

# A Networking Testbed for IPv6-Based Future Air Traffic Management (ATM) Network

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**Abstract.** This paper presents a networking testbed, which is developed within the EC FP7 project SANDRA<sup>1</sup> to test and validate IPv6-based protocols for future Air Traffic Management (ATM) network. The development was originally initiated within the EC FP6 project NEWSKY which aimed at developing a concept for a global, heterogeneous communication network for aeronautical communications, based on IPv6 protocol stack. The SANDRA project aims at designing and implementing an integrated aeronautical communication system and validating it through a testbed and, further, in-flight trials on an Airbus A320. Central design paradigm is the improvement of efficiency and cost-effectiveness by ensuring a high degree of flexibility, scalability, modularity and re-configurability. Whereas the NEWSKY testbed is considered to be a *proof-of-concept*, the SANDRA testbed will represent a *prototype* aircraft communication system, integrating prototypes developed and implemented in SANDRA, comprising AeroMACS, Integrated Modular Radio (IMR), Integrated Router (IR), and a novel Ku-band antenna.

**Keywords:** NEWSKY, SANDRA, ATM, ATC, COCR, ATS, AOC, AAC, APC, IPv6, testbed, in-flight trials, aeronautical communication, RoHC, RoHCoIPsec, NeXT, NEMO, MIPv6, Integrated Modular Radio, Integrated Router.

## 1 Introduction

Several European research activities are being undertaken with the goal to develop improved communication technologies for aeronautical communication. These activities comprise ground-based, satellite-based, aircraft-to-aircraft and airport communication for all different application classes, both safety and non-safety, namely air-traffic services (ATS), airline operational and administrative communication (AOC, AAC), and aeronautical passenger communication (APC).

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<sup>1</sup> The research presented in this paper has been partially funded by the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n° 233679. The SANDRA project is a Large Scale Integrating Project for the FP7 Topic AAT.2008.4.4.2 (Integrated approach to network centric aircraft communications for global aircraft operations). The project started on 1st October 2009 and the consortium consists of 31 multi-national partners from 11 countries and from industry including several SMEs, research institutions and public bodies.

In this paper, the development of a networking testbed to test and validate IPv6-based protocols for future Air Traffic Management (ATM) network is presented.

The development was originally initiated within the EC FP6 project NEWSKY (Networking the Sky for Aeronautical Communications), which aimed at developing a concept for a global, heterogeneous communication network for aeronautical communications, based on IPv6 protocol stack. The NEWSKY network integrates different applications (ATS, AOC, AAC, and APC) and different data link technologies (legacy and future long range terrestrial radio, satellite, airport data link, etc.) using a common IPv6 network layer. For proof-of-concept, the NEWSKY testbed has successfully implemented NEWSKY network mobility, handover, and quality of service solutions, and tested and demonstrated them over real satellite link [1].

Also the EC FP7 project SANDRA (Seamless Aeronautical Networking through integration of Data-Links, Radios and Antennas) [2] aims at designing and implementing an integrated aeronautical communication system and validating it through a testbed and, further, in-flight trials on an A320. Central design paradigm is the improvement of efficiency and cost-effectiveness by ensuring a high degree of flexibility, scalability, modularity and re-configurability.

Whereas the NEWSKY testbed is considered to be a *proof of concept*, the SANDRA testbed will represent a *prototype* aircraft communication system, integrating prototypes developed and implemented in SANDRA, comprising AeroMACS, Integrated Modular Radio (IMR), Integrated Router (IR), and a novel Ku-band antenna.

The design of the SANDRA testbed network was already finalised and the SANDRA testbed detailed interfaces, software, and hardware specifications were started recently and are ongoing.

SANDRA focuses on the air-to-ground communication and on the development of the on-board airborne SANDRA terminal. The SANDRA terminal, in particular the IR and the IMR have to jointly implement the capabilities of resource allocation among heterogeneous link access technologies and link reconfigurability (e.g. when new links become available or previously available become unavailable, including handover between links). The required technology-dependent functions (such as control of the heterogeneous link technologies) reside in the IMR, whereas technology-independent functions are implemented in the IR, while using IP to achieve convergence and interoperability between the different link access technologies. Although the focus is on the airborne terminal, the testbed of course also has to implement a ground network side.

The main aspects of the testbed design and the testbed core concepts and components are presented in this paper, namely the security and QoS (quality of service) provision concepts for segregation of safety and non-safety domains in an integrated system, the Integrated Router, IPv6 and IPv4 internetworking.

The paper is organised as follows.

