<td>512</td>
<td>The number of subnetworks per aircraft Equivalent to LOC in NSAP</td>
</tr>
</tbody>
</table>

This proposal has the following advantages/disadvantages:
- Segregation of different service classes on a high level of the addressing structure (field: Provider specific)
- Sufficient number of aircraft supported
- Reserved field allows to increase either the number of supported aircraft or the number of segregation classes
- Number of subnets provided for each segregation/service class should be adequate

2.2.2.5 Illustration of proposed Addressing Plan

A graphical representation of the addressing plan is provided in Figure 2.2. The common /26 ICAO prefix is on the very left, whereas aircraft and site subnets are on the very right.
Red lines paths indicate the allocated prefixes/addresses, whereas the remaining address space remains reserved. As can be seen, less than 25% of the ICAO allocated prefix has been used in our proposal.

Certain fields are splitting the overall prefix into specific subspaces, e.g. “ICAO managed - airborne vs ground”: value = 1 indicates a ground network prefix, value = 0 indicates an airborne network prefix.

The same holds for the “safety vs non-safety” field, which duplicates the entire tree structure to the right of this field. For simplicity of the illustration, this has not be shown in the figure.
Figure 2.2: Illustration of the proposed SANDRA addressing plan.
3 Naming

3.1 Overview

We will discuss the Domain Name System (DNS) structure for aeronautical communications. We will distinguish between two separate sets of requirements for:

- Safety related communications (such as ATS or AOC): assumed to be non routable on public Internet, separated and accessible only to authorized entities involved in safety related air transport communications. Consequently, the DNS is private and visible only to entities involved in safety related communications. We assume either the PI or the PA addressing plan identified above.

- Non-Safety related communication (such as AAC or APC): assumed to be routable on Internet and the DNS is part of the public DNS.

In preparing this section, we have conducted desk research to identify aviation specific DNS material and found that this area is significantly under-studied compared to the subject of IP addressing. In particular, there is no coherent and agreed set of business requirements that could be used to design a naming structure.

Below, we provide a brief overview of DNS technology, describe existing proposals and implementation experiences and use these proposals to propose a set of business requirements for DNS. Subsequently, we propose a domain name structure to match these requirements and identify various implementation issues that need to be considered further prior to deployment. Since this is probably the first attempt for a comprehensive review, the resulting proposal will require considerable peer review and testing prior to deployment.

3.1.1 DNS Overview

First, it is important that the reader shares an understanding of DNS and its key features. Domain Name System ("DNS") is a distributed database system which maps names to “things” and acts primarily as a directory service linking domain names to different “things.”
Domain names may point to many different “things” at the same time. Protocol asks for \{name, type, class\}. Most frequent requests are for records of name servers, IP Addresses and Mail eXchange servers. There are many other record types, for example Naming Authority Pointer Record (NAPTR) may be pointing to SIP URN for a VoIP service or in the world of RFID, it may be used to identify an information service provided by an entity responsible for managing a set of unique identifiers. Further, the user may store in the database additional information such as the name and contact details of the database administrator or even a public key associated with the domain.

When designing a naming structure, it is important to take into account certain key properties of the DNS which include the following:

- **HIGH-AVAILABILITY DATABASE** - Standard availability SLA for all generic Top Level Domain operators contracted by ICANN such as .com or .aero is 99.999%. Internet users expect and rely on high availability.

- **HIERARCHICAL NATURE OF THE DATABASE** - the database is organized in a strict hierarchy with dots separating domains on different levels of the database hierarchy. The rightmost domain is the highest in the hierarchy. Take the example of the fully qualified domain name (“FQDN”) departure.gva.aero. – the third level domain name “departure” is in “aero” top level domain, in “gva” second level domain.

- **DECENTRALIZED NATURE OF THE DATABASE** - There is no one central database of all domain names in DNS. Database entries linked to one domain are completely independent from all other domains.

- **DISTRIBUTED AND DECENTRALIZED ADMINISTRATION** - Administration of the system is usually distributed between many parties and is highly decentralized. Each node must recognize the existence of its leaves to allow the users of DNS database to find them. For example, the administrator of gva.aero domain has to include relevant record for departures.gva.aero in gva.aero zone file to allow system users to find departures.gva.aero.

### 3.1.2 DNS use in ATS communications to date

Despite its widespread use on public internet and in many private networks, air transport communications use very little of DNS today. For example, ICAO Document 9896 does not mention DNS at all. We see several reasons including the following:

- Many air transport communications protocol today do not use IP at all. DNS is a directory service for IP based networks.

- IP based air transport communications networks were designed before DNS was widely adopted. Take as an example RFC 2351 MATIP (Mapping of Airline Reservation, Ticketing, and Messaging Traffic over IP) [22], it is based fully on IP addressing system.

- Air transport communications networks are designed for machine-to-machine communications therefore the value of memorable names is lower than in more end-user oriented applications such as using a search engine on google.com.

- Adding a directory service such as DNS means adding one more element that “can break” or cause delays, inherently increases the risk.
However, the addition of DNS in air transport communications appears almost inevitable because it is a ubiquitous method to achieve the separation between the logical address of a service (a service name) and an IP address of a machine that may be running the service at a given time.
3.2 Proposed Naming Scheme

3.2.1. Assumptions & Requirements

3.2.1.1 The purpose and scope

The purpose of the naming structure is to provide convenient and efficient directory system needed to locate services associated with uniquely identified objects and entities participating in aeronautical communications.

The naming structure is intended to domains defined in SANDRA D2.2.2.1 [16] and scenarios defined in Section 1.2 of this document.

There will be two separate DNS structure for safety and non safety related communication domains. The safety related communications (and the use of the DNS directory system) is not accessible to public Internet users and is managed as a “closed DNS”. The non safety related DNS structure will be linked to public internet and its entries may be accessible from Internet.

The design will aim for strict segregation between naming based on various industry codes - hierarchical and strictly enforced - and naming based on company names and possibly even product names or brands.

The key purpose of the DNS in the context of this document

- to allow a ground based aeronautical systems to locate an IP address of an aircraft on the basis of a predictable domain name containing an ICAO 24 bit aircraft identifier (expressed as alphanumeric string).
- to allow an aircraft based system to locate a ground system for a particular location on the basis of a predictable domain name using an ICAO for letter ground facility identifier.

The naming system will use existing and established coding systems where possible to facilitate transition from existing communication systems such as entity and system naming in ATN based communications while avoiding to carry over legacy coding systems that are being already replaced by new structures. For example, we will not use IATA 2 character airline identifiers as these have been replaced by ICAO 3 letter airline identifiers for the purpose of ATC communications.

