www.newsky-fp6.eu

NEWSKY Final Activity Report

Project Information	
Project Name	NEWSKY – Networking the Sky for Aeronautical Communications
EC Instrument	Specific Targeted Research Project (STREP) within FP6
Call	AERO-2005-1.3.1.4G (Innovative ATM Research)
Contract Number	37160
Project Duration	26/02/2007 – 26/09/2009 (30 months)
Project Coordinator	German Aerospace Center (DLR)
Project Partners	Thales Alenia Space France (TAS), QinetiQ Ltd, University of Salzburg (UniSBG), Frequentis GmbH (FRQ), TriaGnoSys GmbH (TGS), Deutsche Flugsicherung GmbH (DFS)

Document Information	
Title	NEWSKY Final Activity Report
Version	1.0
Work Package	WP0
Dissemination Level	PU

Document Authors and Authorization		
Document Responsible	Frank Schreckenbach (DLR) frank.schreckenbach@dlr.de +49 8153 282899	
Released by	Frank Schreckenbach (DLR)	Date: 18.02.2010

Project co-funded by the European Commission within the 6th Framework Programme

DOCUMENT HISTORY			
Version	Date	Modified Contents	Implemented by
1.0	18.02.2010	First Issue	F. Schreckenbach

Contents

Illustrations

Tables

1 Executive summary

Today, different application classes for aeronautical communication with different safety and reliability requirements exist ranging from Air-Traffic Services (ATS) over Airline Operational Communication (AOC) and Airline Administrative Communication (AAC) to Aeronautical Passenger Communication (APC).

Safety critical ATS communication between pilots and controller is still mainly based on analogue voice communication using a technology which has been introduced in the 1950s. Voice communication is supplemented by digital data communication, in particular using ACARS messaging, VHF Digital Link Mode 2 (VDL2) in combination with the Aeronautical Telecommunication Network based on OSI technologies (ATN/OSI) and satellite communication systems.

However, due to the growth of air transportation and the need for more efficient Air Traffic Management (ATM) procedures to increase safety, cost efficiency and environmental sustainability, it is expected that current ATS communication systems are running out of capacity within the next 10-15 years. In addition, AOC and AAC data traffic will strongly increase for efficient airline operations. APC systems are foreseen to be further developed to meet passengers' expectations of on board broadband communication services.

To modernize the current ATM system, the European Commission has launched the SESAR JU (Single European Sky ATM Research Joint Undertaking). SESAR JU provides guidance and leadership to all ATM-related activities in Europe and is now in the development phase.

NEWSKY is contributing to the development of the ATM communication infrastructure on two topics:

- Design, simulation and prototype implementation of an aeronautical communication network based on Internet technologies (IPv6) tailored to be applicable for aeronautical communications (ATS, AOC, AAC, APC)
- Specification of algorithms and signalling interfaces to realize the multiple-link concept and to integrate different data link technologies (long range air-ground links, airport links, satellite links)

The mobile communication network shall ensure that the application data is properly packetized and transmitted over the different data links. In particular, the network shall ensure that the data packets are appropriately routed, prioritized according to the given Quality of Service requirements, that seamless worldwide connectivity is ensured and that the requirements on data security are met.

The NEWSKY solutions are technical enabler for the SWIM concepts (System Wide Information Management) and for the efficient use of multiple data links. The key achievement of NEWSKY is the development and demonstration of the first air traffic control network based on IPv6 to integrate satellite and air-ground data links.

The project results have been presented at commercial fairs and dedicated workshops to stakeholders. The proposed solutions are fed to:

- SESAR JU
- FP7 project SANDRA
- Standardization bodies: ICAO ACP WG-I during the specification of ATN/IPS, AEEC NIS MAGIC

2 Project Objectives and Contour

The development of efficient aeronautical communication systems is currently a predominant topic in view of the expected saturation of ATM communications by 2020-2025 due to air traffic increase, the envisaged paradigm shift in ATM as developed in SESAR JU, and the existing high market demand for passenger communications. It is foreseen that different services, data links and networking solutions will be deployed.

Trends for the different **aeronautical services** include:

- Air Traffic Services (ATS) will be primarily based on highly safety-related data communication required to implement the SESAR concepts of operation (trajectory based ATM, System Wide Information Management (SWIM), Collaborative Decision Making (CDM)). Voice communication will be mostly used as fallback solution.
- Airline Operational Communication (AOC) and Airline Administrative Communication (AAC) data traffic will strongly increase for efficient airline operations.
- Aeronautical Passenger Communications (APC) systems are foreseen to be further developed to meet passengers' expectations of on board broadband communication services.

These different services with highly diverse requirements shall coexist and partly or totally share the aeronautical network infrastructure as well as a number of data links, through adequate pre-emption policies to prioritize safety critical applications in front of non-safety critical applications. Different levels of integration are possible and subject to trade-off between costs, reliability and security.

According to SESAR JU and Action Plan 17 of the Future Communications Study (Eurocontrol/FAA), several **data links** are required to fulfil the ATM communication requirements: a satellite link (new standard developed within ESA Iris program), an airport link (based on WiMAX technology), a high data rate air-ground link (L-DACS-1/2) and support of data links currently being deployed (e.g. VDL2). Further data links for APC will be in operation.

As **networking solution**, the Aeronautical Telecommunication Network (ATN) based on the ISO/OSI reference model is currently being deployed (e.g. Link2000 program) to enable advanced services. However, due to the marginal deployment of the OSI protocols in other areas than aeronautical communications, operation and maintenance costs are considerable. It is hence foreseen that the IETF Internet Protocol Suite (IPS), which is currently used for aeronautical ground-ground communications, will also be deployed for aeronautical air-ground communications for cost savings, high reliability and an optimal alignment with the evolution of communication and security technologies in the commercial world. ICAO has recently specified within ACP WG-I an ATN based on IPv6, commonly known an ATN/IPS.

Summarizing, users of aeronautical communication services face a highly complex and fragmented communication architecture with different services, different data links and different networking solutions to be supported. Interoperability and modularity of future communication systems are of major importance in this context.

The **NEWSKY project** has addressed this challenge and has developed an initial specification of a new aeronautical communication network based on Internet technologies (IPv6).

NEWSKY has pursued the vision of “Networking the Sky” by integrating different data link technologies (long range air-ground links, airport links, satellite links) and different services (ATS, AOC, AAC, APC) in a single, seamless network.

Whereas SWIM provides a conceptual framework for global information sharing, NEWSKY is a technical enabler for the implementation of such an approach. NEWSKY does neither develop new data links nor define the SWIM architecture and services. The NEWSKY project rather focuses on the design of a tailored IPv6 network and transport layer and proposes algorithms and signalling interfaces to realize the multiple data link concept.

NEWSKY areas of innovation include the specification of solutions for Quality of Service (QoS) processing, transport layer usage and optimisation, IP mobility management, inter satellite routing, mobile ad-hoc network routing, data link selection, seamless inter-technology handover, standardised signalling interface to data links, security mechanisms and validation through simulations and an integrated satellite and air-ground communications test-bed.

Table 2-1 summarises the focus of the NEWSKY activities from a service, physical entity and protocol stack point of view. In general, the network entities and network protocols enabling seamless communication with aircraft are within the focus of NEWSKY.

Services	ATS, AOC, AAC, APC. Military services have been considered in the requirements.
Physical entities	*Airborne network entities* relevant for aircraft external communications: mobile router, security access gateways, link access equipment, requirements for end systems. Details of onboard network topologies are out of scope. *Ground network entities* relevant for communication with aircraft: access gateways, home agents, security access gateways, information server, requirements for end systems. Assumptions on ground network topologies have been made, but they have not been designed.
Protocol stack	Transport layer, network layer, signalling interface to data links. Design of new data links, SWIM middleware and new services are out of scope. Figure 2-1 illustrates these facts.

Table 2-1: Focus of the NEWSKY project activities

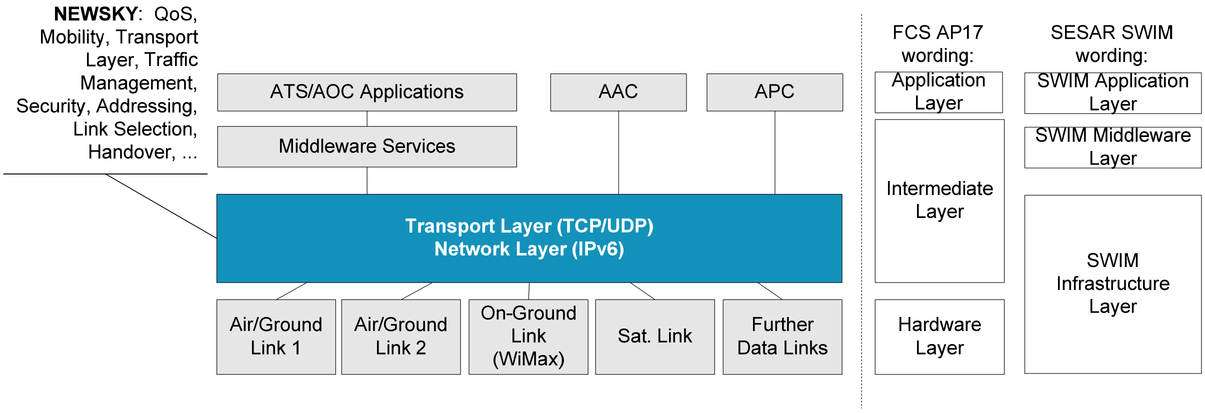

Figure 2-1: Focus of NEWSKY in the protocol stack

The integrated networking approach proposed by NEWSKY shall enable cost efficient operations, better economies of scale, a flexible and effective utilization of the available spectrum resources, optimised communications performance for each type of application, interoperability between different communication systems, and a highly modular and reconfigurable communication system, permitting to easily integrate new data link technologies to be developed in the future.

3 Major Project Achievements

3.1 Study Logic

The scientific and technological objectives are stated in the Annex 1 of the Contract [1] as follows:

- Develop a framework for ATM network transformation
  - Network transformation concept, business case study, deployment plan, and long-term concept evolution study
- Identify relevant application scenarios and service requirements
- Develop a framework for NEWSKY network concept and architecture
  - Design and definition of the network topology, functional architecture and protocol stack
- Design and evaluate NEWSKY integrated aeronautical network
  - QoS management, end-to-end data transport, mobility management (incl. hand-over techniques, routing, multihoming), network security
- Validate NEWSKY integrated aeronautical network design
  - Computer simulations and laboratory test-bed trials

The NEWSKY Consortium has addressed these objectives by decomposing the work in 4 technical work packages as recalled in the WBS in Figure 3-1 and following the overall study logic depicted in Figure 3-2. For a better readability, only the major relations between the activities are shown in the figure. The NEWSKY project comprises 4 phases:

- Requirements and initiation phase: Review of state-of-the-art system architectures and technologies, consolidation of project scope, derivation of requirements
- Design phase: Specification of NEWSKY system
- Validation phase: Validation of NEWSKY system through simulations and laboratory test-bed trials
- Dissemination and exploitation phase