First, in Sec. 2 the NEWSKY project will be shortly described, including the study objectives and the architecture of an IPv6 network testbed for NEWSKY demonstration is also described.

The following Sec. 3 contains a short overview of the SANDRA main goals and testbed purpose. The main differences of the SANDRA testbed from the NEWSKY

testbed will become evident. This includes improvements in the protocols and configuration taking into account lessons learnt in NEWSKY, additional features such as automatic modem and bandwidth control, Integrated Modular Radio (IMR), and the additional requirement that the testbed shall be integrated in an aircraft for in-flight test.

Sec. 4 focuses on presenting the overall SANDRA testbed network architecture. This includes a reference network architecture, which is independent of restrictions specific to the testbed implementation, and the actual testbed network architecture which has to take into account various constraints, e.g. unavailability of IPv6 satellite access networks.

Sec. 5 presents in some more detail the selected topics related to the SANDRA testbed which are specifically interesting aspects of implementation and investigation; IPv6 over IPv4 network traversal and header compression.

Finally, Sec. 6 gives a short summary and presents the next steps and schedule for the testbed implementation and laboratory and flight trials.

## 2 NEWSKY Testbed Overview

The main objective of the laboratory testbed development in NEWSKY was to implement some basic functionalities of the NEWSKY networking design, in particular with respect to mobility, security, and quality of service (QoS) aspects. However, due to the constraints within the project, not all design aspects are implemented in the testbed. This section describes the NEWSKY testbed architecture, components, and points out the differences between the design and the implementation wherever applicable.

The laboratory testbed consists of two main subnetworks: the *airborne mobile network* representing an aircraft, and the *ground network* representing a connected ATC and airline network, and the public Internet. The two main subnetworks are connected by two different data links. The network architecture is depicted in Fig.1.

The airborne network consists of the Mobile Network Node (MNN) and the Mobile Router (MR). The MNN represents the airborne user terminal, which could belong either to the cockpit (e.g. an interface for pilot-ATC communication) or to the cabin (e.g. passenger's laptop). As part of the NEMO (Network Mobility) protocol (see description below), a Home Agent (HA) is installed in the ground network. The Corresponding Node (CN) acts as the other end point of the communication, e.g. it could be the air traffic controller, or the airline. An interface to the public Internet is also implemented to emulate passenger Internet connectivity.

Further testbed components are described in the following:

**Network Mobility Protocol.** Mobile IPv6 (MIPv6)/NEMO [5,6] and its extensions have been selected by the International Civil Aviation Organization (ICAO) Aeronautical Communications Panel Working Group I (ACP WG-I) to be the solution for global network mobility in future IPv6-based aeronautical telecommunication network (ATN). NEWSKY took the same approach by specifying MIPv6 as its solution for mobility. Network Mobility (NEMO) protocol is introduced to extend MIPv6, to enable the mobility of a complete network instead of just a single host. The testbed uses Linux based NEMO protocol from the Nautilus6 project [14].

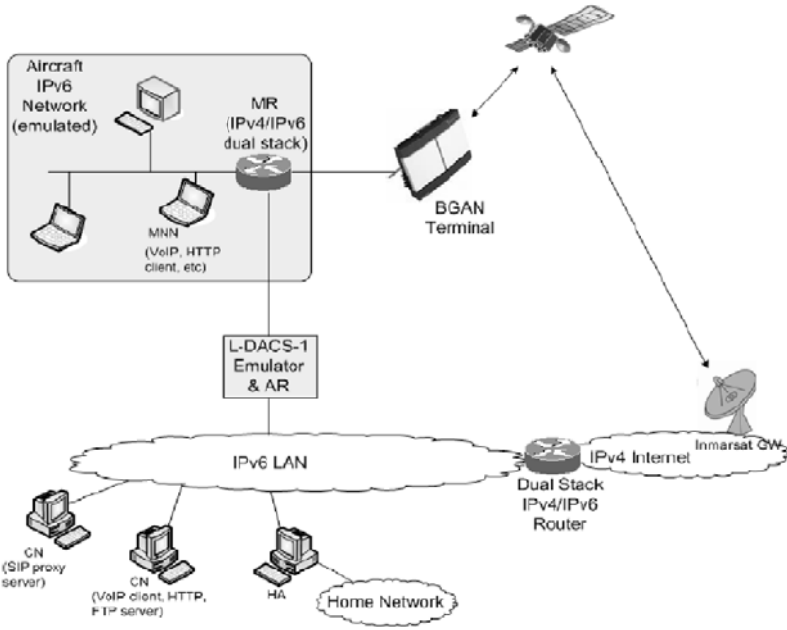


Fig. 1. NEWSKY laboratory testbed network architecture

**Data Links.** Two data link technologies are integrated in the testbed, namely the Broadband Global Area Network (BGAN) system from Inmarsat, and an emulated terrestrial link of a potential future air-ground data link technology, L-DACS-1 (L-band digital aeronautical communications system). The satellite link is a real physical link through the Inmarsat I4 satellites, whereas the emulator is software which adds delays to and limits the data rate of an Ethernet link, representing the physical and data-link layer of L-DACS-1.