Further, we assume that DNS will not be used as means to bind a flight number to an aircraft, particularly not for safety related communications, for the following two reasons:

- Such binding may be context specific - there may be two flights with the same flight number operating at the same time
- Flight number-aircraft binding may change often and unexpectedly (e.g. an aircraft change due to technical problems) and DNS was not initially designed as a real time system. Feasibility of using Dynamic DNS for this purpose is outside of the scope of this document.
3.2.1.2 Intended system users

Authorised systems of the users listed below (organisation or companies, "y" indicates whose systems may need to use the directory) will require access to DNS directory service.

<table>
<thead>
<tr>
<th>System user</th>
<th>Safety</th>
<th>Non safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air operators</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Air traffic management organisations</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Airport operators</td>
<td>[tbc]</td>
<td>Y</td>
</tr>
<tr>
<td>Civil Aviation Authorities (national, regional, international)</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>3rd parties providing services requiring safety related aeronautical communications or services necessary to operate the infrastructure for safety related communications.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3rd parties providing services to the above organisations that do not require safety communications (fuel providers, weather, NOTAMs, engine manufacturers not requiring ATS access)</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Individual pilots (excludes individual operating on behalf of an organization defined above such as an airline pilot accessing on behalf of an airline)</td>
<td>[tbc]</td>
<td>Y</td>
</tr>
<tr>
<td>Individual aeronautical professionals (excludes individuals operating on behalf of an organization defined above such as incident investigators)</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>General public including passengers</td>
<td>N</td>
<td>Y</td>
</tr>
</tbody>
</table>

3.2.1.3 Entities to be named and proposed means of their identification

The following table outlines the objects and entities that may require names in the DNS system and lists known coding systems that may be used to uniquely identify the object. Identifier in bold is the one that we have selected to use in DNS design.
<table>
<thead>
<tr>
<th>Object or entity</th>
<th>Identification system(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATSUs</td>
<td>4-character ICAO designator for the ground facility</td>
</tr>
<tr>
<td>Airport</td>
<td>3 letter IATA location designator</td>
</tr>
<tr>
<td></td>
<td>4 letter ICAO location designator</td>
</tr>
<tr>
<td>Air operator</td>
<td>3 letter ICAO air operator designator</td>
</tr>
<tr>
<td></td>
<td>2 character IATA airline designator</td>
</tr>
<tr>
<td>Flight</td>
<td>Flight Identifier (FI). The Flight Identifier is composed of a two character Airline Identifier and a four character Flight Number. (ARINC 618). In ATC context, the flight number has been replaced with ICAO 3 letter airline identifier and a four character flight number.</td>
</tr>
<tr>
<td>Aircraft</td>
<td>Aircraft Registration Number (AN) identified in ARINC 620 e.g., N1003X and assigned by national registration authority.</td>
</tr>
<tr>
<td></td>
<td>I CAO assigned 24 bit ID</td>
</tr>
<tr>
<td></td>
<td>Aircraft manufacturer created aircraft digital identity (being considered by manufacturers but not yet in existence.)</td>
</tr>
<tr>
<td>Systems and services on board of an aircraft</td>
<td>See service identifier below</td>
</tr>
<tr>
<td>Country</td>
<td>3 character country code assigned by ISO</td>
</tr>
<tr>
<td></td>
<td>2 character country code assigned by ISO</td>
</tr>
<tr>
<td>Aircraft part</td>
<td>Unique part identifier (UID) defined in ATA e-business SPEC2000 chapter 9.5 and its URI representation</td>
</tr>
<tr>
<td></td>
<td>Other form of part designation in the context of an aircraft</td>
</tr>
<tr>
<td>Organisation</td>
<td>Organisation name</td>
</tr>
<tr>
<td>Service identifier</td>
<td>Common service name or abbreviation agreed by relevant industry standard for the purpose of DNS (i.e. “gw” for gateway) proposed in [21]</td>
</tr>
<tr>
<td></td>
<td>IATA Office function designator (as in the 4th and 5th character of a 7 letter address)</td>
</tr>
<tr>
<td></td>
<td>Function name defined in ATN NSAP [Project Acronym]</td>
</tr>
<tr>
<td>Ground systems [non ATC]</td>
<td>A/C needs to be able to determine the addresses of the ground systems using a 4 character ICAO ground facility identifier</td>
</tr>
</tbody>
</table>
3.2.1.4 The relationship between the users and objects that need to be named

Individual aircraft
- Is operated by an airline on a given flight
- Provides systems and services on board of an aircraft for use by 3 parties on the ground (or other aircraft?)
- Consists of components and subsystems that may need to be addressed individually by 3rd parties communicating with the aircraft. For flexibility, it may be desirable to maintain some names in a structured manner without reference to a specific carrier operating the aircraft at a given time.
- Some components may be owned and managed by 3rd party service providers, the service providers may change. For flexibility, it may be desirable to maintain the names of some components and systems independent of the name of the provider actually operating them at a given time.

Air operators (ground based operations)
- Provide Systems and services available to the aircraft
- Provide Systems and services available to ATM users
- Provide Systems and services available to the airport operator
- Provide System and services available to 3rd parties providing service to the above organisations
- Operate an aircraft on a given flight and manage its configuration

Airport operators (ground based operations)
- Provide Systems and services available to the aircraft
- Provide Systems and services available to ATM users
- Provide Systems and services available to the air operators
- System and services available to 3rd parties providing service to the above organisations

Air Traffic Management Organisations (ground based operations)
- Provide Systems and services available to the aircraft
- Provide Systems and services available to ATM users
- Systems and services are identified by a location (i.e. communication with a ground facility identified by ICAO 4 letter ground facility designator)
- System and services may be organised by a region (i.e. country or other regional air space designations such as FABEC)

Civil Aviation Authorities
- Register an aircraft and issue its license plate
- Issue ICAO 24bit identifier to aircraft
- License ATMOs operating in their territory

Manufacturers (airframers and OEMs)
- Produce aircraft and issue aircraft digital identity
- Produce aircraft parts and assign their digital identity
3.2.1.5 Assumptions about the use of the system

It is not possible to define exhaustively the uses of DNS. This section lists possible use examples that were referenced in reviewed literature or appear plausible based on the current knowledge. It does not imply that the system will or should be used that way. There are more that 60 resource records.

<table>
<thead>
<tr>
<th>DNS Resource record</th>
<th>Possible use</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>Name server</td>
</tr>
<tr>
<td>SOA</td>
<td>Start of a zone of authority</td>
</tr>
<tr>
<td>A</td>
<td>IPv4 address</td>
</tr>
<tr>
<td>AAAA</td>
<td>IPv6 address</td>
</tr>
<tr>
<td>PTR</td>
<td>A domain name pointer</td>
</tr>
<tr>
<td>MX</td>
<td>Mail Exchange server</td>
</tr>
<tr>
<td>SRV</td>
<td>Services record</td>
</tr>
<tr>
<td>NAPTR</td>
<td>Naming Authority Pointer Record</td>
</tr>
</tbody>
</table>

3.2.2. DNS Hierarchy

Given the considerations outline above, we propose the following:

ICAO should attempt to obtain one Top Level Domain from ICANN for exclusive use by aviation for aeronautical communications on terms that suit the need of aeronautical communications. That may be a new Top Level domain or policy adaptation of an existing industry domain .aero.