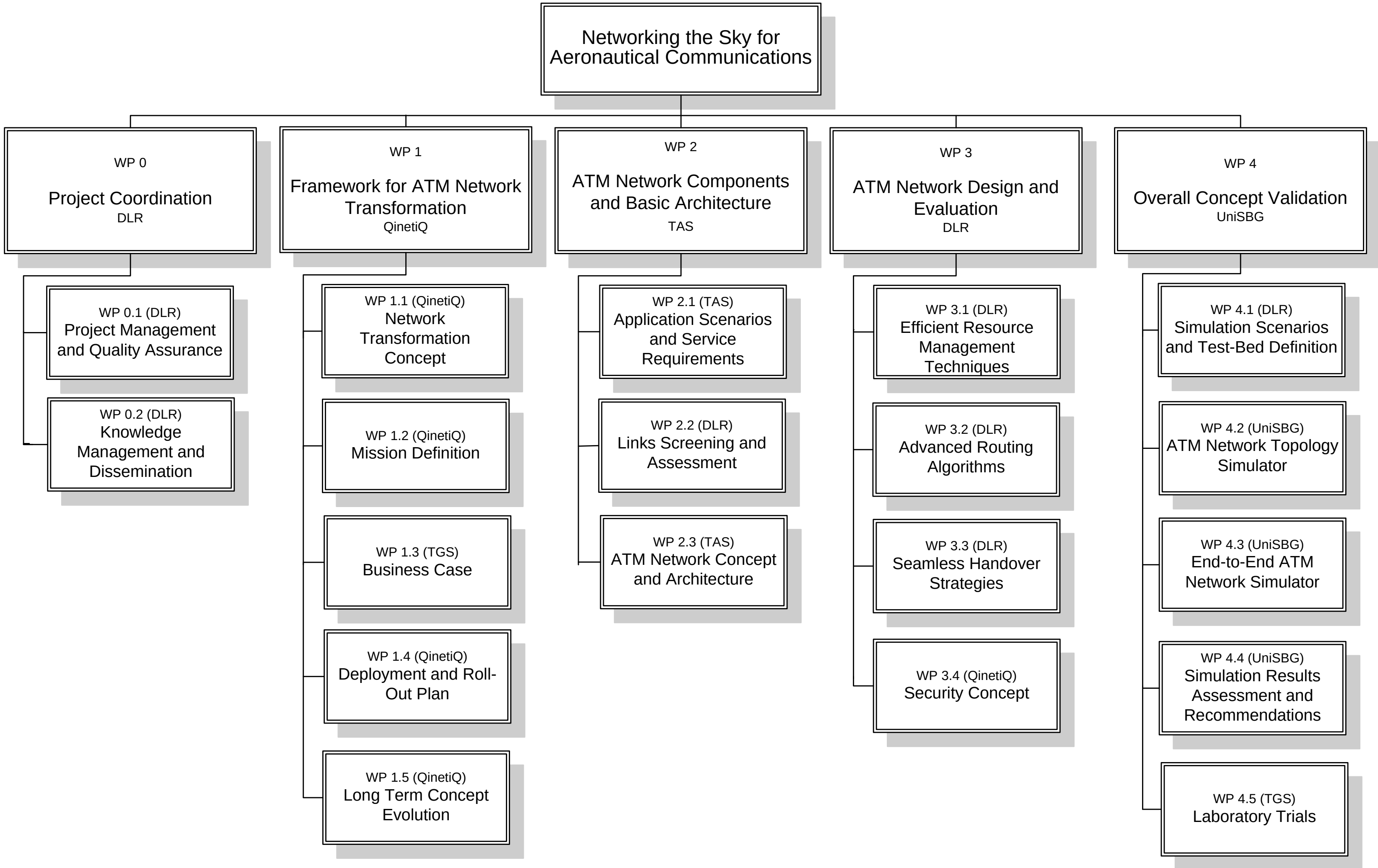

Figure 3-1: NEWSKY WBS

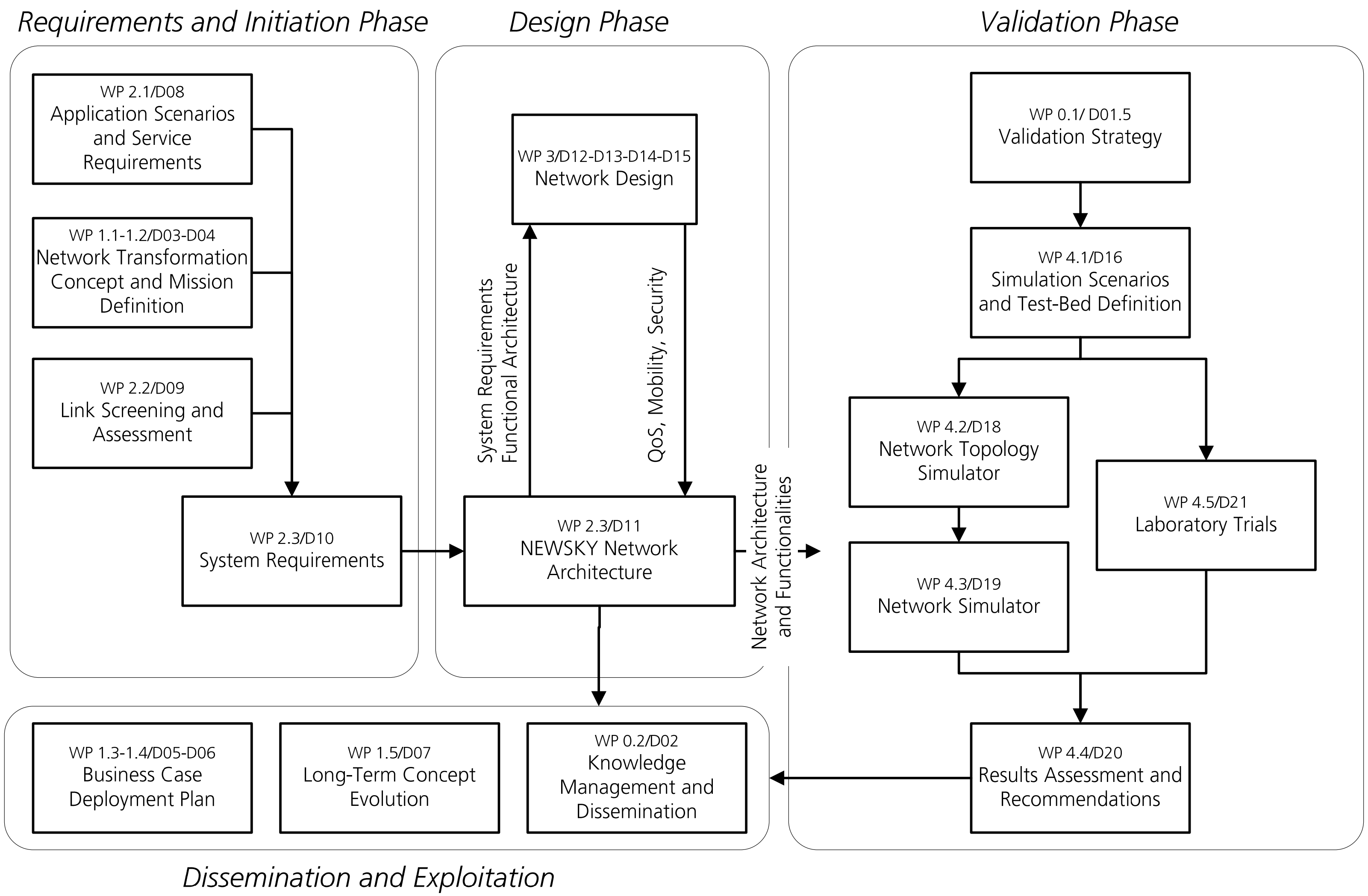

Figure 3-2: NEWSKY Study Logic

3.2 Requirements and Initiation Phase

The NEWSKY project started with the derivation of NEWSKY system requirements from a user perspective (WP2.1, D08 [12]). All types of users were considered, in particular ATM service provider, airspace user, airport operator, passenger, and military user. The derivation of user requirements was supported by inputs of studies from SESAR, ICAO, Eurocontrol, FAA and other major players, but also from direct feedback from ATM stakeholders obtained through dedicated user workshops organized by NEWSKY.

To highlight the NEWSKY capabilities in a multi-services/multi-user environment two application scenarios for the NEWSKY system were defined: The first scenario considers the transition to an IP-based network integrating the available data links for safety-related operational ATS/AOC applications, resulting in a user friendly, highly reliable and spectrum efficient communication system. The second scenario considers a long-term option integrating both operational (ATS/AOC) and non-operational (AAC/APC) services to avoid disparate communication systems.

After having derived the user requirements, further inputs for the design and validation phase were elaborated, in particular the review of Service Oriented Architecture (SOA) implementations (WP1.1/1.2, D03/04 [7][8]) and the characterisation of data links to be integrated in the NEWSKY network (WP2.2/D09 [13]). D03/04 sets the scene starting from protocol stack layers above the NEWSKY focus on network and transport layer and D09 captures and characterises relevant features from lower layers.

D03/04 provides recommendations for NEWSKY resulting from investigations on techniques such as Network Enabled Capability (NEC), Network Centric Warfare (NCW) and Service Oriented Architecture (SOA) implementations. These requirements have been a general input to the system requirements and follow-up design phase, but the detailed design of middleware and SOAs is outside of the scope of NEWSKY (see Table 2-1 and Figure 2-1).

A key output of D09 is the definition of technology categories which are representative of current or future possible data link technologies. Nine categories were defined, specified by the type of service they support (ATS/AOC/AAC/APC), the link type (airport, A/G, A/A, SatCom), and the airspace they are available (APT, TMA, ENR, ORP). These categories were an input for the design phase and for the characterization of link layer technologies in the simulation activities (WP4.2/4.3) of the validation phase.

Following these activities, the NEWSKY system requirements are derived in WP2.3/D10 [14]. A draft functional architecture was specified with the definition of the different tasks performed by each function and the interfaces between the different network functions. Functions were grouped to the three main areas of mobility management (including hand-over), security management, and data traffic management. These functions and the related network architecture have then been specified in detail in the WP3 activities.

3.3 Design Phase

3.3.1 Efficient Resource Management Techniques – WP3.1/D12 [16]

In the NEWSKY target solution, several link technologies such as satellite communication and terrestrial communication complement each other and form a transparent global network. This is a challenging environment to ensure the strict QoS requirements of operational services are met while using the scare communication resources in an efficient way. D12 proposes specifications and solutions for

- QoS architecture
- Link assignment strategies
- Transport layer usage and optimization

QoS architecture

The investigations on the possible architectures for QoS management showed that a sophisticated architecture with resource reservation techniques is not beneficial for a network which already has reserved bandwidth for operational communications. A prioritisation scheme based on data packet tagging and the DiffServ architecture with a well dimensioned network capacity seems more suitable and sufficient to comply with the operational requirements. The usage of DiffServ also avoids problems with mobility, security and scalability and also avoids a high signalling overhead. Therefore, the DiffServ approach with a suitable capacity dimensioning has been selected as the preferred solution in NEWSKY.

For the application of DiffServ as QoS architecture it was necessary to define a number of aggregate classes which are used within the network to handle priority. The mapping of COCR services to these network layer priority classes has been investigated and a specific approach meeting the requirements while minimizing the required data rate has been proposed. In addition, various scheduling options have been discussed and relevant (on ground and on board) algorithms selected.

Link assignment strategies

In the multiple link usage scenario of NEWSKY, the selection of the data link used to transmit data is not straightforward since it depends on a variety of attributes like contractual obligations, link delays, packet error rates and bandwidth. A simple link selection approach suitable for operation with legacy equipment as well as a multi-criteria link selection technique which allows taking into account a variable set of sophisticated data link attributes like cost and geographical coverage have been proposed. As third possibility, concepts of path diversity coding were investigated which produce a variable amount of redundant blocks on the network layer which are then send along different paths to the receiver where they are resembled. This concept seemed interesting since it can reduce the total packet error rate thanks to the added redundancy and the diversity along different paths. However, calculations have shown that due to the nature of the links present in the NEWSKY environment, the performance improvements of path diversity coding do not justify the increased complexity.

Transport layer usage and optimisation

Transport layer services using TCP are the most promising and common solution to allow reliable end-to-end communication. The NEWSKY multiple link usage scenario is challenging in this context as the communication performance might dramatically degrade if the TCP parameters are not adapted to the diverse link characteristics (error rate, delay, throughput …). A tuned TCP with adapted parameters for ATS/AOC and Performance Enhancing Proxies (PEPs) for AAC/APC have been investigated and specified in NEWSKY to address this problem. For the long-term, it is recommended to further investigate the use of a tailored transport layer protocol providing reliability and being based on the widely deployed UDP protocol.