**IPv4 Network Traversal.** Although NEWSKY focuses only on IPv6, in reality the Inmarsat BGAN system is based on IPv4. In the testbed, we implemented the Network Crossing via Translation protocol (NeXT) to efficiently traverse the satellite IPv4 network. NeXT is an overhead optimised NAPT-PT (Network Address and Port Translation - Protocol Translation) mechanism [10].

**Applications.** Future ATM communications will rely more on data services, and the usage of voice as in the current VHF-based radio system will be greatly reduced. Therefore in the testbed we implemented some representative IP-based applications, e.g. VoIP and FTP data transfer.

**QoS Management.** NEWSKY specifies DiffServ to guarantee the prioritisation of message coming from different applications. In the testbed this is implemented using Linux based *tc* tool to direct IPv6 packet flows into different queue classes, instead of putting traffic class marks directly to the packet as in DiffServ.

**Domain Separation.** For safety and security reasons, the on-board aircraft mobile network is divided into safety-critical subnetwork for ATS/AOC applications, and non-safety-critical subnetwork for APC applications. In the current airborne network this separation is achieved physically with different hardware. NEWSKY proposed a future airborne network architecture, where the separation is achieved logically using IPsec security tunnels. At the time of the project, however, this was not implemented, and a firewall is configured at the MR to enable a simpler separation of the domains.

Improvement of the testbed was continued even after NEWSKY was completed. Some of the new improvements include the integration of Multiple Care-of Address (MCoA) extension for NEMO [7], and the implementation of NEWSKY IPsec based domain separation. The testbed served as an initial proof-of-concept of the NEWSKY's future ATM networking design, and is to be further developed into a prototype within the SANDRA project.

### 3 SANDRA Key Elements

A key contribution of the SANDRA project to the definition of future aeronautical communication system is the integration on different system levels to overcome the drawbacks (such as limited coverage of direct A/G data links, high delay of satellite systems, etc.) of existing aeronautical communications systems based on single radio technologies and individual radio access systems:

- Integration of services from the safety and non-safety domains (ATS, AOC, AAC, APC).
- Integration of different networks, based on interworking of different radio access technologies through a common IP-based aeronautical network whilst maintaining support for existing network technologies (ACARS, ATN/OSI, ATN/IPS, IPv4, IPv6).
- Integration of different radio technologies in an Integrated Modular Radio (IMR), applying concepts for Integrated Modular Avionics (IMA) to communication avionics.
- Integration of Ku- and L-band antennas in a single hybrid Ku/L band satellite communication antenna providing an asymmetric broadband link.
- Design and implementation of AeroMACS (similar to WiMAX) for integrated multi-domain airport connectivity.

To prove all of the concepts developed in the SANDRA global system architecture the IMR will be capable of interfacing with a sufficient number of bearers, comprising Inmarsat SwiftBroadband (SBB) class 6/7, Ku DVB-S2 (2<sup>nd</sup> generation Digital video broadcast, receive only), AeroMACS, VHF Voice and VDL Mode 2 (VDL2).

Closely related to the key contributions, the SANDRA partners confirmed in Dec. 2009<sup>2</sup> that key requirements for SANDRA comprise

- Support of data and digital voice services for ATS, AOC, AAC and APC.
- Support of interfacing with legacy and future data links.

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<sup>2</sup> At the kick-off of the SANDRA sub-projects "SP2 - Requirements and Global System Architecture" and "SP3 - Seamless Networking"

- Ensuring network interoperability comprising ACARS, ATN/OSI, IPv4, IPv6.
- Deploying IPv6 as unification.
- Compatibility with ATN/IPS.
- Performing link selection based on information from applications, policies, and link layer information.

A further key element of the SANDRA project is the testbed, which has the purpose to implement and demonstrate as many of these SANDRA key elements as possible for validation of the overall SANDRA concept and architecture up to Technology Readiness Level (TRL) 5-6<sup>3</sup>.