The primary role of ICAO will be to maintain policy and administration authority of the entire Top Level Domain and determine registration and use policies relating to names registered in all its subdomains. The operation of the registry and associated names servers may be delegated by ICAO to 3rd party with necessary expertise but subject always to policy authority of ICAO.
For the purpose of this document we will call this domain .avi.

ICAO should then split the domain into two subdomains as follows:

1. .safety.avi
2. .public.avi

Note: this distinction between safety and non safety could be omitted if the industry is comfortable managing two parallel structures corresponding to closed and public version of the same tree but at this stage feasibility of doing so has not been established.

**Safety.avi**

This domain will only exist in the closed network used for safety-related aeronautical communications and will **not** be advertised in the public Internet.

The registry operator of this domain is ICAO, or a 3rd party performing this task on behalf of ICAO.

The domain will be structured as follows:

**aircraft.safety.avi.**

Aircraft subdomain will contain ONLY domain names corresponding to alphanumeric expression of an ICAO 24 bit aircraft identifier.

These domains will be delegated to aircraft operators (the end-users from a domain registration perspective) as integral part of the aircraft registration process managed by ICAO.
The registration process will be handled by national authorities (e.g. civil aviation authority) acting as “registrars” for one zone containing all aircraft registrations.

In accordance to the addressing plan in Section 2.3, this domain will point to a AAAA record containing the safety-related /55 prefix assigned to an aircraft.

atsu.safety.avi.

ATSU subdomain will contain ONLY domain names corresponding to alphanumeric expression of an ICAO 4 letter ground facility as published in Doc 7910

These domains will be delegated by ICAO to air traffic management organisation (ANSP) responsible for operation of the ground facilities.

As in the aircraft domain case, the registration process can be handled by national authorities acting as “registrars” for atsu zone containing all ground facilities.

We recommend this method (as opposed to structuring the name space by countries or geographical regions) for the reasons outlined in “Design considerations” below.

operators.safety.avi.

Operators subdomain will only contain domain names corresponding to aircraft operators as identified ICAO’s three letter airline identifier.

These domains will be delegated by ICAO to the operators (airlines) responsible for operation of the aircraft as an integral part of the code allocation process.

Locations.safety.avi.

Location will contain ONLY domain names corresponding to 4 letter ICAO location identifiers.

These domains will be delegated by ICAO and their registration to entities which provide airport services at these locations may be processed by national aviation authorities acting as “registrars” for the locations in their area.

Entities.safety.avi.

This domain is intended for registration of any entity names and similar names that must be part of the domain naming system but are not represented by an established coding system. Providers of services that need domain names would be allocated domains in this area, for example Eurocontrol or ARINC.

Entity names are subject to change and difficult to predict, given that our structure is intended primarily for machine to machine communication where the value of a memorable name is very low, we do not recommend widespread use of entity names.

These domains will be delegated by ICAO and their registration to 3rd parties providing services requiring safety related aeronautical communications or services necessary to operate the infrastructure for safety related communications. Registrations may be processed by national aviation authorities acting as “registrars” for entities in their area.

Public.avi.
The public.avi domain is intended for non safety related communications among the same entities as defined above, as well as additional users who are only engaged in non safety related communications (fuel providers, weather services, NOTAMs, engine manufacturers for data exchanges not related to communications.) The domain should be structured in the same way using exactly the same coding system and exactly the same allocation process as described above in the safety domain.

Note that this domain is designed as public because the addresses it allows to manage are intended to be routable on Internet and the domain names may be eventually exposed on Internet. The industry has to decide whether and when to expose the structure to the public Internet. However, the public.avi domain also intended primarily for machine-to machine communications and not for use as a branding tool to access directly by people who need short memorable addresses.

The registry operator of this domain is also ICAO, or a 3rd party performing this task on behalf of ICAO, all registrations are performed concurrently with registrations in the safety.avi domain.

### 3.2.2.1 Design considerations

Here we list some design considerations that lead us to the above structure.

- Design a simple and flat structure: prior experiences have shown that a deep structure is difficult to understand, complex to manage and practically impossible to enforce.
  - The deeper the structure is, the more difficult is to manage a change in situations where the node itself changes or where the relationship between leaves and nodes changes (i.e. ground facility is reclassified as belonging to another region or a new country emerges).
  - With a deep structure, the user must have a full understanding of the structure to locate the desired node. For example, if we have structured the ground facility designators by regions, the user would have to keep a region-facility correspondence table to be able to locate the facility domain.

- Eliminate risk of collisions by using one sub-domain for one coding system.
  - If we have subdivided the domain, for example by preceding the ICAO 24 bit aircraft identifier by a country or region code, there is a risk that the same aircraft identifier could be registered twice in different regions.
  - If we have allowed two coding systems in one domain, there is a risk that the coding systems would collide eventually.

- Brand names and trademarks:
  - by selecting dedicated domains for coding, we eliminate any confusion with strings corresponding to brands and trade-names that otherwise could be subject to special protection. The domain “entity” is likely to be subject of such protection as it is intended for entity names that are not subject to a coding system.

- Strong link between code allocation and name registration
3.2.3. DNSSEC Usage and other security considerations

DNSSEC [3][4][5] is a protocol that allows administrators of domain names to digitally sign entries in DNS and allow the users to authenticate the responses that they receive from a DNS service. For example, the user looking for an IP address of an aircraft can use DNSSEC to ensure that the IP address that the DNS provides, is the address that the aircraft operator entered in the DNS system. As for any other application, the operators and users need to deploy a combination of tools and techniques to counter individual threats the infrastructure may face. Notably, DNSSEC does not prevent denial of service attack.

Subject to further prototyping and testing we recommend the use of DNSSEC to authenticate DNS responses. In particular, we recommend the following:

- The closed domain Safety.avi will be signed by a separate private key held by ICAO and will act as the “root” key for all safety related aeronautical communications (on the forward DNS-tree).
- The domain .avi will be also signed by a separate private key held by ICAO and will act as the “root” key for all aeronautical communications (on the forward DNS-tree) unless or until the Internet root key is deemed satisfactory for the use in non safety aeronautical communications for the reasons outlines below.

The Internet root has been already signed by ICANN however, the algorithm used for the signature (RSA SHA-1) is not deemed strong enough for deployment in aeronautical communications. The certificate used to sign the .avi domain, at least its private part intended for safety related communications, must use at least RSA SHA-256. See [9].

In addition, in air-ground communications the preferred cryptographic algorithm is not RSA, but Elliptic Curve Cryptography (ECC). We therefore recommend using ECDSA/SHA-256. It should be noted that ECC based signature algorithms have not yet been allocated. See [11] and http://www.iana.org/assignments/dns-sec-alg-numbers/dns-sec-alg-numbers.xml.