3.3.2 Advanced Routing Algorithms - WP3.2/D13 [17]

Three aspects related to advanced routing issues in aeronautical communications have been addressed in NEWSKY:

- Mobility Management
- Aeronautical Mesh Networks
- Inter Satellite Link (ISL) Routing

Mobility Management

Global mobility management is one of the key enabler of providing seamless connectivity to the NEWSKY users. The investigations considered the work of different standardization bodies such as ICAO, IETF, industrial trends like Connexion By Boeing, 3GPP, WiMAX, and EC projects like MOWGLY. As a result of the analysis, Mobile IPv6 and its extensions are selected as the global mobility solution for the NEWSKY network. Home Agents (HA) are the anchor points on the ground maintaining the knowledge of the current aircraft Mobile Router (MR) address. Network mobility (NEMO), network-based local mobility management (NETLMM), and multihoming are the main approaches that are analysed as Mobile IPv6 extensions.

NEMO functionality is the main part of the NEWSKY mobility architecture. NEMO enables the handling of an aircraft as a moving network rather than as a number of moving hosts. This approach dramatically reduces the signalling overhead over the aeronautical data links. The main drawback of the NEMO protocol is that it does not support route optimization (RO), a feature which provides better end-to-end delay and overhead performance in the network.

Considering operational services, two different Route Optimisation solutions are proposed for the near and the far term. In the near term, the mobility architecture uses two complementary infrastructure-based solutions; namely Global HAHA, where several interconnected Home Agents (HA) are deployed over the world, and Correspondent Router (CR), where CRs are deployed as additional entities. Global HAHA approach is well suited for the aeronautical environment considering the global coverage of Global Air/ground Communication Service Providers (GACSPs). In addition, we believe CR approach is a kind of add on solution to Global HAHA which might be used in case of HA failures and to provide a better optimized route from a Mobile Router (MR) to a Correspondent Node (CN). In the far term, the mobility architecture uses “Mobile IPv6 Route Optimization in NEMO (MIRON)” protocol which provides direct communication between mobile and correspondent node on the ground. However, MIRON approach requires modifications to the ground end nodes (i.e. Mobile IPv6 features in the CNs) and some protocol issues still need further refinement. Therefore, it is only an option for the far term.

Considering non-operational services (e.g. Aeronautical Passenger Service (APC)), Global HAHA is the suitable protocol assuming that the Internet Service Providers (ISPs) will provide services over a large domain (e.g. USA or whole Europe) so that the Global HAHA deployment in such a network becomes practicable.

Local mobility functionality (i.e. Proxy Mobile IPv6 – PMIPv6) is another part of the NEWSKY mobility architecture that also aims to reduce the signalling on the wireless link. There, the mobility signalling within one access network is handled by ground entities rather than by the mobile node.

Figure 3-3 depicts an exemplarily set-up with Global HAHA mobility architecture and the combination of global and local mobility. The Global HAHA protocol is used in the Global ACSP (GACSP) network. After the aircraft attaches to the GACSP network, it finds the topologically closest HA and builds a mobility tunnel with the HA. Afterwards MR starts data transmission with the ground entities (e.g. ATS CNs) via the corresponding HA. With local mobility, the aircraft uses PMIPv6 functionality as long as it attaches to the home GACSP network. When it attaches to the foreign network (i.e. ANSP network in the figure), it performs standard NEMO signalling with the topologically closest HA.

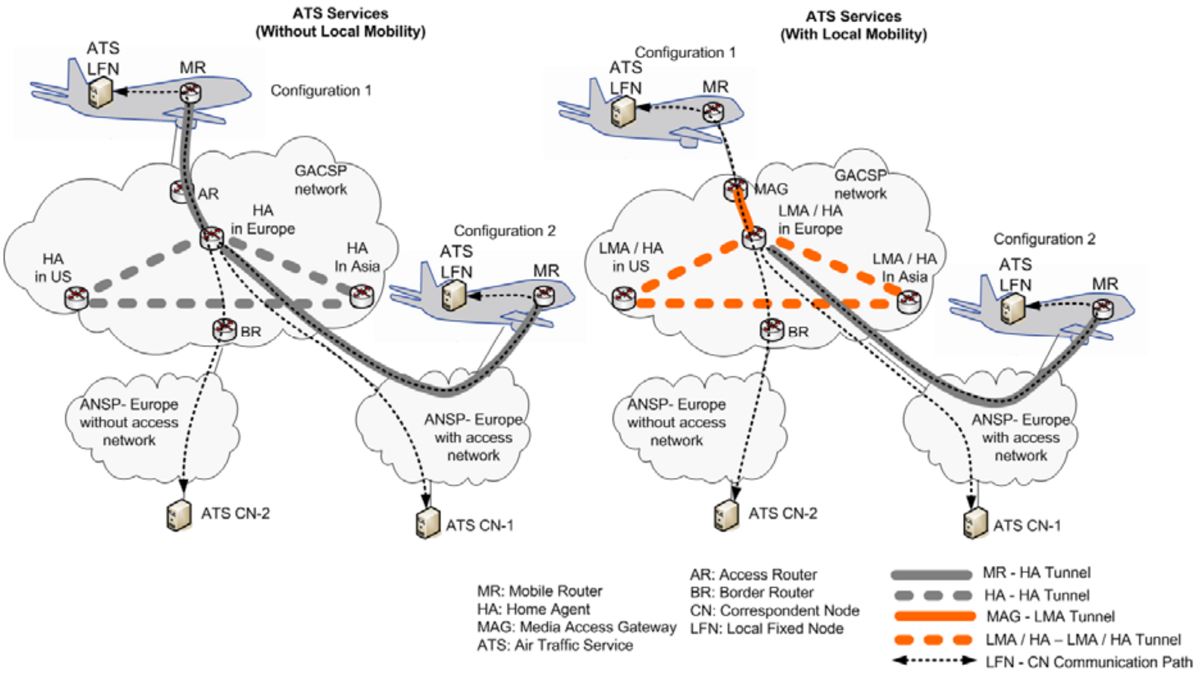

Figure 3-3: Integration of global and local mobility with Global HAHA as solution for Route Optimization

Multihoming functionality is the last part of the NEWSKY mobility architecture which is mainly used for providing simultaneous usage of independent data links. The main benefits of this feature are increasing the link reliability (very critical for ATS services), load balancing and make-before-break handovers over different link technologies.

All those features may be implemented through policies that directly depend on other system implementation considerations. For example, for achieving seamless handover, safer approaches could consist in transmitting some data twice (on the previous and on the new link), depending whether the handover decision management favours early link switches or try to maintain the link connection as far as possible, when the new link usage is of lower preference. For load-balancing, a static planning strategy could be decided in advance, but a more dynamic approach could probably be more suited. Such choice also depends on the wireless links – and ground network - loads that ANSPs and ACSPs would probably like to optimize.

Aeronautical Mesh Networks

Aircraft-to-Aircraft (A2A) multi-hop communications have been investigated for coverage extension of future broadband Air/Ground (A/G) access networks via mesh networking. This long term approach appears to be feasible in a number of scenarios, notably the North Atlantic Corridor. Advanced techniques such as adaptive antennas and cross-layer optimization between the routing and scheduling layers, as well as appropriate Internet Gateway selection and handover mechanisms are required to be performance competitive for passenger services and to meet the stringent requirements of operational communications. Once such communications capabilities are extensively deployed in onboard avionics, the NEWSKY consortium believes that aeronautical mesh networking could become interesting among airlines as an alternative or complementary access solution in all airspaces.

Inter Satellite Link (ISL) Routing

As one distinctive backbone component of a global routing architecture, a meshed satellite sub-network based on Low Earth Orbit (LEO) or Medium Earth Orbit (MEO) satellites can be defined to support a truly global networking including all oceanic airspace and polar regions efficiently, and to provide an overlay and/or backup backbone routing for the terrestrial Air Traffic Management (ATM) core networks. The space-based network is implemented by means of microwave or optical inter satellite links (ISLs) between adjacent satellites within the same or neighbouring orbits. While the connections between moving satellites are established by means of such physical ISLs which are variable in pointing and distance, the combination of two key concepts provides a controlled networking operation, namely the creation of a *permanent virtual topology*, and Multiprotocol Label Switching (MPLS) based operation of the core backbone ISL network. Yet, routing across these ISL networks, including in particular the dynamic satellite-ground links, presents a challenge in terms of routing protocols and meeting performance requirements. Extensive ATM traffic simulations for two reference constellations and ISL topologies show the basic suitability of an ISL backbone network for future global ATM communications, and allow an initial performance assessment.

3.3.3 Seamless Handover Strategies - WP3.3/D14 [18]

The problems and challenges of network handovers within an aeronautical environment are investigated. Generic handover scenarios for the various service classes (ATS/AOC/AAC/APC) are specified for estimating the rough number of handovers that are to be expected.

Note that the handovers addressed in NEWSKY do not refer to operational handovers in the ATS context; instead we talk about “technical” handovers between different base stations, gateways or access routers. A handover itself is a process that consists of various steps, starting from the layer 2 handover over IP address configuration up to mobility protocol signalling. It is shown that with a standard IP stack the delay until an interface/link becomes fully operational is in the order of many seconds.

Due to this, the IEEE 802.21 framework is thoroughly investigated and it’s usefulness for optimizing the handover process identified. This framework defines a Media Independent Handover function (MIHF) as signalling interface between the data links and the network layer. This provides abstract link layer intelligence and network information to upper layers for optimized link selection. Furthermore, the use of a technology independent interface enables easy integration of future data links. The concept of network-initiated handovers among different link technologies, as made possible by 802.21, is presented.

Similarly, the Fast Handovers for MIPv6 (FMIPv6) extension protocol is investigated with regard to its usefulness in the aeronautical environment. The recommendation is to use the combination of 802.21 and IP multihoming rather than FMIPv6.

Finally, the overall handover framework is defined with its interactions and required information exchanges between different elements of the protocol stack in an implementation independent way. Detailed scenarios are created to identify the relevant primitives and information elements provided by the 802.21 standard. Network-initiated handovers are identified as basically feasible, although they have to be treated with care due to signalling overhead and delay.

3.3.4 Security Concept - WP3.4/D15 [19]

A threat assessment methodology tailored to NEWSKY has been developed. The assessment of the potential threats has generated security objectives, architectures and requirements. The main threats considered relevant to the NEWSKY concept are Access – whereby an authorised user may gain unauthorised access to the system; Denial – where system resources may become exhausted due to system error, non-malicious user actions or denial-of-service attack; and Entry – whereby an unauthorized user gains access to the system. All threats have been assessed in each of the four types of communication services investigated in NEWSKY (ATS, AOC, AAC and APC) with consideration as to how likely the threats were to occur and the severity of the threat if it was realised.

Two logical security architectures have been derived to provide a framework for the remainder of the security concept investigations. The unconstrained logical security architecture provides a framework that could be used if policy and regulations allowed greater convergence of services, and appropriate sharing of the bearers. The unconstrained, fully integrated architecture is considered as a long term concept, where the services are separated through security tunnels managed by a single airborne router.

For NEWSKY, a constrained logical security architecture has been defined as baseline that takes into account current conventions on traffic routing and physically separated operational (ATS/AOC) and non-operational (AAC/APC) traffic. Nevertheless, the integration of ATS/AOC services on one side and AAC/APC services on the other side is foreseen. This architecture led to the generation of security requirements based on failure modes, communication link, flexibility and various other security variables.

An assessment of security options and mechanisms has been undertaken to propose a NEWSKY security solution that fulfils the security requirements generated in the risk assessment. The security architecture is based on security tunnels between on-board and ground Security Access Gateways. It was concluded that the IPSec framework provides the most reasonable solution.

3.3.5 Synthesis of NEWSKY Architecture - WP2.3/D11 [15]

To finalise the NEWSKY design phase, the overall NEWSKY system was defined in the second version of D11 integrating the results of the detailed design activities on resource management, mobility, handover and security in WP3. A harmonized and consistent functional, network and protocol stack architecture are specified.

Figure 3-4 depicts the baseline functional architecture for the short term constrained architecture. The definition of the different tasks performed by each function and the interfaces between the different network functions are detailed in D11. Data plane and control plane are considered separately. The functions related to traffic management (signalling or data) are in blue, those related to mobility management are in yellow and those related to security in orange in the figure. Data exchanges are represented in blue and signalling in white/black. Green arrows represent some external outputs (static tables). Multiple boxes indicate there is one such function per data link. Some boxes are implemented on the ground, some on-board and some are shared between on-board and ground.