The SANDRA testbed design and implementation will also take into account more specific and comprehensive requirements definitions prepared within SANDRA in various Work Packages (WP). SANDRA activities being relevant for the testbed specification are “WP3.1 - Detailed network requirements”, “WP3.2 - Network architecture”, “WP3.5 - IPS network design”, “WP4.2 - IMR interface”, “WP7.1 - identification of specific hardware available for the testbed”, “WP7.2 - Use cases and scenarios to be covered by the testbed”, “WP7.3 - Identification and Implementation of Applications”.

According to the envisaged TRL, a central goal of the SANDRA testbed is the development of a SANDRA *prototype* (in contrast to NEWSKY’s testbed for *proof-of-concept*), integrating the prototypes implemented in SANDRA (Integrated Router (IR), Integrated Modular Radio (IMR), novel Ku-band antenna, and AeroMACS) for validation&verification but also demonstration

- a) in a laboratory set-up of a high-fidelity representation of the target SANDRA system, including the airborne and the ground networks, and also comprising a realistic system environment for the airborne network (i.e. an aircraft) and
- b) during flight trials (planned for 2<sup>nd</sup> quarter 2013).

In addition to the SANDRA prototypes all network elements will be implemented and integrated in the testbed that are necessary to create the high-fidelity representation of the SANDRA target system (e.g., global geographically distributed networks, mobility via NEMO including extensions, security provisions, techniques for improving efficiency (e.g. Robust Header Compression/RoHC, etc.), including the 4 domains (ATS, AOC, AAC, and APC) for the ES which will host the applications and all other entities in the airborne and in the ground networks (cf. Sec. 4 and 5 for details).

The detailed testbed requirements specification and implementation phase was started in Oct. 2010 and is expected to be on-going until end of 2<sup>nd</sup> quarter 2012. The subsequent integration of all components and testbed trials will continue until 1<sup>st</sup> quarter 2013.

In addition to the above stated main purpose of the testbed, further suggestions and new algorithms from SANDRA activities running in parallel to the testbed design and implementation will be considered for implementation in the testbed.

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<sup>3</sup> TRL 5: components and/or breadboard validation in *relevant* environment; thus, flight trials will be performed within SANDRA. TRL 6: system & subsystem model or prototype demonstration in a relevant environment (ground or space). The highest TRL (TRL 9) corresponds to the actual system “flight proven” through successful mission operations.

Thus this paper shows work in progress and cannot provide all details of the SANDRA testbed, in particular presentation of results will have to wait until the testbed implementation is finalised and trials have been performed.

Finally, as stated above, the SANDRA testbed will be deployed in a laboratory environment and in an aircraft for flight trials. The testbed set-up for the flight trials will be subject to some restrictions, e.g. no Ku-band link will be available for the flight trials because of the too high costs for the installation and certification of the Ku-band antenna on the aircraft fuselage. However, we will not further address in the following the differences between the two testbed set-ups (laboratory and flight trials) and will not address in more detail the restrictions for the flight trials.

## 4 SANDRA Testbed Network Architecture Overview

### 4.1 Testbed Reference Network Architecture

In Oct. 2010, the SANDRA testbed network architecture was finalised in a Software Requirements Document (SRD). In this SRD, the SANDRA testbed reference network architecture is defined, which initially is independent of the restrictions specific to the testbed (e.g. no IPv6 satellite network); a schematic overview is shown in Fig. 2.<sup>4</sup> ATC (air traffic control, safety related) ground networks and (public) Internet (non-safety related) and CN for the 4 domains are also available in other geographical regions (region 2 and 3 in reference architecture diagram) but not shown to keep the figure simpler.

Depending on geographical location, the MR connects to a respective AR. ATC regional ground subnetworks are interconnected to implement global connectivity and the same holds for the Internet and its regional subnetworks.

The ES (MNN and CN) are not addressed in detail this paper, which only deals with the IP network up to the interfaces where the ES are connected to.

Although integration of legacy data links and interoperability with ACARS, ATN/OSI, IPv4 are considered essential for SANDRA (cf. Sec. 3), in the testbed the focus is on IP networking (IPv6 and IPv4). However, integration of legacy ES and applications (VDL2, ACARS, ATN/OSI, analog voice) into the testbed is under investigation in terms of use cases/scenarios, requirements, and implementation but also effort and may be included in the testbed.

### 4.2 Testbed Network Architecture

In contrast to the reference SANDRA testbed network architecture presented in the previous section, the actual testbed architecture and implementation will have to take into account various constraints, such as the necessity to include IPv4 access and ground networks also for ATS/AOC because of the current unavailability of IPv6 satellite networks.