Other security considerations

In the public Internet, a typical requirement for TLD operators is to provide regular free access to the entire zone file to any party that requests such access and signs a standard ICANN-prescribed agreement. This may not be appropriate in a safety-related setting and the eventual application to ICANN for a top level domain should consider this issue. Given the sensitivity of the domain names binding aircraft to its IP addresses, the zone manager should not allow access to the entire zone file.
The operator will also need to implement measures preventing enumeration of the zone. In the event DNSSEC is deployed, the design should consider the use of NSEC3 [17], a method that provides for authenticated denial of existence of a domain without revealing information about other domains in the zone. The design should consider the use of NSEC3 which provides for hashed authenticated denial of existence and therefore preventing enumeration of the zone.

The signing of the reverse tree is covered in the next section.

### 3.2.4. DNS Reverse Tree Structure

The reverse tree is used to perform lookups with an IP address as input. The response will usually contain a PTR record to the domain name that is associated to the IP address.

The tree structure is illustrated in Figure 3.1. As IPv6 allocations have already been made for ground-ground networks (e.g. the /32 allocation managed by Eurocontrol), these have to be included in the overall DNS tree. This is illustrated by the “Existing Safety Prefix Allocations” on the very right of the figure ((sub-tree D)). Our proposed addressing plan with the common /22 prefix from Section 2.2 is in the centre of the figure and split into two parts, according to the safety (sub-tree C) and non-safety (sub-tree B) segregation of the address space. Finally, it is assumed that address space for service providers or organizations that is allocated directly from a Regional Internet Registry (RIR) and not from ICAO is only used for non-safety services (sub-tree A).

Sub-trees A and B are reachable from the public Internet, while sub-trees C and D are only reachable within the safety-related domain.
DNS Server Operation

For each instance of Sub-tree D (e.g. for the ECTL address allocation for Europe), a name server is needed. This server will act as a root server for this allocation.

A dedicated set of name servers for sub-tree C has to be operated. Whether this refers to name-servers operated by ICAO, by selected aeronautical organizations or by 3rd parties is out of scope for our discussion. These name servers are located within the closed safety-related networks.

In case of a DNS query with target address from sub-tree D, the name servers of sub-tree C will have to refer to the responsible name server(s) of sub-tree D.

The name servers of sub-tree B are integrated within the DNS structure of the public Internet. In case there are no top-level name servers for the ICAO allocation within the public Internet, the servers of the individual regions and/or organizations will probably have to be registered directly with the root servers. In case ICAO, or another organization on behalf of ICAO, operates a name server for this sub-tree, it has to be registered directly with the root servers of the public Internet.

As addresses of sub-tree A are allocated by standard procedures that are in place in the public Internet, the associated name servers will also be incorporated within the public DNS structure as in any other commercial setting.

Application of DNSSEC to reverse tree

As sub-tree A follows standard address allocation procedures, it can be signed by the respective RIR that assigned the address space. A delegation chain from the public root of the Internet is then available.

For sub-tree B, the delegation chain depends on whether ICAO, or a 3rd party on behalf of ICAO, operates a top-level name server for this sub-tree:

- If a name server is available for the non-safety ICAO prefix, it will have a key that is signed by the RIR or IANA, depending on who allocated the address space to ICAO.

- If no such name server is available, the keys used by the individual organizations or regions would have to be signed directly by the entity that allocated the ICAO address space (RIR or IANA).

In both cases, a delegation chain back to the public root would be available. However, the second scenario might cause difficulties, as the RIR/IANA might be unwilling to perform a signing operation for address space it did not directly allocate.

It might be possible that the public Internet root is not available for sub-tree C, given that the safety-related networks are segregated from the public Internet. In this case, the key used for the common /25 ICAO safety prefix should act as a root key for the safety-related domain.
In case no segregation is in place between safety and non-safety networks, the options to construct a delegation chain to the public Internet root key are equivalent to those of sub-tree B (see above). Security considerations might prohibit this approach though.

The incorporation of the already existing address allocations in sub-tree D depends on whether segregation between safety and non-safety networks is in place:

- No segregation: a delegation chain from the public root key can be constructed via the responsible RIR.
- Segregation is in place: an additional root key for this allocation is necessary. This key will coexist with the ICAO root key (for the /25 or /22 prefix), but is only applicable for the existing allocation.

The prefix allocated to ICAO will be a /22, which is split into two /25 prefixes for use in safety and non-safety networks. If there is a signed key for the /22 allocation, this key will have to be used in both domains. This might cause security concerns.

An alternative would be to ask the RIR/IANA to sign only keys for the /25 prefixes. This would result in two different keys that can each be used independently from each other within their domains.

### 4 Summary

This document presented the SANDRA addressing and naming plan for both safety and non-safety related communications. Both plans take into account the aircraft (mobile network) as well as the ground networks.

ICAO will maintain policy and administration authority of the common IPv6 prefix and the associated Top Level Domain. It will determine registration and use policies relating to assigned addresses and names that are parts of the overall ICAO tree.

The operation of the necessary registries and associated names servers may be delegated by ICAO to 3rd party with necessary expertise but are always subject to policy authority of ICAO.

The proposed addressing plan provides a prefix level addressing with the following properties:

- ICAO should attempt to obtain a common /22 prefix for airborne and ground networks for both safety and non-safety related communications.
- Segregation of addresses between safety and non-safety networks is performed on the top level.
• Hard split between ground and airborne networks based on a single bit in the front part of the common prefix.

• More than 75% of the overall address space is reserved within the existing /22 allocation

The proposed naming plan provides an organization level plan for ground networks and a per-aircraft plan for the airborne networks with the following properties:

• ICAO should attempt to obtain one Top Level Domain from ICANN for exclusive use by aviation for aeronautical. That may be a new Top Level domain or policy adaptation of an existing industry domain .aero.

• TLD structure: the naming is segregated into safety and non safety related communications. The safety structure is maintained as closed, outside of public Internet. Noting that safety and non-safety communications occur among the same entities, the same naming structure is maintained for both the safety and non-safety domains. The naming structure is kept simple and flat, while using sub-domains to eliminate the risk of collision between two names from different coding systems.

• DNSSEC: We propose to use a stronger root key for all aeronautical communications. The public (Internet) root key could be considered for non-safety related communications when it has been upgraded to the required level of strength. An independent root key is maintained for all safety-related domains.

Within the DNS reverse tree, the addressing plan and naming plan necessarily converge to certain extends. The most important properties are:

• Top-level name servers should be operated under policy authority of ICAO; the actual technical operation can be outsourced to 3rd parties with established credentials in their operation

• Use dedicated root keys for ICAO safety prefix and existing safety prefix allocations
5 References

6 Appendix: Review of Existing Addressing Schemes

In the following we provide a summary of the various ICAO ACP WG I working papers that have been presented in the past.