The long term unconstrained functional architecture, where solutions have been explored to integrate operational and the non-operational services onboard in a reasonable way, requires QoS management to be done on a global scale.

Figure 3-5 shows the simplified overall architecture with the retained baseline features:

- Global HAHA mobility solution for ATS, AOC, APC and AAC,
- Separation of operational and non-operational traffic as derived from the constrained security architecture,
- No encryption for ATS services (only authentication), encryption for AOC, AAC and APC services,
- DiffServ QoS architecture based on DSCP (Differentiated Services Code Point) tagging in Local Fixed Node (LFN) for ATS, AOC and AAC downlink traffic or in on-board network equipment for APC downlink traffic or in edge router on the ground for uplink traffic.

The end-to-end protocol stack options proposed for NEWSKY are depicted in Figure 3-6 and were driven by transport layer considerations. The optimized transport layer strongly depends on the different traffic profiles for operational and non-operational services and on the different characteristics of the considered data links. For these two reasons a flexible architecture providing a transport layer that can be adapted depending on the type of link and type of service is proposed as detailed in Section 3.3.1.

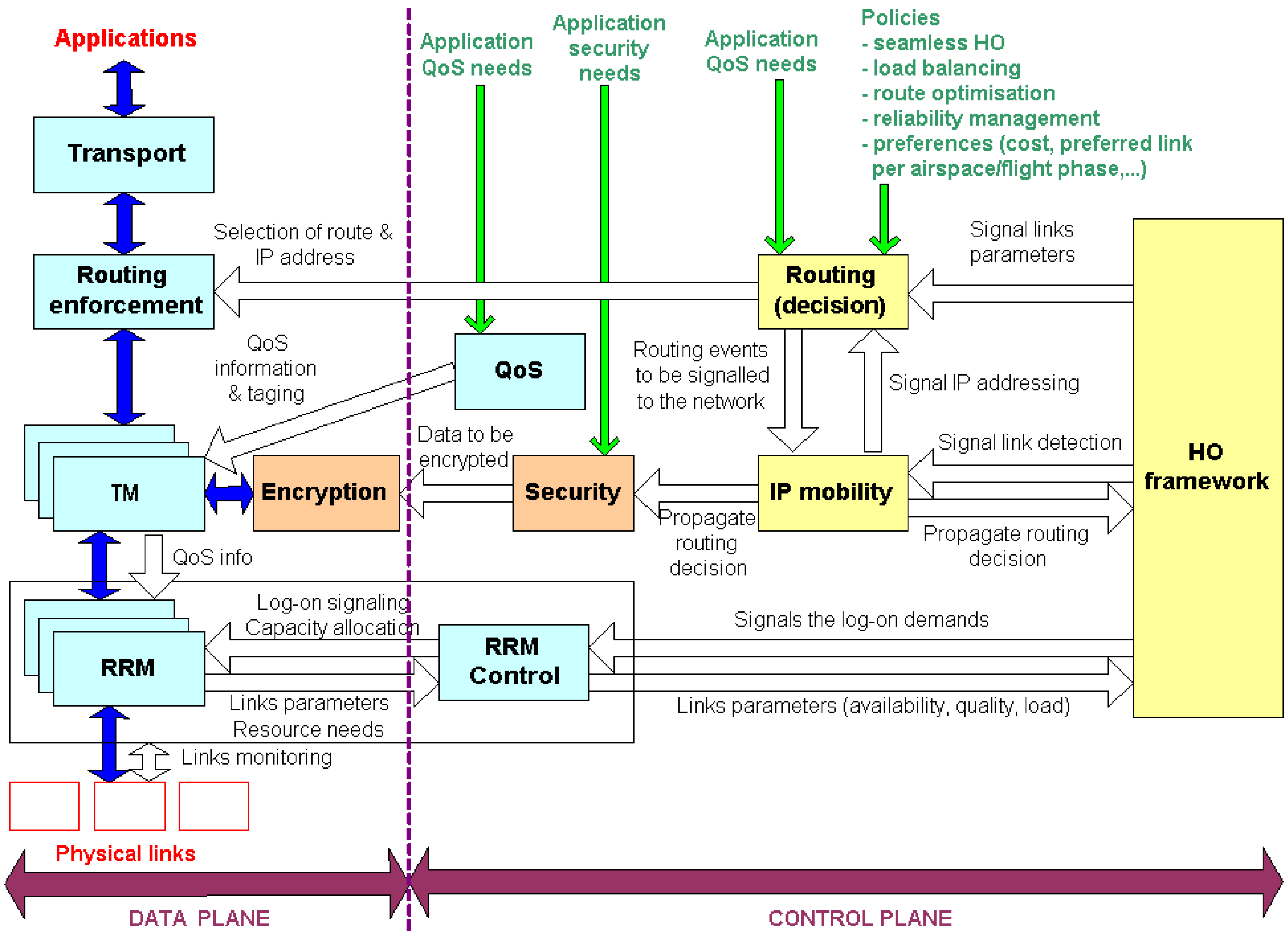

Figure 3-4: NEWSKY baseline functional architecture (short term)

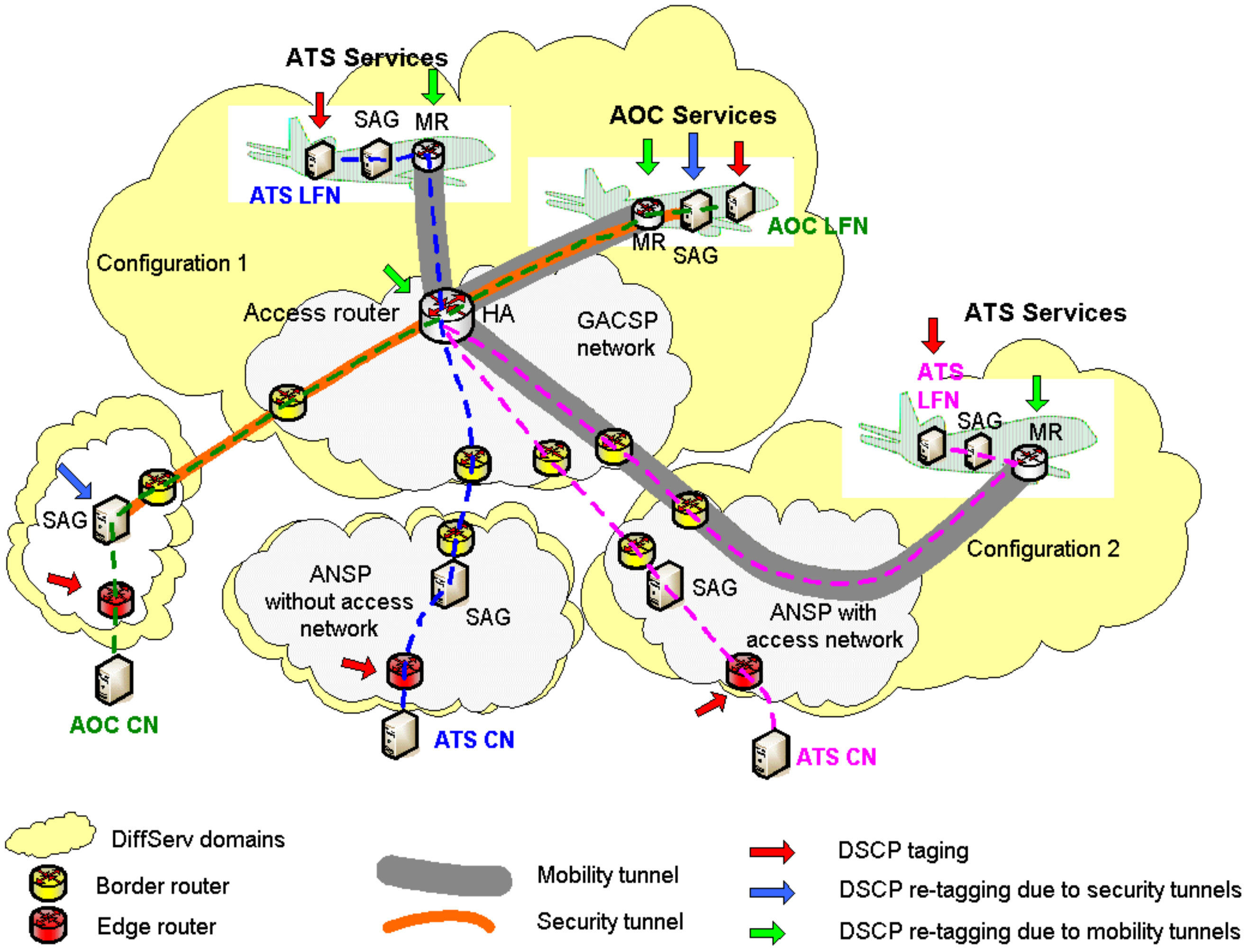

Figure 3-5: Overall network architecture (Depicted only for ATS and AOC)

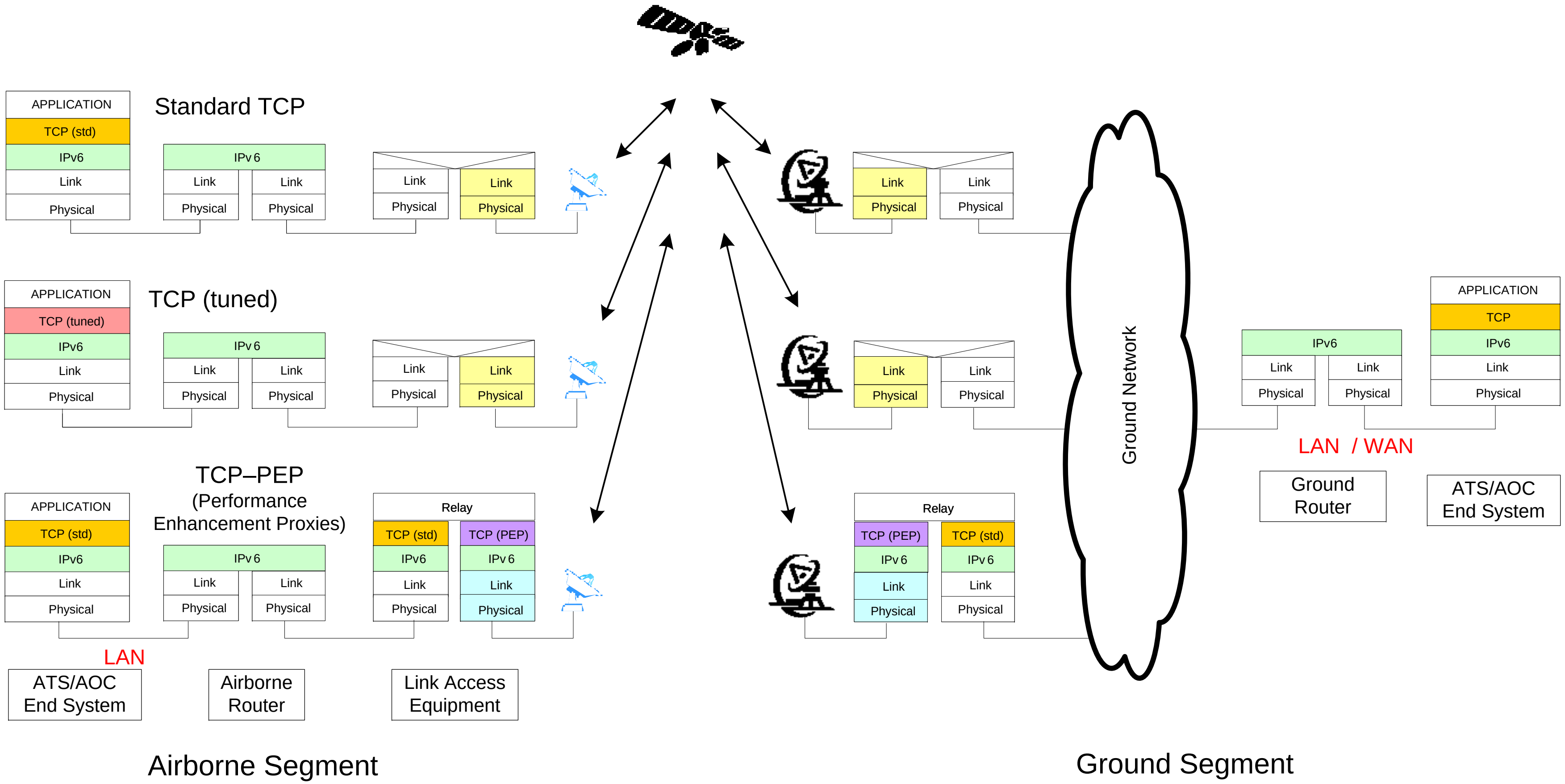

Figure 3-6: Protocol stacks for three candidate TCP architectures (satellite link as example)

3.4 Validation Phase

NEWSKY verification and validation activities include both simulations and test-bed trials.