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<sup>4</sup> Because NEMO is used for mobility support, the reference architecture uses the nomenclature of [6], comprising Mobile Network Nodes (MNN), Mobile Router (MR), Home Agent (HA), and Correspondent Node (CN).

The testbed ground-network will mainly be set-up at TriaGnoSys (TGS) premises. Also the airborne side will initially be set-up at TGS premises as well.

Due to limitations for the flight trials that do not apply to the laboratory set-up (e.g. no Ku-band antenna on aircraft), only a subset of the laboratory equipment of the airborne network will be used in the flight trials and installed in the aircraft.

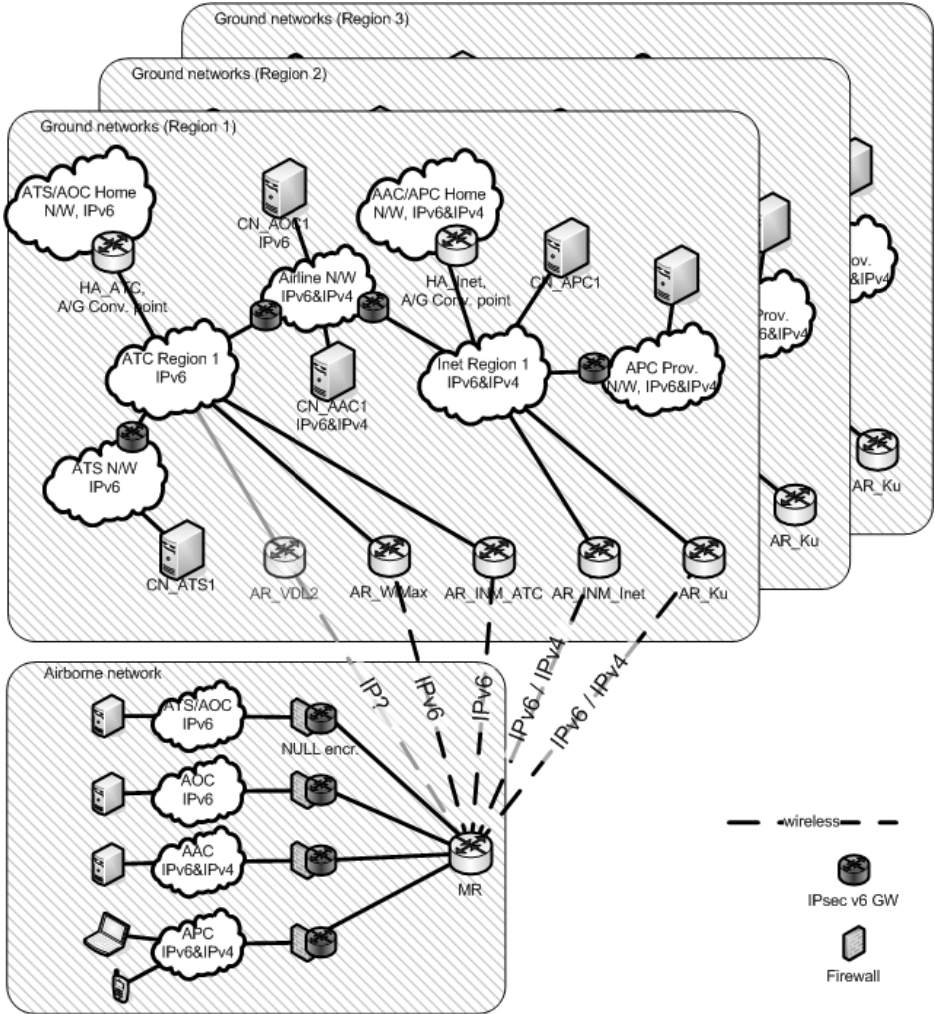


Fig. 2. SANDRA reference network architecture

Note that, as already stated above, the actual testbed network architecture will comprise IPv4 access and ground networks between the IPv6 only ATS/AOC airborne and ground networks due to the lack of support of IPv6 in the satellite networks available for the testbed implementation.



In contrast to ATS/AOC, for AAC/APC the IPv4 access and ground networks are a desired element of the testbed, because support of IPv4 hosts and access networks is required for AAC/APC.