6.1.1 NEWSKY / 16 Proposal at WG-I Meeting #7

The first addressing proposal from the project NEWSKY, consisting of two options, has been presented at the 7th ICAO ACP WG-I meeting in 2008.

6.1.1.1 Option 1

Option 1 is the first proposal presented in paper [20]. The proposed format is shown in Figure 6.1. The VER field in the NSAP address is replaced by the Traffic Type (TT) field in the IPv6 address, which is used to indicate whether this address corresponds to an airborne or ground system, and what type of service this system is used for (e.g. ATS, AOC, AAC, APC, etc.). The 4-bit TT field effectively partitions the ICAO IPv6 address space into 16 logically separate equally sized subspaces.

![Figure 6.1: Proposed ATN IPv6 Address Format (Option 1)](image)

The TT field could be encoded, for example, as shown in Table 6.1. TT Field Encoding.

<table>
<thead>
<tr>
<th>TT Value</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>Airborne ATS Systems</td>
</tr>
<tr>
<td>0001</td>
<td>Ground ATS Systems</td>
</tr>
<tr>
<td>0010</td>
<td>Airborne AOC Systems</td>
</tr>
<tr>
<td>0011</td>
<td>Ground AOC Systems</td>
</tr>
<tr>
<td>0100</td>
<td>Airborne AAC Systems</td>
</tr>
<tr>
<td>0101</td>
<td>Ground AAC Systems</td>
</tr>
<tr>
<td>0110</td>
<td>Airborne APC Systems</td>
</tr>
<tr>
<td>0111</td>
<td>Ground APC Systems</td>
</tr>
<tr>
<td>1xxx</td>
<td>Reserved</td>
</tr>
</tbody>
</table>
The least significant bit in the TT field indicates whether the address corresponds to an airborne or ground system. The rationale for having separate address spaces for airborne and fixed systems is as follows. Without this separation, an organization (airline or state) advertising itself would cause all traffic from the ATN directed to its aircraft (CA or GA) to be routed to its routing domain, instead of being routed directly to the current point of attachment of the aircraft. Even with solution as NEMO, which maintains reachability of the aircraft at a permanent prefix, this is undesirable, since it forces the airline or state to deploy a Home Agent in its routing domain, which could otherwise be deployed by a contracted organization, such as a service provider. For example, Lufthansa could contract Deutsche Telekom to connect their ground infrastructure to the ATN, and a different service provider (e.g. SITA) to act as Home (Mobility Service Provider) for all Lufthansa aircraft (as opposed to having to deploy the Home Agent themselves).

Note - By reserving the bit combinations 1xxx, ICAO reserves 50% of its available /16 address space for future use.

The ORG field is a variable length field indicating the organization to which the system belongs (e.g. airline, state, service provider, etc.). This makes it possible for large organizations (e.g. FAA) to have a shorter ORG field and therefore a larger number of sites, whereas small organizations (e.g. CAAs of very small countries), which are likely to have a very small number of sites, are assigned a longer ORG field. This approach is similar to that used by the ICAO 24-bit aircraft address structure.

Note - This precludes the use of the ICAO 24-bit aircraft address in airborne IPv6 addresses, since the Site ID field may be shorter than 24 bits, e.g. for small countries.

6.1.1.2 Option 2

The second option from [20], proposes a different format for airborne and ground sites – see Figure 6.2. The ground site format is the same as in Option 1, but airborne sites are identified by the 24-bit ICAO aircraft address. A 4-bit R field is reserved for future use and set to 0000. This field could be used in the future to indicate the aircraft type, e.g. commercial, general aviation, military, UAV, experimental, etc.
The problem with this approach is that it prevents aggregation based on the ORG field for airborne sites. Some amount of aggregation is possible given the state-based hierarchical structure of the ICAO 24-bit aircraft address. However, for commercial aircraft, it is desirable to include the organization (airline) in the airborne site prefix, in order to be able to advertise airline-based aggregates. For example, all airborne sites could be advertised from the service provider that acts as Mobility Service Provider for this airline.
6.1.2 ICAO ACP WG-I #7 Recommended Format

The addressing format that WG-I concluded on during the 7th meeting in 2008 is as follows [1]. A visual representation is shown in Figure 6.3.

The final conclusion of the group for ICAO IPv6 Address Allocation Plan is only for Airborne Sites; address allocation for ground systems will be dealt with separately.

RIRs allocate Mobility Service Providers (MSPs) a /32 to be used for airborne site allocation. MSPs may be ACSPs, ANSPs, airlines, airport authorities, government organizations, etc. Beyond this 32 bit boundary, ICAO recommends the IPv6 address format for airborne sites shown below.

In particular:

- Each aircraft constitutes a /56 IPv6 end site, based on the ICAO 24 bit aircraft address.

- NEMO is assumed as the Internet mobility management solution to maintain Internet reachability of the aircraft nodes at a permanent IP address. Each aircraft is assumed to be associated with one or more MSPs.

- An aircraft may have different subnets for different services (ATS, AOC, AAC, APC, etc.).

Mobility Service Providers (MSPs), which deploy a Home Agent advertising a /32 aggregate prefix route that contains the aircraft's assignment.

Mobility Service Provider (MSP): a service provider that provides Internet mobility service (i.e. Home Agents binding an IPv6 address to the current point of attachment of the aircraft).

![WG-I #7 recommended address format.](image-url)
6.1.3 NEWSKY D11

The final addressing proposal from the NEWSKY project is available in NEWSKY D11 [1]. We will summarize it in the following.

This final proposal tried to incorporate the lessons learned so far from the previous proposals. This addressing plan is based on the following assumptions:

- As specified in [8], it is assumed that Interface Identifiers have 64 bits, therefore leaving the remaining 64 bits for the prefix itself.
- The plan is based on provider-independent (PI) addressing. The advantages and disadvantages of PI vs PA addressing are explained in [8].
- For the first new proposal it is assumed that ICAO will not receive more than a /32 allocation.
- For the second new proposal, it is assumed that ICAO will receive an allocation that is larger than /32. The least necessary (preferred) size of this allocation will be determined.
- The second proposal is built on the first one.

6.1.3.1 /32 Proposal for Air-Ground Addressing

Receiving a /32 address block is certainly possible for ICAO, and therefore the first addressing plan that is based upon this prefix length.

The 64bit prefix format is as follows:

|          32 bits          |   16 bits   |   12 bits   | 4 bits |
+---------------------------+-------------+-------------+--------+
|    Global ICAO prefix     |    ORG ID   |     A/C     | Subnet |
+---------------------------+-------------+-------------+--------+

The explanation of the individual fields is provided in Errore. L’origine riferimento non è stata trovata. and provided in the following.