The simulations allow functionalities to be validated in a large environment involving thousands of aircraft, where a large subset of the protocols and algorithms investigated in WP3 is implemented. In the simulations, the focus is on the overall network behaviour.

The objective of the trials running in the NEWSKY laboratory test-bed is to validate a subset of NEWSKY functionalities in a small scale with one mobile network (i.e. one aircraft). The focus is the validation of IPv6 network mobility solutions and session continuity during a handover event between two different access networks, in particular between a terrestrial and a satellite link and access network.

From a technical perspective, Table 3-1 lists the protocols that have been retained following the design in WP3, the protocols implemented for the global simulations and the protocols implemented in the test-bed.

Major protocols/algorithms retained in WP3	**Protocols/ Algorithms implemented in simulations**	**Protocols/ Algorithms implemented in test-bed**
RFC 4861 (Neighbor Discovery)	☒	☒
RFC 4862 (Stateless Autoconfiguration)	☒	☒
RFC 3774 (Mobile IPv6)	☒	☒
RFC 3963 (Network Mobility - NEMO Basic Support)	☒	☒
RFC 5213 (Proxy Mobile IPv6)	☒	☐
draft-thubert-mext-global-haha-00 (Global HAHA, NEMO Route Optimisation)	☒	☐
draft-wakikawa-mip6-nemo-haha-01 (Inter Home Agents Protocol for Global HAHA)	☒	☐
Correspondent Router (NEMO Route Optimisation)	☐	☐
MIRON (NEMO Route Optimisation)	☐	☐
RFC5648 (Multihoming)	simplified version	☐
Basic IEEE 802.21 primitives	☒	☐
IEEE 802.21 Information Service	☐	☐
IEEE 802.21 based network-initiated handover	☐	☐
Dynamic multi-criteria decision link selection	☒	☐
Conservative link selection based on geographical coverage and flight phase	☒	☒
TCP performance enhancing adaptations	☒	☐
Performance Enhancing Proxies	☐	☐
Priority scheduling mechanisms	☒	☒

DiffServ architecture + Mapping	☒	☒
IKEv2 / IPsec security	☐	☐

Table 3-1: List of protocols implemented for the simulations and in the test-bed

3.4.1 Validation Strategy WP4.1 - D01.5 / D16 / D17 [5][20][21]

The E-OCVM (European-Operational Concept Validation Methodology) methodology has provided the framework for the NEWSKY validation activities. The first steps of E-OCVM were investigated in D01.5 "Validation Strategy", including the identification of stakeholders, their needs and expectations, the definition of validation objectives in key performance areas, and the selection of validation tools and techniques.

Then, both for the simulations (D16) and the test-bed trials (D17), validation objectives, a list of indicators and metrics and finally a detailed list of validation scenarios were defined. 17 scenarios are defined for the simulations, covering the areas of mobility, QoS, link selection, transport layer, load balancing and resilience against failures. 3 scenarios covering mobility and handovers are defined for the test-bed.

3.4.2 Topology and Network Simulation WP4.2 / 4.3 – D18 [22], D19 [23]

Large scale link layer network topologies involving thousands of aircrafts are defined and implemented in [22] for the simulations.

A model for the movement and density of the aircrafts as mobile nodes (air traffic model) is specified using extrapolations to year 2025 on the basis of the Eurocontrol medium-term and long-term forecasts. The access link and access network model is defined based on the descriptions in D09 [13]. Then, a ground network model is derived including the relevant entities and inter-connections on the ground, abstracted to a level allowing a sound investigation of the NEWSKY algorithms and protocols. Ground nodes may be located in regional networks. Typical examples of such nodes are routers of ATC centres, AOC/AAC centres, APC gateways, and home agents. The core network interconnects all access networks and regional networks with varying delay according to their geographic location.

Figure 3-7 depicts a snapshot of the network topology visualisation.

Figure 3-7: Large scale link layer NEWSKY network topology

The next step is the implementation for the global simulations of a large subset of the protocols and algorithms investigated in WP3, see also Table 3-1.

A mapping between the simulation scenarios defined in [20] and the corresponding algorithms and protocols to be implemented for the simulations is done. Then, relevant functionalities of the algorithms and protocols are selected and specified to a high level of detail for the implementation. Following the implementation, values for a large number of network parameters are specified, significantly impacting the performance, as documented in [23]. In particular, the signalling traffic for the mobility protocols MIPv6/NEMO and PMIPv6 over the low bandwidth aeronautical data links is a key issue.

Finally, extensive simulations resulted in detailed simulations reports for each of the simulation scenarios as input to WP4.4 for the assessment and to derive recommendations.

3.4.3 Integrated satellite and air-ground communications laboratory test-bed WP4.5 – D21 [25]

An integrated satellite and air-ground communications test-bed has been designed and implemented to validate a number of requirements, to investigate selected functionalities using real data links and networks for a single isolated aircraft, and to assess the performance according to the scenarios defined in [21].

The laboratory trials are not intended to implement and validate the whole NEWSKY protocols designed in WP3. Rather, the focus is on the validation of inter-technology handovers and their impact on real-world applications, in particular hand-over between satellite and terrestrial data links, demonstration of MobileIPv6/NEMO functionalities in an aeronautical environment and failure of a terrestrial base station.

The architecture of the test-bed is depicted in Figure 3-8 and includes the following networks and domains:

- A/C (Aircraft) Mobile Network: The traffic towards/from the on-board ATS/AOC sub-network and the one towards/from the on-board AAC/APC sub-network are securely separated through a firewall at the MR.
- ATC domain: The ground ATC network is private with respect to the public Internet, and not accessible from non-ATC hosts. This network is placed within TriaGnoSys LAN. It comprises a Home Agent (HA), the two Access Routers (ARs) (for INMARSAT BGAN and for L-DACS emulator) and several Correspondent Nodes (CNs).
- APC Domain: Access to public IPv6 global Internet. In order to allow access to public IPv6 Global Internet from an APC host an IPv6-inUDP-inIPv4 tunnel is created between the HA and a public IPv6 Tunnel Broker.

Two characteristic data links are integrated in the test-bed:

- L-DACS: Software emulation of L-band Digital Aeronautical Communications System (L-DACS-1)
- Inmarsat Link: Real Inmarsat link with a BGAN (Broadband Global Area Network) terminal. The NEWSKY network is based on IPv6. Nevertheless, as Inmarsat network is an IPv4 network a mechanism to transport IPv6 packets through IPv4 network[1] is needed. For these, two approaches have been investigated, a standard L2TP tunnelling mechanism and NeXT, a new protocol specially developed for NEWSKY that deals with address network translation.

The major test-bed entities are:

- Mobile Router (MR): The MR is a Linux computer configured for IPv6, running MIPv6/NEMO protocol, that manages all MIPv6 related signalling for all nodes inside the airborne mobile network. The NEWSKY test-bed uses an open source MIPv6 and NEMO protocol implementation from the Nautilus6 project. As the satellite modem gets a public IPv4 address from the Inmarsat network, the MR requires a dual IPv4/IPv6 stack. The MR also runs a software implementation for the link selection rules, the L2TP and NeXT protocols for the encapsulation/translation of IPv6 packets into IPv4 streams, the firewall rules for traffic segregation, and mechanisms to provide QoS through traffic priorisation.
- Home Agent (HA): a router on the home link with which the MR registers its current care-of-address, intercepts packets destined to MR's home address while it is away from home. The HA is a Linux computer configured for IPv6, running MIPv6/NEMO protocol. The MR registers its current care-of-address at the HA and the HA intercepts packets destined to MR's home address while it is away from home.
- Access Routers (AR): the default router in the visited/foreign network, provides care-of-address to the MR.
- Correspondent Node (CN): the peer node with which the node inside the mobile network (i.e. the Host) is communicating.

[1] Future satellite systems may already provide IPv6 support thus making a mechanism to traverse IPv4 network unnecessary

The following representative applications have been included in the test-bed:

- ATS and AOC selected applications: VoIP calls, file download (e.g. weather map download) as TCP traffic, and short messaging application (e.g. COCR-like messages).
- APC applications: standard Internet applications such as web browsing or file download.

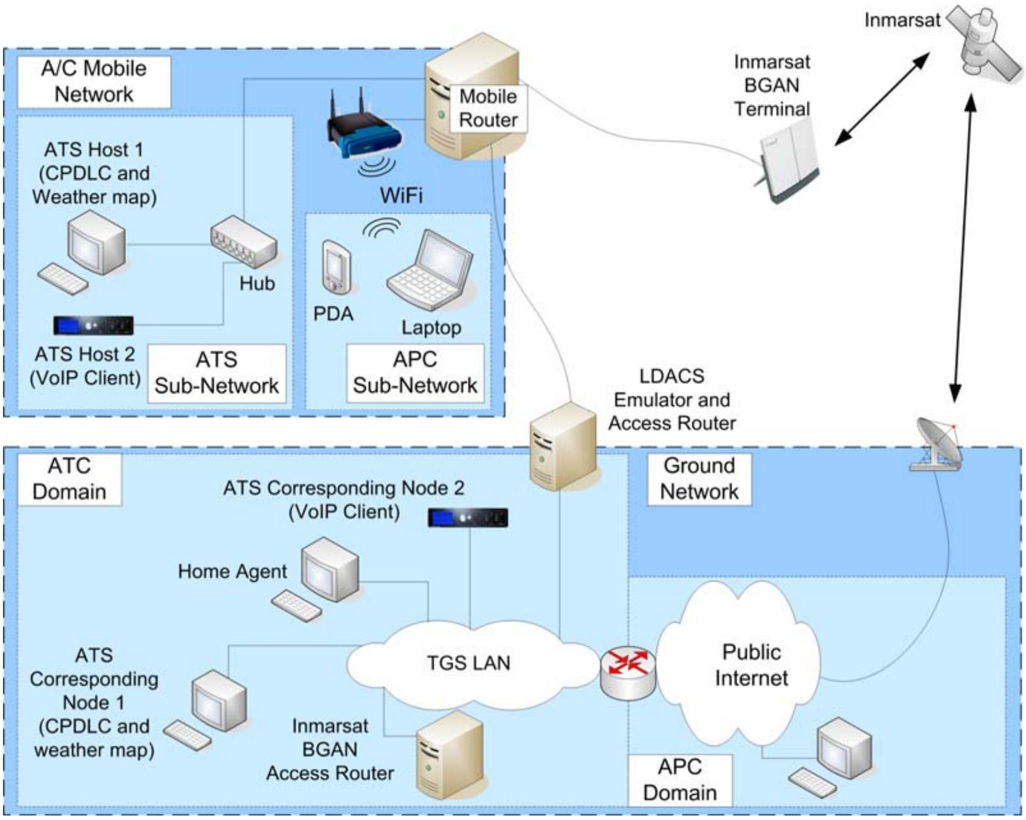

Figure 3-8: NEWSKY test-bed setup

Additionally, a Graphical User Interface (GUI) for visualization and control of the test bed scenario was developed. On one side, it allows monitoring the handover events, the traffic running over the two access routers, and the available communication link(s). On the other side, it allows selecting the handover rule between automatic and manual, selecting the preferred link in manual mode, and setting the speed of the emulated flight.

Once the test-bed implementation was completed, extensive trials recording more than 400 Mbytes of measurement data have been carried out allowing the comparison in the situation of a handover event of total throughput, handover delay, packet loss rate and end-to-end delay for layer 3 IP packets, with either using L2TP or NeXT and for two traffic types, namely UDP (when running VoIP) and TCP (when doing a file download).