The network nodes in the airborne network are:

- Airborne mobile network nodes (MNN) in the domains ATS, AOC, AAC, and APC; these are hosting the applications. Note that middleware and/or transition gateways may need to be deployed to integrate end-nodes that do not provide IPv6 interfaces. Note that these MNN and any middleware or transition gateways are not addressed in this paper.
- Firewalls at the entry/exits points of the 4 operational and non-operational domains to inhibit entry/exit of packets from malicious hosts (intentional or unintentional). Firewalls will not be implemented in the testbed because no penetration tests will be performed.
- IPsec (IPv6) gateways to provide authentication and integrity, with or without encryption, for safety (ATS/AOC) and non-safety related data traffic (AAC/APC). Further, IPsec enforces in the airborne network segregation of the safety domains from the non-safety domains. Also VLANs, port or tag based, are possible options to further enforce segregation but, like the firewalls, will not be implemented in the testbed.
- The Mobile Router (MR, IPv4 and IPv6) (also referred to as the Integrated Router, IR), is responsible for controlling the modems (for the fall-back solution<sup>5</sup>) or the IMR, resource allocation, QoS provision at IP packet level, etc. The NEMO related functionalities of the MR are specified in [6] and [7], including, e.g., registration of multiple CoAs at the HA.
- The network nodes in the ground network are:
  - Access routers (AR); at least one AR is deployed for each access technology (different provider may deploy different ARs or several geographically distributed ARs are deployed together with multiple radio access stations). Access routers provide CoA to the MR.
  - Home Agents (HA); at least one HA is deployed. The functionality of the HA are again specified in [6] and [7]. An HA further represents an air-ground routing convergence point, being aware of all routing paths (multiple CoAs) to the aircraft MR and forwarding traffic by policy routing to the MR on a particular routing path, e.g. based on QoS requirements.
  - IPsec gateways being the counterparts of the airborne IPsec gateways securing the ATS, AOC, AAC, and APC domains.
  - Correspondent Nodes (CN) in the domains ATS, AOC, AAC, APC; these are hosting the respective applications. Like the MNN, the CN are not addressed in detail in this paper.

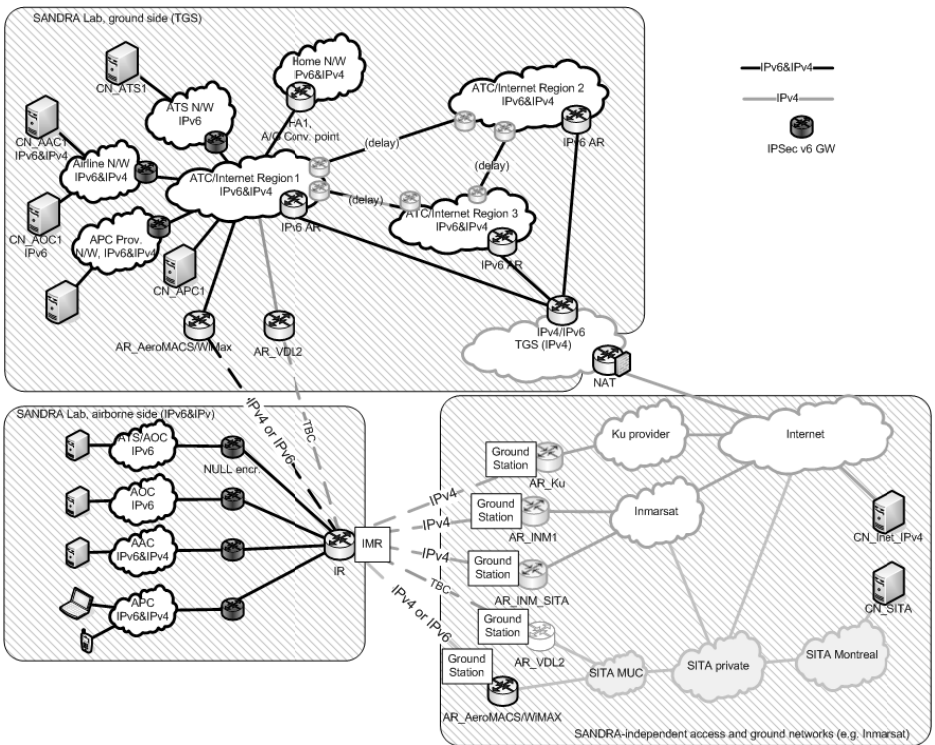
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<sup>5</sup> Already included in the SANDRA proposal is a fall-back solution *without* the IMR, in which case the IR directly interfaces with respective COTS (Commercial off-the-shelf) modems (SBB, DVB-S2, WiMAX). The fall-back solution is included to mitigate a potential risk of delay in the IMR implementation due to the high complexity of this prototype development. In this case, the IR has to implement some functionalities of the IMR, such as modem control and handover management.