Table 6.2: Field encodings.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Bits</th>
<th>Addressable entities</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global ICAO prefix</td>
<td>32</td>
<td>-</td>
<td>Assumption is that ICAO receives a /32 prefix.</td>
</tr>
<tr>
<td>ORG ID</td>
<td>16 / 14</td>
<td>65.536 / 16.384</td>
<td>This field refers to airlines and further organisations in need of Mobile Network Prefixes or mobile addresses.</td>
</tr>
<tr>
<td>A/C</td>
<td>12</td>
<td>4.096</td>
<td>The number of aircraft supported for each organization.</td>
</tr>
<tr>
<td>Subnet</td>
<td>4</td>
<td>16</td>
<td>The number of networks per aircraft.</td>
</tr>
</tbody>
</table>

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This format is aligned on /32 and /48 boundaries as also suggested in [10],[12]. ICAO acts as a /32 LIR and organizations receive their /48 from this block.

The organization ID should be considered as large enough: the ICAO code system is based on three letters for airline designations and therefore imposes a maximum number of 17,576 airlines. This leaves enough address space for later inclusion of general aviation considering a length of 16 bits.

The prefix managed by each organization is a /48 and therefore follows the advice from [12] that says that "small and large enterprises" should receive an allocation of this size.

Each organization can then provide addresses for over four thousand aircraft from their prefix allocation. At the moment, American Airlines is the largest airline in passenger fleet size with 906 aircraft and currently 38 orders (944 overall) [30]. Due to the future growth of air traffic and mergers between airlines, a number larger than 1000 aircraft per airline should be supported and therefore we propose to allocate 12 bits for this purpose.

Note: The ICAO 24-bit address is not included; instead a 12-bit identifier is used. This significantly reduces address length while still providing sufficient aircraft addresses per organization.

A number of up to 16 networks per aircraft are supported by this addressing scheme.

Note: Especially the structure of the /48 is a recommendation only. It should be left open to organizations to restructure the “A/C” and “Subnet” bits. E.g., the “Subnet” portion might be extended by reducing the length of “A/C” or vice versa.

Up to now, the different domains – ATS, AOC, AAC, APC - have not yet been addressed explicitly. However a separation between these, at least in terms of different prefixes, should be considered. For this purpose, the ORG ID field will have to be reduced by 2 bits, therefore effectively splitting the /32 into four /30 address blocks. From these blocks ICAO can assign /48s to the individual organizations.

It would be advisable that ATS/AOC and APC prefixes are not allocated from the same /30 block. Reserving one of the /30s for the purpose of APC might proof to be a good idea. AAC prefixes could be taken from either ATS/AOC continuous address space or from the APC /30, depending on how airlines choose to implement it.

This modification reduces the number of possible organizations to 16,384 which would still provide every single one out of the 192 UN member states [31] with an averaged overall number of 83 different organizations for the purpose of air-/ground addressing.

The final /32 addressing scheme looks as follows:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Bits</th>
<th>Addressable entities</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global ICAO prefix</td>
<td>32</td>
<td>-</td>
<td>Assumption is that ICAO receives a /32 prefix.</td>
</tr>
<tr>
<td>ICAO Managed</td>
<td>2</td>
<td>-</td>
<td>Partitioning of the ICAO /32 into several smaller address blocks.</td>
</tr>
<tr>
<td>ORG ID</td>
<td>14</td>
<td>16.384</td>
<td>This field refers to airlines and further organisations in need of Mobile Network Prefixes or mobile addresses.</td>
</tr>
</tbody>
</table>
Note: For passenger communications, PI addressing might not be necessary and PA could be used. In this case, the length of the ORG ID field of the /30 APC block can be reduced in exchange for an increase of the A/C and/or subnet field.

Note: In case a /48 should not be sufficient for an organization, an additional /48 block could be allocated.

Note: With this addressing scheme, an aircraft can have up to 16 on-board networks for ATS/AOC and additional 16 networks for APC. AAC prefix assignments decrease the available number of networks of one of these two categories.

6.1.3.2 / 27 Proposal Including A/ G and G/ G Addressing

The previous proposal limited itself to a /32 ICAO prefix for air-ground communications. This addressing plan was extended to incorporate ground networks. The new plan therefore considers an address allocation plan that is based on a larger address block, also taking into account addresses for ground networks.

The following allocations were proposed for the larger prefix; Air-ground communications:

- One dedicated /32 prefix for ATS/AOC air-ground addresses, except for the ORG ID field having the full 16 bits.
- One dedicated /32 prefix for APC air-ground addresses. Format similar to the previous one, except for the ORG ID field having the full 16 bits.

Ground-Ground:

- Allocations of the size /32 for the seven ICAO regions for the purpose of ATS/AOC ground-ground communications. The ICAO regional office or any other institution that could act as a LIR delegate for a certain region receives and manages these allocations. The LIR should delegate /48 blocks to the individual organizations within their region.

Note: In Europe ECTL already acts as a LIR that received address space from RIPE. In that case, a prefix from an ICAO allocation would not be necessary anymore.

- At least one /32 for APC ground networks (e.g. hotspots at airports). Again, /48 allocations to individual organizations.
- Reservation of additional /32 blocks for delegation to existing and future large service providers. Some of these blocks are partially also for the purpose of APC.

In summary, following allocations are required:

1x /32 for ATS/AOC air-ground
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1x /32 for APC air-ground  
7x /32 for ATS/AOC ground-ground  
1x /32 for APC ground networks  
N x /32 for for large service providers  

Number of /32s: 10+N

This proposal effectively requires 16 /32 blocks, therefore making an ICAO prefix allocation of length /27 necessary. The assignment of N=6 seems reasonable, as at the moment there are already two existing large service providers for ATS/AOC. In the future, additional providers might emerge, especially for APC. Due to this, address space should be reserved.

Further it is recommended to allocate this /27 block from a reserved continuous address block of size /26 to allow for future growth. This allows for 32 allocations with a size of each /32.

This way, APC networks on the ground could also rely on an ICAO LIR based approach as proposed for ATS/AOC.

Note: Again, the allocation of different /32 address blocks to ATS/AOC and APC is supposed to allow for simpler segregation of the different domains (for security reasons).

Note: When ignoring ground-ground addressing, the size of the prefix can be reduced to a /31 (two times a /32 allocation). To support future growth, it is recommended to perform the allocation from a reserved continuous /30 address block.

### 6.1.3.3 Rationale for not using ICAO 24-bit address in IP prefixes

NEWSKY D11 also provided a discussion why the ICAO 24-bit address should not be encoded inside the IP address prefix, as often promoted by ICAO ACP WG-I.

Making use of the ICAO 24-bit address in the addressing scheme was proposed in the preliminary MSP-based addressing plan in [1]. We argue that this is an inefficient way to do air-ground IPv6 addressing - this is especially true if PI addresses are supposed to be used.