The measurement results have been input to WP4.4 for assessment and to derive recommendations.

3.4.4 Results Assessment and Recommendations WP4.4 – D20 [24]

The results of the simulations and the results of the test-bed trials are analysed and recommendations are derived. Furthermore, the NEWSKY system requirements defined in [14] are tracked and their fulfilment is verified, by design inspection and/or through the simulations and test-bed trials

The assessment of the NEWSKY simulations results and tests showed that the NEWSKY system design does fulfil the identified requirements. No significant discrepancies have been identified.

The results of each simulation scenario as defined in [20] have been analysed, addressing the topics of mobility, handover, link assignment, load balancing, traffic management, Quality of Service and transport layer adaptation. The major conclusions from the simulations are:

- Make-before-break handover: The assessment of the simulation based evaluation of the NEWSKY system showed that IEEE 802.21 Media Independent Handover (MIH) functionality provides a significant improvement of the handover latency values, which additionally reduces the packet loss rate. In addition the periodic Router Advertisement (RA) message transmission interval can be decreased so that the RA transmission overhead in the wireless link becomes negligible. Further improvements towards true seamless handovers are expected by using multihoming protocols as described in [17] and [18].
- Node based vs. network based mobility: The benefits of the combination of PMIPv6 with MIPv6/NEMO over stand-alone MIPv6/NEMO are uncertain in the aeronautical domain. Stand-alone MIPv6/NEMO allows the use of multicast router advertisements (RA). Although assigning a common prefix to all mobiles is a non-standard deployment, this approach allows for a significant reduction of signalling traffic on the wireless link. PMIPv6 on the other side requires sending addressed RAs to each mobile router. This has the consequence that the load of the wireless link may be significantly increased in highly populated radio cells.

  A benefit of PMIPv6 is that the MIPv6/NEMO tunnel is not required in the home domain. This result in small performance gains and a reduction of the wireless link load. However, this benefit is only given in the home domain and may be diminished by header compression.
- NEMO Route Optimization: It has been shown that Global HAHA as Route Optimization approach can provide a significant reduction in end-to-end latency where inter-continental round-trip times are usually incurred. For intra-continental situations the advantages of Global HAHA in terms of Route Optimization are hardly noticeable, at least for the European case.
- Link assignment and load balancing: A multi-criteria link selection algorithm achieves the goal to balance the traffic load among available links by a decentralized approach. The impact of this approach on TCP performance and resource request/allocation issues on lower layers is subject of future work.
- Traffic Management and Quality of Service: The assessment showed that DiffServ priority scheduling can indeed produce the desired prioritization between different service classes. The strict priority scheduling serves the purpose to prefer urgent packets over lower service classes.
- Transport Layer: The results strongly support the use of high max congestion window with TCP, possibly with window scaling, to extend the 64 Kbyte limit. Such

optimization is of primary importance for medium size object download (e.g. map data, etc…) to bulky file transfers representing as big as several megabytes.

A non-standard setting of the TCP Initial Window (more than to 1 segment) seems definitively a good approach. Other simulations performed and reported in [13] with different data links showed that better performances could be indeed achieved for higher bandwidth data links.

- Global assessment: Our assessment indicates that the NEWSKY system is robust against catastrophic events like the simultaneous failure of multiple base stations.

The NEWSKY test-bed has demonstrated that the selected protocols (MIPv6 with NEMO extensions) are indeed capable of providing session continuity during handovers for ATS, AOC and APC applications:

- Session continuity for ATS and AOC FTP traffic (i.e. weather map download) has been demonstrated. The results of the test-bed trials indicate that most ATS and AOC applications (i.e. short COCR message exchanges) are not negatively affected by handovers.
- The TCP-based file transfer (e.g. weather map download) showed that the interruption of bulk TCP transfers by handovers may cause problems although session continuity is kept. The delay induced by the falsely triggered TCP congestion avoidance mechanisms is in the order of several seconds and the TCP connection may need a considerable amount of time (in the order of tens of seconds) to recover.
- Regarding the handover delay as seen by the IP layer without enhancement mechanisms such as IEEE 802.21 and/or multihoming, the test bed measurements indicate that 10s are to be the expected value when a handover between terrestrial link and satellite link takes place. This does not allow the use of time-critical ATS applications. However, for AOC and all other data applications the impact is acceptable.
- For UDP/VoIP the handover delay is lower (1.5s - 3.5s) and has to be compared to today's situation when HF voice is used. In this context this value seems to be acceptable. Of course, in addition, no manual operation is needed to perform the handover, which also reduces the risk of bad operations that would take time to detect and correct.

3.5 Deployment and Concept Evolution

The deployment and roll-out plan is derived in D06 [10]. Starting from the current situation and an analysis of the NEWSKY system from the roll-out perspective, technical and non-technical issues on the deployment have been addressed. Key investigations and recommendations are:

- Coordination with SESAR JU deployment plans and consideration of the current status of air/ground communications from a range of stakeholder perspectives
- Investigation of protocol stack interoperability of ACARS, ATN/OSI, IPv4/IPv6 and transition mechanisms like tunnelling, dual stack and translation of protocols
- NEWSKY could be introduced as part of the roll-out of new data link technologies for ATS/AOC within an end-to-end communication system

- NEWSKY could assist in helping ‘future proof’ the investment for APC by offering a stable environment into which new technologies could be introduced more easily. For non-safety-related applications, there is more freedom for the deployment of NEWSKY based on individual business needs. This will provide the earliest opportunity to deploy NEWSKY and to get experience in use of the protocols which could then verify that the protocols operate correctly in a non-safety environment
- A plan has been developed showing a sequence of activities that should be undertaken to achieve deployment of NEWSKY by 2020+

Furthermore, potential future evolutionary factors that could have an impact on the NEWSKY system from 2030 onwards are considered in D07 [11]. The factors addressed include growth in air traffic, Air Traffic Management (ATM) concepts, airspace user expectations, public expectations and technology evolution.

High level guidelines are provided for effective and transparent evolution. The recommendations made will be for NEWSKY to consider when moving from concept to the prototyping phase of the lifecycle model.

- Ensure NEWSKY can provide a scalable service from 2030+ to enable new capability to meet the increasing communication loads in the longer term.
- Be adaptable to support C2 or C3 links for UAS.
- Be scalable to handle a wide spectrum of different future applications that are currently being considered.
- Recognise that there is an increase in air–to-air communication and multicasting of data.
- Support the introduction of hybrid communication and navigational capability.
- Consider the increasing integration on the higher protocol layers to improve network efficiency.
- Recognise the need for worldwide agreement on standards and protocols to ensure that on-board aircraft equipment can operate globally.

While the evolution of commercial network applications and equipment is happening at a very fast pace it is expected that the aeronautical evolution of new operational applications and equipment will happen in much slower time. NEWSKY proposes technology independent interfaces to ensure its introduction and deployment will be as future proof as possible. Furthermore, an unconstrained architecture whereby any communications bearer (operational and non-operational) can send any data messages from the aircraft to the ground is seen as a promising solution to overcome any bottlenecks from particular data link technologies.

4 Dissemination and Use

The knowledge developed during the project has enabled NEWSKY partners to be at the forefront of the development of IPv6 based aeronautical networks. Dissemination and standardisation activities have ensured that the knowledge is appropriately shared among the key stakeholder and that the desired impact is achieved.

4.1 Exploitable Knowledge and its Use

The exploitable results of NEWSKY are the design, system architecture and initial validation through simulations and test-bed trials of an aeronautical telecommunication network based on IPv6 and integrating satellite and terrestrial data links.

The NEWSKY Consortium has contributed to the major standardisation activities listed below. The project results will be used in follow-up activities pushing the technologies to higher technology readiness levels in SESAR JU and the FP7 project SANDRA.

4.1.1 NEWSKY Inputs to Standardisation Bodies

The NEWSKY results have been input to the following standardisation bodies:

- Strong involvement in ICAO ACP WG-I with 9 working paper contributions. WG-I has developed a technical manual and guidance material for the IPS (Internet Protocol Suite) based ATN, the main reference document being ICAO Doc 9896 "Manual for the ATN using IPS Standards and Protocols" [26];
- Involvement in AEEC NIS (Network Infrastructure and Security) with contributions to the MAGIC (Manager of Air-Ground Interface Communications) technical WG;
- Involvement in IETF MEXT WG (Mobility EXTensions for IPv6) with preparation of drafts and contributions to the mailing list.

The technical inputs to these standardisation bodies are summarised in Table 4-1.

ICAO ACP WG-I	QoS architecture, transport layer design, mobility management, security solutions, IPv6 addressing
AEEC NIS MAGIC	Architecture of integrated mobile network Adaptation of IEEE 802.21 for media independent handover signalling between data links and network entities for seamless handover and as standardised signalling interface
IETF MEXT	ATN topology review and solutions for Route Optimisation for network mobility (NEMO RO)

Table 4-1: NEWSKY Inputs to Standardisation Bodies

4.1.2 NEWSKY Inputs to SESAR JU

Within the SESAR JU Work Programme, NEWSKY addresses mainly WP15, WP9, and WP16:

- **WP15** (CNS) is the main SESAR JU WP addressed by NEWSKY. NEWSKY may provide direct inputs for architecture (protocol architecture, network topology) and network functionalities (QoS processing, mobility management, transport layer design) for the relevant airborne and ground network entities.

This is relevant in particular for 15.2.4 (Future Mobile Data Link System Definition) and, to a lesser extent, for WP15.2.6 (Future Mobile Satellite Communications), WP15.2.7 (Airport Surface Datalink) and WP15.2.8 (Civil-Military Data Link Interoperability) for the integration of a future satellite link, the airport link and of military data links into a global network, respectively.

- **WP9** (Aircraft) is addressed by the airborne part of the NEWSKY system. NEWSKY may provide inputs regarding the integration of new data links and the related functionalities of the airborne air-ground router and data link management. This might be relevant to SESAR WP9.16 (New Communication Technology at Airport), WP9.20 (Military Datalink Accomodation) and WP9.44 (Flexible Communication Avionics).
- **WP16** (R&D transversal areas) is addressed by the NEWSKY activities on security and on business case elements.

The knowledge transfer is ensured by the NEWSKY partners that either members or subcontractors of SESAR JU members. Furthermore, formal and informal communications between the NEWSKY Consortium and SESAR JU management and other SESAR JU members has taken place (see Table 4-2 and Table 4-4).

4.1.3 NEWSKY Follow-Up Work in FP7 Project SANDRA

The FP7 project SANDRA (Seamless Aeronautical Networking through integration of Data links, Radios, and Antennas) has been kicked-off in October 2009. 31 European partners are members of the SANDRA Consortium.

The SANDRA project will design, implement and validate through in-flight trials and in close cooperation with SESAR JU an integrated aeronautical communications system based on an open architecture, a common set of interfaces and on well-proven industry standards. Integration will be addressed at four different levels, namely:

- integration at service level, supporting a full range of services such as airlines operations, cabin crew operations, in-flight and on-ground passenger services, airport operations, security services and air traffic management related operations through a Service Oriented architectural approach
- integration at network level having an IPv6 aeronautical network as final unification point, but addressing interoperability with network technologies such as ACARS and ATN/OSI, to ensure a realistic transition from the current procedures to the new system
- integration of several existing radio technologies into an Integrated Modular Radio (IMR) platform, allowing to dramatically reduce the size, weight, and cost in avionics with respect to current radio systems implemented as standalone equipments. The modular approach will additionally ensure the possibility to dynamically reconfigure each radio element to operate a specific type of radio link
- integration at antenna and RF level by means of a very low profile satellite antenna prototype allowing the provision of reliable, low maintenance, broadband connectivity, especially meant for bandwidth demanding passenger and cabin applications.

The activities on the integration at network level are direct follow-up activities of NEWSKY. Major advances will be the integration with middleware services, full definition of interfaces with specific data link technologies, prototype implementation, in flight trials and in general the achievement of a higher technology readiness level.

The knowledge transfer is ensured by the 5 NEWSKY partners that have leading roles in SANDRA and by the dissemination of the NEWSKY results within the SANDRA Consortium.