In an aeronautical communication system that is deployed world-wide, MNN/MR, AR, HA, and CN are generally geographically distributed. Latencies between nodes that are close to each other are typically small, whereas latencies between nodes that are far away from each other may be significantly larger[15]. To reflect this, the testbed ground network is separated in three regions (three regions are considered sufficient for most scenarios, e.g. that AR, HA, and CN are located in at most three different regions); latencies between nodes in the same region are small, whereas latencies between nodes in different regions may be significantly larger.

Further, it is currently not foreseen to implement separate ATC and public Internet ground networks (cf. reference network architecture from previous section). However, if later definition of use cases, scenarios, and applications, not known currently, will require this, then separate ground networks will be implemented by deployment of additional routers (possibly virtual).

The resulting SANDRA testbed network architecture is shown in Fig.3.



**Fig. 3.** Testbed network architecture overview, including IPv4 access and ground networks

As for NEWSKY, the mobility solution for the SANDRA testbed is NEMO [6], including the possibility to register multiple Care-of-Addresses [7]. NEMO Route Optimisation (RO) will be considered (e.g. Global HAHA, Correspondent Router, etc.), however, implementation in the testbed will depend on an assessment of benefit and effort of the implementation, in particular if open source implementations are not yet available.

Use of multiple CoAs requires synchronisation of policy routing rules at the MR and the HA. This is addressed in a recent IETF draft [8], which also will be considered in the SANDRA testbed.

Finally, NEMO Basic Mobility Support as specified in [6] does not foresee IPv4 access networks. Two options allowing deployment of NEMO over IPv4 access networks will be considered for implementation in the testbed; first, RFC 5555 [9] and, second, a NAPT-PTbased solution [10] that was already successfully deployed in the NEWSKY testbed.

## 5 Selected Topics in the SANDRA Testbed

Due to the limited number of pages available for this paper we have to restrict a more detailed description to few selected topics in the SANDRA testbed.

### 5.1 IPv6 Over IPv4 Network Traversal

For each connected access network, the IR obtains from the IMR (or directly from a modem in case of the fall-back solution) one or more IPv6 or IPv4 CoAs (e.g. SBB allocates an IPv4 address for each primary PDP context), which are provided by the respective AR (by which protocol this is specifically done may depend on the IMR interface to the IR, the specific modem, the access network etc., which are not yet defined in the necessary detail).

In case RFC 5555 is deployed for IPv4 network traversal, IPv4 CoA are registered at the HA via a binding update [9]. IPv6 packets, including NEMO signalling, are tunnelled between MR and HA in IPv4 and a UDP header is added in case that NAT (Network Address Translation) is present on the path.

When NeXT is deployed, traversal of the IPv4 access network for IPv6 packets is achieved via IPv4/IPv6 translation. A context is set-up between NeXT master (in the IR) and slave (e.g. located at the border between IPv4 Internet and IPv6 SANDRA ground networks), mapping IPv4 CoA to an IPv6 CoA for NAPT-PT.

### 5.2 Header Compression

The network architecture which is driven by the security, mobility, and quality of service requirements, imposes the addition of a significant amount of header to the original message payload. Fig. 4 shows the structure of packets sent to the air interface at the egress of the IR. A quick observation shows that the amount of overhead justifies the need for implementing a header compression mechanism in particular for low bandwidth links.

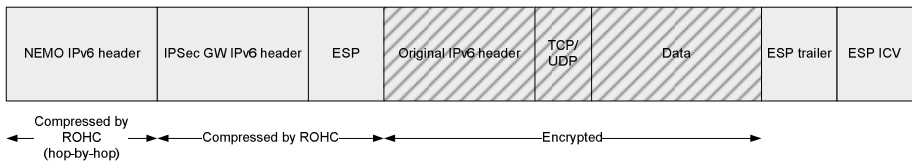


Fig. 4. Packet structure going out from airborne Integrated Router

Plenty of header compression schemes currently exist and are standardised in various IETF RFCs. For the SANDRA testbed, Robust Header Compression (RoHC) [4] is chosen because of its flexibility and the well-known good performance also over long-delay, error prone links, such as satellite links. Further, RoHC is the header compression scheme considered in the ICAO ATN IPS SARPS (ICAO Standards and Recommended Practices) for optional implementation in IP nodes [16].