Starting with the fields as defined in Section 11.6.1, the “A/C” field is replaced by an “ICAO A/C ID” field with a fixed length of 24 bits:

<table>
<thead>
<tr>
<th>36-n bits</th>
<th>ORG ID</th>
<th>24 bits</th>
<th>4 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>+-----------------------+-----------------------------------------------+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global ICAO prefix</td>
<td>n bits</td>
<td>ICAO A/C ID</td>
<td>Subnet</td>
</tr>
<tr>
<td>+-----------------------+-----------------------------------------------+</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Shown in the following is the effect that assigning a certain length to the ORG ID field has on the required ICAO prefix length:

Table 6.4: Field encodings.

<table>
<thead>
<tr>
<th>ORG ID Field Size (in Bits)</th>
<th>Number of Organizations</th>
<th>Global ICAO Prefix Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>12</td>
<td>4,096</td>
<td>24</td>
</tr>
<tr>
<td>14</td>
<td>16,384</td>
<td>22</td>
</tr>
<tr>
<td>16</td>
<td>65,536</td>
<td>20</td>
</tr>
</tbody>
</table>

To provide the same number of organizations as in the /32 proposal in Section 11.6.1, the ICAO prefix must have the size /22.

Again, it should be noted that the number of organizations provided by a certain length of the ORG ID field is not fully available due to the segregation of the different service classes (ATS/AOC/AAC/ APC).

Also, if the ICAO prefix is chosen as aircraft identifier, a total number of 224 aircraft per organization are supported – providing prefixes for 16,777,216 aircraft per airline is clearly an unrealistic and wasteful allocation.
7 Appendix: Review of Existing Naming Schemes

In the following we provide a summary of the various ICAO ACP WG I working papers that have been presented in the past.

7.1.1 ICAO (ATS/ AOC)

In the review of existing documents dealing with DNS in the context of aeronautical networking, we will start with the following two working papers developed by Naoki Kanada from the Electronic Navigation Research Institute and presented at ACP WG-I:

- Fully Qualified Domain Name on Aeronautical IP network, WG-I 10th Meeting, Montreal, Canada, Apr 27– Mar 1 2009 [20]

- Name resolution without root servers, WG-I 11th Meeting, Montreal, Canada, Nov 18– Nov 20 2009 [8] and subsequent proposal to include DNS into the ATN/IPS for mobile and fixed nodes presented at WG-I 12th meeting [13]

“Fully Qualified Domain Name on Aeronautical IP network” paper [20] argues that “Almost nobody use IP addresses directly on IP networks to determine servers (e.g. SIP servers, Web servers, E-mail servers, etc.) because the Domain Name Service (DNS) is a most popular service on IP network.” The author proposes to use a Fully Qualified Domain Name (FQDN) as an identifier for an aircraft and for various services provided by ground service providers. For example an aircraft with a tail number JA8801, can be described in this scheme by its FQDN as ja8801.jp.atn.icao.int. VoIP server at Tokyo Area Control Center (Tokyo ACC, ICAO 4-letter code: RJTG) can be described in this scheme as voip.rjtg.jp.atn.icao.int.

“Name resolution without root servers” paper [8] proposes, responding to an argument that ICAO is not equipped to operate high availability DNS servers, that DNS service is operated without the root servers on the level of each ANSP and that ICAO publishes a list of the name servers of ANSPs by other forms such as a text document published on https://www.icao.int or a printed document.

Assessment:

Strong points:
- Both papers clearly identify the need to use DNS to facilitate administration of medium to large IP networks.
- The proposed structure is simple and easy to understand
- Proposal for administration of the naming structure for aircraft identifications (tail numbers) by national administrators is very pragmatic and practical. Assuming that tail numbers are always assigned by their national administrator and there is no possibility that two aircrafts may have the same tail number at the same time, requiring the administrator to act as the registry of corresponding domain names is a good choice.

Disadvantages and questions for further investigation
- The documents use naming examples with icao.int domain however, [7] at the same time acknowledges that ICAO intends to acquire a top level internet domain. This needs to be further clarified.
• [7] and [8] were developed in response to a concern that ICAO is not in a position to operate high availability DNS infrastructure while national ANSPs can do so. It suggests that ICAO prints addresses of regional name servers instead of operating a root DNS service. In our view, introduction of an interim step is impractical and will be difficult to administer and there is no need for an alternative management of the "root". Neither ICAO nor ANSPs are experts in high availability DNS operation. However, either of them can outsource the technical operation to an experienced DNS operator while retaining the policy and administrative rights that they need to possess.

Requirements identified in the above papers that we take forward include
• The requirement to address an aircraft using DNS
• The requirement to address application services provided by ANSPs using DNS
• Implementation should take into account that fact that ICAO is not currently equipped to operate high availability DNS services.

7.1.2 .AERO (AAC/ APC)

Another experience has been made by SITA when developing .aero, the first industry specific Internet Top Level domain. While this domain is not specifically focused on aeronautical communications, indeed, it is intended for public use on Internet; it is a fully operational industry specific domain and as such offers number of practical experiences particularly in the event the industry decides to request an inclusion of a domain dedicated to aeronautical communications in the Internet root.

The experiences may be summarised as follows:

• Naming structure and use by humans
  o Complex naming structure can be very difficult to manage and its enforcement is due to distributed nature of the database practically impossible. It is very important to maintain a simple system that can be understood by all users and enforced.

• Policy setting and policy implementation
  o Policy setting process in .aero involves consultation with key aviation stakeholders. Through Dot Aero Council, SITA, the sponsor receives regular inputs from representatives of aviation organisation and associations such as IATA, ICAO, ACI, NBAA or FAI. ICANN is contractually bound to consult with these bodies in the eventual re-delegation of the domain to another entity to ensure it remains managed in the best interest of aviation. Consequently, ICAO and the aviation community at large are in the position to influence the policy setting and develop policies that may be required for the use of the domain in aeronautical communications.

  o However, certain policies concerning protection of intellectual property and the actual process of registering domain names are highly influenced by the requirements of ICANN. Allocation of names corresponding to codes is accomplished by central eligibility check where eligibility administrator assigns codes to airlines or airports according to IATA coding directory, subsequent registration of the domain name takes place with a 3rd party commercial domain registrar. While this system guarantees correct allocation of names, it is very cumbersome for all parties involved. It would have been much more practical to delegate domains corresponding to codes as part of the actual code issuance by the relevant aviation authority.

• Commercial structure, particularly involvement of commercial registrars
• The current ICANN regulations do not permit the operator of the Top Level Domain to act as a registrar and manage the delegation of second level names to users. This also applies to lower level domains where the registry manages the subdomain such as allocations in airport.aero. For example, within the current rules, ICAO, if it decided to apply for a new Top Level Domain, would be unable to delegate the second level domains of the domain itself and would be required to engage 3rd party commercial registrars to provide the registration service for names corresponding to aircraft identifiers. Indeed, the current regulation enforces a specific commercial model that may not be suitable for use in aeronautical communications

• Reliability can be achieved with correct design and choice of technology providers

• .aero TLD has operated within the required 99.999% availability since its launch in 2002.