4.2 Dissemination of Knowledge

In D02 (Dissemination and Use Plan [6]), key stakeholder have been identified and the dissemination approach has been specified. A detailed stakeholder analysis including the list of key players and their needs was also provided in Deliverable D01.5 (Validation Strategy [5]).

Table 4-2 summarizes the major dissemination activities undertaken with respect the stakeholders. Specific publications, meetings and contributions to standardization bodies are detailed in the follow-up tables.

Stakeholder	Purpose	Events
Aeronautical Industry	General dissemination objectives: ▪ Raising awareness ▪ Enhancing understanding ▪ Building conviction ▪ Stimulating action	▪ NEWSKY User Workshop, 27.04.2007 in Toulouse ▪ Organisation of dedicated telephone conferences with presentations on the NEWSKY approach and results to major stakeholder ▪ Presentations and discussions during conferences, meetings and working groups of standardisation bodies (Table 4-3 and Table 4-4) ▪ Dissemination material: Website, flyer, distribution of specific NEWSKY presentations by email to interested people etc. ▪ NEWSKY stand at ATC Global exhibition, 17.-19.03.2009 in Amsterdam ▪ NEWSKY final event, 06.10.2009 in Munich

SESAR JU	Close cooperation with SESAR JU as the key European initiative for the modernisation of the Air Traffic Management system. Alignment of NEWSKY to SESAR JU activities. Information to SESAR JU about NEWSKY results.	▪ Presentation of NEWSKY objectives and SESAR alignment during two SESAR coordination meetings 09-10.01.07 and 14.11.07 ▪ Contact through SESAR WP3.1 data collection team (document mapping NEWSKY to SESAR was submitted) ▪ Meeting with Patrick Ky (SESAR JU Executive Director) and Luc Tytgat (DG-TREN, Head of Unit) ▪ Mid-term review meeting and review of NEWSKY documentation by Peter Hotham (SESAR JU Chief Architect) ▪ Communication and knowledge transfer to SESAR JU through NEWSKY partners that are member or subcontractor of SESAR JU members.
EUROCONTROL	Coordination with EUROCONTROL activities, providing inputs.	▪ Eurocontrol was present at PM1 - PM5 and at the final event ▪ PM3 was held at Eurocontrol premises in Brussels ▪ Review of NEWSKY deliverables by Eurocontrol ▪ Presentations at Eurocontrol INO workshop and AGCFG meetings
ICAO ACP	Coordination with ICAO activities, providing inputs in particular to WG-I for the specification of the ATN/IPS.	▪ Active participation at ACP WG-I meetings including 9 NEWSKY working papers with material that has been included in ATN/IPS manual and guidance material ▪ NEWSKY panel workshop during ACP/1, 15.05.07
AEEC	Coordination with AEEC activities, providing inputs in particular to the MAGIC WG.	▪ NEWSKY presentation during AEEC Data Link User Forum, 16.-17.07.2008, Brussels ▪ NEWSKY presentation during AEEC SAI (Systems Architecture and Interfaces) meeting, 05.-06.08.2008, Vienna ▪ NEWSKY contribution to AEEC NIS (Network Infrastructure and Security) meeting, 17.-20.11.2008, Lisbon ▪ Organisation of first AEEC MAGIC meeting at DLR with NEWSKY contributions, 4.-5.03.2009, Munich ▪ Further contributions to AEEC MAGIC meetings (Table 4-4)

IETF	Raise the awareness of the needs and restrictions in the aeronautical domain during the development and standardization of new networking technologies. Support aeronautical domain activities in IETF.	▪ IETF WG Mailing lists: NEWSKY contribution with description of aeronautical scenario for MONAMI6 ▪ Participation at IETF MEXT WG interim meeting, 7-8.02.2008 ▪ Presentation of draft on ATN topology at general IETF meeting #72, 27.07-01.08.2008 ▪ Preparation of draft on solution space analysis for mobility solutions (NEMO RO), 09.09.2009
Further related projects, in particular ANASTASIA, ASPASIA, SWIM-SUIT, B-VHF/B-AMC, MOWGLY, MINERVAA, etc.	Benefit from knowledge sharing and collaboration.	▪ ASPASIA advisory board meeting participation ▪ Jean-Yves Catros (ANASTASIA) present at NEWSKY user workshop ▪ Joint preparation of a discussion paper on synergies between SWIM-SUIT and NEWSKY, 04.2009 ▪ Informal discussions, participation of NEWSKY partners in most of these projects
FAA	Coordination with FAA activities	▪ Aeronautical conferences (in particular ICNS and DASC) ▪ ICAO WG-I as discussing platform ▪ Attending AGC-FG and NexSAT SG meeting 13-14.09.2007 and 24.-25.03.2009

Table 4-2: NEWSKY stakeholder and related dissemination activities

Two major NEWSKY dissemination events have been organised by the end of the project: NEWSKY stand at ATC Global 2009 and NEWSKY final event.

The NEWSKY Consortium has set-up a stand during ATC Global, 17-19 March 2009 in Amsterdam. The NEWSKY Consortium presented there a live demonstration of the first air traffic control network based on IPv6 to integrate satellite and air-ground links. Voice over IP (VoIP), weather map download and CPDLC applications were used to demonstrate the capabilities of the NEWSKY IPv6 network. Inter-technology handover between a real BGAN Inmarsat satellite link and an emulated air-ground L-DACS link as well as the network mobility functionality were demonstrated. Furthermore, the results from the NEWSKY design phase and the implementation of the NEWSKY network topology simulator was presented.

Figure 4-1: NEWSKY stand set-up during ATC Global 2009

About 50 participants from major stakeholders have attended the NEWSKY project final event held at DLR in Munich/Oberpfaffenhofen October 6th, 2009. Technical presentations on the results of the design phase and live demonstrations of the NEWSKY simulation environment and test-bed have been prepared. A panel of experts addressed topics related to deployment issues, exploitation of results and follow-up work. Reports on the event have been published in newspaper, radio and TV.

Further NEWSKY dissemination activities include:

- Setup and maintenance of a project public website for dissemination of relevant findings: www.newsky-fp6.eu; The news&events page disseminates major events and news from the NEWSKY project: http://www.newsky-fp6.eu/news_events.htm
- Press releases have been issued at the beginning of the project, for ATC Global and for the final event
- A flyer was produced for distribution

The following tables summarize key NEWSKY dissemination activities:

- Table 4-3: publication at aeronautical and communication journals and conferences
- Table 4-4: presentation of NEWSKY approach and results to stakeholder and standardisation bodies

Ref No	Event	Title	Authors	Location	Event Date	Remarks
1	DASC Conference	A Concept for Networking the Sky for Civil Aeronautical Communications	M. Schnell and S. Scalise	Portland, USA	15.-19.10.2006	Before actual start of the project
2	VDE Congress	Networking the Sky	M. Schnell and S. Scalise	Aachen, Germany	23.-25.10.2006	Before actual start of the project
3	ATN Conference	NEWSKY – A Concept for Networking the Sky for Civil Aeronautical Communications	M. Schnell, S. Scalise and P. Platt	London, UK	27.-29.11.2006	Before actual start of the project Best Session Paper Award
4	ICNS Conference	NEWSKY - Networking the Sky for Aeronautical Communications	F. Schreckenbach, M. Schnell, S. Scalise and P. Platt	Washington DC, USA	01.-3.05.2007	
5	IEEE Aerospace and Electronic Systems Magazine	A Concept for Networking the Sky for Civil Aeronautical Communications	M. Schnell and S. Scalise	---	05.2007	
6	CEAS European Air and Space Conference	NEWSKY - Networking the Sky for Aeronautical Communications	F. Schreckenbach, M. Schnell, S. Scalise	Berlin, Germany	10.-13.09.2007	
7	CEAS European Air and Space Conference	NEWSKY – Novel Simulation Concepts for Future Air Traffic	C.H. Rokitansky, M. Ehammer and T. Gräupl	Berlin, Germany	10.-13.09.2007	
8	KA and Broadband Communications Conference	NEWSKY - Networking the Sky for Aeronautical Communications	F. Schreckenbach, M. Schnell, S. Scalise and Ch. Kissling	Turin, Italy	24.-26.09.2007	Not financed by NEWSKY budget
9	DASC Conference	NEWSKY – Building a simulation environment for an	C.H. Rokitansky,	Dallas, USA	21.-25.10.2007	Best Session Paper Award

		integrated aeronautical network architecture	M. Ehammer and T. Gräupl			
10	Jane's Airport Review (JAR)	Internet Offers new ATM Vision		---	02.2008	
11	International Journal on Space Communications	NEWSKY – A Concept for Networking the Sky for Civil Aeronautical Communications	F. Schreckenbach, M. Schnell, N. Riera Díaz, P. Platt, J.-M. Gaubert, K. Leconte	---	Volume 21, Number 3,4, August 2008	
12	ICNS Conference	Functional Building Blocks for an Integrated Aeronautical IP-Network	Frank Schreckenbach, Katia Leconte, Cedric Baudoin, Nuria Riera, Christian Kissling, Christian Bauer	Washington D.C.	05.-07.05.2008	
13	SECON 2008: IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks	Feasibility of an Aeronautical Mobile Ad Hoc Network Over the North Atlantic Corridor	Daniel Medina, Felix Hoffmann, Serkan Ayaz, Carl-Herbert Rokitansky	San Francisco, USA	16.-20.06.2008	Not financed by NEWSKY budget
14	ICT Mobile Summit	Mobility Options in the IP-based Aeronautical Telecommunication Network	Serkan Ayaz, Christian Bauer, Thomas Gräupl, Max Ehammer, Fabrice Arnal	Stockholm, Sweden	10.-12.06.2008	
15	ASMS (Advanced Satellite Mobile Systems) 2008	Protocol Stack options in heterogeneous aeronautical networks	Christian Kissling, Cedric Baudoin, Christian Bauer	Bologna, Italy	26.-28.08.2008	Not financed by NEWSKY budget
16	ASMS (Advanced Satellite Mobile Systems) 2008	Technology Characterisation for Integration in the NEWSKY Aeronautical Communication Network	Katia Leconte, Núria Riera Díaz, Phil Platt, Frank Schreckenbach	Bologna, Italy	26.-28.08.2008	Not financed by NEWSKY budget

17	MobiWorld	Infrastructure-based Route Optimization for NEMO based on Combined Local and Global Mobility	Christian Bauer, Serkan Ayaz, Max Ehammer, Thomas Gräupl, Fabrice Arnal	I-Lan, Taiwan	10.-12.09.2008	
18	IEEE VTC 2008 Fall	A thorough investigation of Mobile IPv6 for aeronautical networks	Christian Bauer, Serkan Ayaz	Calgary, Canada	22.-25.09.2008	
19	IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MAAS)	Topology Characterization of High Density Airspace Aeronautical Ad Hoc Networks	Daniel Medina, Felix Hoffmann, Serkan Ayaz, Carl-Herbert Rokitansky	Atlanta, USA	29.09.-02.10.2008	Not financed by NEWSKY budget
20	WiMob	Securing Dynamic Home Agent Address Discovery with Cryptographically Generated Addresses and RSA Signatures	Christian Bauer, Max Ehammer	Avignon, France	12.-14.10.2008	
21	DASC (Digital Avionics Systems Conference) 2008	Security Considerations for IP based Aeronautical Networks	M. Ehammer, T. Gräupl, C.-H. Rokitansky, T. Brikey	St Paul, Minnesota, USA	26.-30.10.2008	
22	ITST (International Conference on Intelligent Transport System Communication)	NEMO Route Optimization Solution Space Analysis and Evaluation Criteria for Aviation	Serkan Ayaz, Christian Bauer, Wesley M. Eddy, Fabrice Arnal	Phuket, Thailand	22.-24.10.2008	
23	Eurocontrol Innovative Research Workshops and Exhibition	Integrated IP Networking for Air-Ground Communications – The NEWSKY Project	Frank Schreckenbach	Eurocontrol Experimental Centre (south of Paris)	2.-4.12.2008	
24	VTC Spring 2009	IP Overhead Comparison in a Test Bed for Air Traffic	Àngels Via, Eriza Hafid Fazli, Sébastien Duflot,	Barcelona, Spain	26–29.04.2009	