RoHC could generally be deployed between several instances<sup>6</sup>

- between the IR and the HA to reduce overhead of the IPv4 and IPv6 packets tunnelled by NEMO. Note: compression gains, respectively, implementation complexity is significantly affected by IPsec deployment, in particular if encryption is used (cf. next bullet)
- if IPsec is deployed the relatively new RoHCoIPsec related RFCs could be implemented [11,12,13] and deployed in the respective IPsec gateways,
- between the IR and the AR, e.g. within a PPP context, if supported by the AR.

RoHC requires access to IP and TCP/UDP header for compressing packets. When these headers are encrypted (e.g. when using IPsec ESP) the compression is not possible. RoHC has defined a profile for ESP, but it only enables the compression of IP and the 8-Byte ESP header. Moreover, the compression works only in a hop-by-hop basis. The encrypted inner header remains untouched, as indicated in Fig. 4.

A framework for integrating RoHC over IPsec (RoHCoIPsec) is defined in [11]. It defines the modification required in IPsec protocol stack to allow the compression of IPsec encrypted packets.

Further investigations will be performed in the frame of the testbed development to assess in detail whether the expected compression gain obtained by implementing RoHCoIPSec justifies the implementation effort. Also alternatives to RoHCoIPsec will be investigated, such as Multilayer-IPsec [17].

Due to regulatory constraints, ANSPs (Air Navigation Service Providers) do not allow data traffic in their network to be encrypted. This puts ATS, AOC traffic in a particular situation, where IPsec is used for ensuring domain separation, authenticity, and integrity of the packets, but not their confidentiality. As the inner IPv6 and transport layer header are visible, a dedicated RoHC profile could be defined to compress all the headers except the outermost one, as it is needed for routing.

### 5.3 ATS and AOC Data Traffic

Performance assessment in the testbed, not only for the assessment of RoHCoIPsec, requires realistic ATS, AOC, AAC, and APC data traffic.

For ATS and AOC, the services defined in the COCR (Communications Operating Concept and Requirements for the Future Radio System) will be used[3]. A challenge is to obtain a communication traffic profile per aircraft (i.e. packet length, and frequency of occurrence), imposed by the COCR messages to the network. A realistic estimate needs to take into account the COCR service instance, which states, for example, that a message exchange shall take place once per sector, once per domain in airport, etc.

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<sup>6</sup> However, nesting RoHC is not recommended and it needs to be investigated how this issue can be addressed in the SANDRA testbed.

Our COCR traffic estimate is obtained from the methodology and tool developed in the framework of the EC project ANASTASIA (Airborne New and Advanced Satellite Techniques & Technologies in A System Integrated Approach) and ESA Iris programmes. The methodology uses information from a global flight route simulation. The obtained information, e.g. average flight duration, average flight duration in a domain, etc., is used to approximate and normalise the COCR service instances, thus simplifying the complex multi-service COCR traffic.

The methodology has been presented to the (satellite) ATM community several times, including Eurocontrol and NexSAT meetings in particular, and received comments have been continuously used to improve methodology and tool. The average traffic intensity of COCR messages (in bit-per-second per aircraft) will be used, e.g. in the context of deriving RoHCoIPSec compression gain.

## 6 Summary and Next Steps

This paper has presented a detailed overview over the SANDRA testbed, including a comparison with its precursor, the NEWSKY testbed.

It was stated that the main difference between the two testbeds is that the SANDRA testbed will represent a *prototype* of a future aeronautical communications system, whereas the NEWSKY testbed resembled a *proof-of-concept*.

This has quite far reaching consequences in terms of complexity of the testbed design and implementation efforts and also for verification&validation and trials, which need to be performed in a relevant environment, comprising integration on an aircraft and performing in-flight trials.

In contrast to the NEWSKY proof-of-concept, the SANDRA prototype needs a high degree of automatism for QoS provision, dynamic link selection, and resource allocation, etc. These functionalities are jointly implemented in SANDRA by the Integrated Router and the Integrated Modular Radio, which both were not present in NEWSKY.

Detailed design and implementation of the SANDRA testbed components including the SANDRA prototypes will continue until 2<sup>nd</sup> quarter 2012. Subsequently, all testbed components will be integrated, followed by extensive laboratory trials (until 1<sup>st</sup> quarter 2013) to verify&validate the SANDRA testbed and to investigate the performance of the deployed prototypes and protocols.

After successful integration of the testbed, flight trials on an Airbus A320 will be performed in the 2<sup>nd</sup> quarter 2013 to assess performance in a real-world scenario.

Of course, we intend to publish the final testbed design and trials results in future publications.

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