• Obtaining a new TLD is possible but it is very complex and subject to many regulations

• Delegation of an Internet top level domain by ICANN is subject to significant amount of regulations driven by the commercial use of domain names as memorable strings for people to use in day to day business, and is heavily impacted by the need of many players to protect intellectual property and brand. This regulatory environment may not suit the needs of the aviation community, particularly the communications based on industry codes and intended for system-to-system communication.

In conclusion, both options - the use of .aero domain or delegation of a new top level domain for use in aeronautical communications - appear open for further consideration and have about the same level of attractiveness. In both cases, (based on the past experiences and familiarity with the new TLD process as currently designed), delegation of a TLD by ICANN is not a suitable regulatory environment for operating an industry specific domain as the regulatory regime favours TLD operators with a purely commercial approach. We highly recommend ICAO to engage in conversation with ICANN to ensure that eventual delegation of a new TLD or modification of the regulatory environment for the .aero TLD is on the terms that suit the intended purpose.

7.1.3 The Future Communications Infrastructure - Concept and Transition (A/G IP Study)

The next document we have reviewed to identify possible requirements is the A/G IP Study, Deliverable D5/D6 - The Future Communications Infrastructure - Concept and Transition. [20]

The document refers to the following primary instance of DNS use:

• In Data Link Initiation a DNS lookup may need to be performed in order to resolve the IP Address for the ATSU.

• In AOC Communications Establishment Process, following a successful registration/login to an Air/Ground Communication Network, the aircraft determines the IP Address for its Airline Operations Centre. This may require a DNS lookup depending on how the aircraft is configured.

• For an industry standard network such as WiFi, the network registration process must result in the aircraft being allocated an IP Address, and being told the IP Address of the default router and the IP Address of the nearest DNS Server.

• In this architecture, the ATSU Communications Processor is multi-homed and has more than one connection to the Aeronautical Internet and hence more than one IP Address. There will probably at least two such processors, each with two independent interfaces to the Aeronautical Internet and
each with a distinct IP Address. The ATSU will thus have at least four IP Addresses on which it can be contacted. These may all be listed in the DNS as alternative IP Addresses and when the initial tunnel is created by an aircraft during the Data Link Login process, it may choose either of the alternative IP Addresses.

Further DNS related requirements are identified as follows:

- The need for a caching DNS Proxy on board each aircraft (Section 3.3.1)
- The requirement for each Air/Ground Communications Service Provider to provide a DNS Server for use by aircraft. (Section 3.4)

In terms of implementation, the paper suggests that the industry implements a private aeronautical internet with its own private DNS structure. DNS Root Servers will be operated by ICAO and each ATS Provider, ACSP, Airline and other organisation that uses ATN will need to have its own DNS Servers (Primary and Secondary) to provide and maintain DNS entries for its domain.

The proposed domain name structure includes the following top level domains (suffixes):

- .AVS has two uses:
  - Each ICAO Member State has a domain name in the .avs domain, given by the ISO 3166 three letter country code. Within this domain, an Administration may choose to register further sub-domains for example NATS in the UK will probably be registered as nats.gbr.avs.
  - Each ATSU will be designated by unique Ground Facility Designations allocated by ICAO. For example, UAC Maastricht would have the domain name: edyy.avs. Each ATSU will need to maintain DNS entries for, at a minimum, its Air/Ground Communications Gateway e.g. gw.edyy.avs for UAC Maastricht. Other conventional services:
    - “atis” for a D-ATIS Server
    - “otis” for a D-OTIS Server, and
    - “dsc” for a Downstream Clearance Service.

- .AVA has two uses
  - IATA Airlines have a domain name given by the three character alphanumeric symbols representing the appropriate IATA Airline Code or Aeronautical Stakeholder Designator For example, SAS would have the domain name SAS.AVI. Each Airline would need to maintain DNS entries for, at a minimum, its Air/Ground Communications Gateway.
  - Aircraft have a domain name corresponding to the Aircraft Registration Number (Tail Number) with the hyphen removed. For example: gpibb.ava for a UK registered aircraft with the Tail Number “G-PIBB”. Under this domain name could be additional DNS entries to record the ICAO 24-bit Address and Public Key Certificate for the aircraft. Conventional DNS names within the aircraft domain may also be usefully assigned. For example:
    - “ads” for an ADS Server
    - “cpdlc” for the CPDLC Service.
“cm” for the Communications Management Application

“aoc” for an ACARS Message Server.

- .AVI - Top Level domain for the use by the aeronautical industry, primarily those responsible for providing Air/Ground Communication services. No specific structure is foreseen, examples include company names such as e.g. arinc.avi, sita.avi

- .AVO is a top level domain for other organizations that are involved in the provision of ATS Services but are independent of any one state may also need to have domain names. For example: eurocontrol.avo

In section 3.7.3, the paper suggest that DNSSEC should be used as “means to prevent Denial of Service (DDOS) attack.

**Assessment:**

**Strong points:**

- The paper clearly identifies the entities, objects and services that need to be named and those will be used in business requirements defined below.

- The paper gives specific examples of potential usage of DNS and those will be used in business requirements defined below.

- Each coding system is in one domain. This prevents collisions and simplifies administration and operation of the system.

**Disadvantages and questions for further investigation**

- Creating several top level domains appears unnecessarily complex and may be very difficult to manage and use. Particularly, organisation names such as Eurocontrol could arguably appear in more than one domain defined above and users would find it difficult to determine what and where to look for. We recommend strict separation between naming based on various industry codes – hierarchical and strictly enforced - and naming based on company names and possibly even product names or brands. For the latter there, is no need for any specific hierarchy but they must not be mixed with codes in any way and any systems addressing, such as structures coded on aircraft, should not rely on such names.

- Creating numerous top level domains may be difficult to achieve should the industry expect ICANN to reserve and not to allocate all these domains as TLDs in the Internet root. Given the ongoing new TLD process, ICANN may not be able to guarantee such reservation. It may be more practical to set-up one domain in the current Internet naming structure that would be subsequently used for private aeronautical communications purposes.

- The proposal implies that a separate set of Internet root servers will be established. This is possible for as long as all IP address space used within the aeronautical communications environment is originating from the ICAO address space allocation. In this case, this separate set of root servers would only answer for the aeronautical root, which is equivalent to the common ICAO IP prefix. However, there might also be address space used within the aeronautical communications environment that has been allocated from the global public pool of IP addresses. In this case, it is not clear how the reverse IP addressing works.
- DNSSEC technology is certainly useful for authenticating the responses users will receive from DNS, as their directory service, but it is not designed to prevent a denial of service attack. The industry must use other tools and techniques to do so.