		Management Services	Núria Riera, Markus Werner			
25	ICNS 2009	Architecture of an IP-based Aeronautical Network to Integrate Satellite and Air-Ground Links	Serkan Ayaz, Christian Bauer, Christian Kissling, Frank Schreckenbach, Fabrice Arnal, Cedric Baudoin, Katia Leconte, Max Ehammer, Thomas Graeupl	Arlington, Virginia, USA	13.-15.05.2009	Not financed by NEWSKY budget
26	ICNS 2009	The Operation of TCP over Aeronautical Networks	Max Ehammer, Thomas Graeupl, Carl-Herbert Rokitansky, Christian Kissling	Arlington, Virginia, USA	13.-15.05.2009	
27	ICSSC 2009	Data Link Selection in Mobile Aeronautical Telecommunication Networks	Christian Kissling	Edinburgh, Scotland	01.-04.06.2009	
28	ICC 2009	Demonstration of IPv6 Network Mobility in Aeronautical Communications Network	Eriza Hafid Fazli, Angels Via, Sébastien Duflot, Markus Werner	Dresden, Germany	14.-18.06.2009	
29	ICC 2009	Optimum Internet Gateway Selection in Ad Hoc Networks	Felix Hoffmann, Daniel Medina	Dresden, Germany	14.-18.06.2009	Not financed by NEWSKY budget
30	IWSSC 2009	A delay model for satellite constellation networks with inter-satellite links	Romain Hermenier, Christian Kissling, Anton Donner	Siena, Italy	09.11.09.2009	
31	International Workshop on Satellite and Space Communications (IWSSC 2009)	Laboratory Test-bed Development for IPv6 Network Mobility Demonstration in Aeronautical Communications Network	Eriza Hafid Fazli, Àngels Via, Markus Werner	Siena-Tuscany, Italy	10.-11.09,2009	

32	DASC 2009	Simulation Results and Assessment of the NEWSKY Concept for Integrated IP-Based Aeronautical Networking	T. Gräupl, M. Ehammer, C.-H. Rokitansky, S. Ayaz,	Orlando, Florida	25.-29.10.2009	

Table 4-3: Conference and journal publications

Ref No	Event	Authors/Participation	Location	Event Date	Remarks
1	SESAR meeting	M. Schnell, S. Scalise and F. Schreckenbach	Brussels, Belgium	9.-10.01.2007	NEWSKY presentation
2	ASPASIA Advisory Board meeting	F. Schreckenbach	Brussels, Belgium	9.02.2007	Coordination of ASPASIA and NEWSKY activities
3	NEWSKY User workshop	DLR - TAS	Toulouse, France	27.04.2007	Presentation and feedback of stakeholder to NEWSKY
4	ICAO ACP/1 Panel Meeting with NEWSKY workshop	M. Schnell and K. Hauf	Montreal, Canada	15.05.2007	Presentation and feedback of stakeholder to NEWSKY Not financed by NEWSKY budget
5	AGCFG/4 - NexSAT/9 meeting	Nuria Riera	Brussels, Belgium	13.-14.09.2007	
6	SESAR meeting	F. Schreckenbach and S. Scalise	Brussels, Belgium	14.11.2007	Presentation on NEWSKY-SESAR coordination
7	ICAO ACP WG-I meeting #2	F. Schreckenbach and D. Medina	Montreal, Canada	27.-31.08.2007	Presentation of NEWSKY project and working paper “Transport Layer Considerations in the ATN/IPS”
8	ICAO ACP WG-I meeting #3	D. Medina	Aarhus, Denmark	08.-12.10.2007	Not financed by NEWSKY budget

9	ICAO ACP WG-I meeting #4	C. Kissling	Montreal, Canada	03.-07.12.2007	Presentation of working paper “QoS Architectures for the ATN/IPS”
10	ICAO ACP WG-I meeting #5	D. Medina, S. Ayaz and C. Bauer	Bangkok, Thailand	14.-18.01.2008	Presentation of working paper “Global Mobility Management in the ATN/IPS” Not financed by NEWSKY budget
11	IETF MEXT Interim Meeting	C. Bauer and S. Ayaz	Madrid, Spain	07.-08.02.2008	
12	ICAO WG-I #6	D. Medina, S. Ayaz, C. Bauer	Montreal, Canada	17.-20.03.2008	Presentation of working paper "Impact of Home Agent (HA) based Global Mobility on the ATN IPv6 Address Allocation Plan"
13	Meeting with DG-TREN and SESAR JU	F. Schreckenbach, S. Scalise	Brussels	17.04.2008	NEWSKY Presentation
14	AEEC Data Link User Forum	C. Kissling	Brussels	16.-17.07.2008	NEWSKY presentation
15	AEEC SAI Meeting	F. Schreckenbach	Vienna	05.-06.08.2008	NEWSKY presentation
16	ICAO Meeting #7	M. Ehammer and T. Graeupl	Montreal, Canada	02.-06.06.2008	Presentation of working paper "Security for IP based aeronautical networks: Analysis and technological aspects"
16	ICAO Meeting #7	D. Medina, C. Bauer, S. Ayaz and F. Schreckenbach	Montreal, Canada	02.-06.06.2008	Presentation of working paper "Draft ICAO IPv6 Addressing Plan"
17	IETF Meeting #72	C. Bauer, S. Ayaz, C.-H. Rokitansky, T.	Dublin, Irland	27.07.-01.08.2008	Presentation of new IETF draft and participation at meeting on

		Gräupl, M. Ehammer			aeronautical RO solutions
18	ICAO WG-I #8	T. Gräupl and C. Kissling	Montreal, Canada	25.-29.08.2008	Presentation of working paper "Options for Transport Layer Usage"
19	ICAO WG-I #9	C. Kissling	Montreal, Canada	20.-23.10.2008	Presentation of working paper "Options for Transport Layer Usage"
20	MTR Meeting with EC and SESAR JU	NEWSKY Consortium	Vienna, Austria	06.11.2009	
21	AEEC NIS Meeting	F. Schreckenbach	Lisbon, Portugal	17.-20.11.2008	
22	AEEC MAGIC Meeting	DLR, TGS, TAS, UniSBG	Munich, Germany	04.-05.03.2009	Organisation of first AEEC MAGIC meeting at DLR with NEWSKY contributions
23	ATC Global		Amsterdam RAI	17.19.03.2009	NEWSKY Stand
24	AGCFG/5 and NexSAT/10 meeting	F. Schreckenbach	Brussels	24.-25.03.2009	Presentation of NEWSKY results
25	AEEC MAGIC Meeting	F. Schreckenbach	Annapolis, USA	11.-12.05.2009	Not financed by NEWSKY budget
26	AEEC MAGIC Meeting	C. Bauer	Hamburg, Germany	25.-27.08.2009	
27	NEWSKY Final Event	NEWSKY Consortium	Munich, Germany	06.10.2009	

Table 4-4: Presentation of NEWSKY approach and results to stakeholder and standardisation bodies

4.3 Publishable Results

All technical NEWSKY Deliverables are public. Therefore, the NEWSKY results described in Section 3 are publishable, including:

- Analysis of data link technologies that can be potentially integrated
- Specification of functional and protocol architecture and of network topology
- Resource Management
  - QoS processing: architecture, priorization, queuing
  - Link selection
  - Transport layer design, usage and optimization
- Mobility Management
  - Selection and optimization of MIPv6 extensions (NEMO, local mobility, multihoming)
  - Specification of mobility architecture: Home Agent deployment, security aspects …
- Inter Satellite Link (ISL) routing, Air-to-air mesh networking
- Handover framework
  - IEEE 802.21 framework: scenarios, useful primitives, interaction with other functionalities
- Security
  - Thread analysis, risk assessment, security architecture, service options and solutions
- Analysis of the possible trade-offs to integrate security, mobility and QoS features within a single aeronautical network (with specific analysis for safety part and non-safety part)
- Results and assessment of computer simulations and laboratory test-bed trials

5 References

[1] Annex I – "Description of Work" of Contract Number 37160 for "NEWSKY – Networking the Sky for Aeronautical Communications"

[2] NEWSKY Deliverable D01.1 "Project Plan", approved 28.05.07

[3] NEWSKY Deliverable D01.2 "Configuration Management Procedures", 05.06.07

[4] NEWSKY Deliverable D01.3 "Quality and Risk Management Procedures", 05.06.07

[5] NEWSKY Deliverable D01.5 "Validation Strategy", 09.01.08

[6] NEWSKY Deliverable D02 "Dissemination and Use Plan", 17.09.07

[7] NEWSKY Deliverable D03 "Network Transformation Concept", 23.01.08

[8] NEWSKY Deliverable D04 "NEWSKY Mission Definition for Network Transformation", 23.01.07

[9] NEWSKY Deliverable D05 "NEWSKY Business Case Analysis for Network Transformation", 26.02.2010

[10] NEWSKY Deliverable D06 "NEWSKY Roll-Out Plan for Network Transformation", 13.10.09

[11] NEWSKY Deliverable D07 "NEWSKY Long Term Concept Evolution for Network Transformation", 18.09.09

[12] NEWSKY Deliverable D08 "NEWSKY Operational Requirements Document", 14.01.08

[13] NEWSKY Deliverable D09 "Technology Screening and Characterisation for Integration in NEWSKY Network", 16.04.08

[14] NEWSKY Deliverable D10 "System Requirements Document", 11.08.08

[15] NEWSKY Deliverable D11 "NEWSKY Design Document", Version 2, 20.03.09

[16] NEWSKY Deliverable D12 "Efficient Resource Management Techniques", 10.03.09

[17] NEWSKY Deliverable D13 "Advanced Routing Algorithms", 20.02.09

[18] NEWSKY Deliverable D14 "Seamless Handover Strategies", 30.01.09

[19] NEWSKY Deliverable D15 "NEWSKY Security Concept", 08.12.08

[20] NEWSKY Deliverable D16 "Simulation Scenarios for Concept Validation", 08.12.08

[21] NEWSKY Deliverable D17 "Laboratory Test-Bed for Concept Validation", 08.12.08

[22] NEWSKY Deliverable D18 "Specification of the ATM Network Topology Simulator", 08.12.08

[23] NEWSKY Deliverable D19 "Specification of the End-to-End ATM Network Simulator", 12.11.09

[24] NEWSKY Deliverable D20 "NEWSKY Performance Evaluation Results Assessment and Recommendations", 12.11.09

[25] NEWSKY Deliverable D21 "Test-Bed and Laboratory Trials Report", 16.07.09

[26] "Manual for the ATN using IPS Standards and Protocols (ATN/IPS)", ICAO ACP WG-I, Doc 9896, Nov. 2008, http://www.icao.int/anb/Panels/ACP/

[27] EUROCONTROL/FAA, “Communications Operating Concept and Requirements for the Future Radio System (COCR),” Version 2, 2007.

6 List of Acronyms and Abbreviations

A/G	Air-Ground
AAC	Airline Administrative Correspondence
ACARS	Aircraft Communications Addressing and Reporting System
ACP	Aeronautical Communication Panel
ACP-WG	ACP Working Group
AEEC	Airlines Electronic Engineering Committee
ANASTASIA	Airborne New and Advanced Satellite techniques and Technologies in A System Integrated Approach
ANG	Access Network Gateway
ANSP	Air Navigation Service Provider
AOC	Aeronautical Operational Control
AP	Access Point
APC	Aeronautical Passenger Communication
AR	Access Router
ASPASIA	Aeronautical Surveillance and Planning by Advanced Satellite-Implemented Applications
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATN/IPS	ATN based on the TCP/IP protocol suite
ATN/OSI	ATN based on the CLNP/TP4 protocol suite
ATS	Air Traffic Services
BGAN	Broadband Global Area Network
BGP	Border Gateway Protocol
B-VHF	Broadband Very High Frequency
CDM	Collaborative Decision Making
CEAS	Council of the European Aerospace Societies
CLNP	Connectionless Network Protocol
CN	Correspondent Node
CNS	Communication, Navigation and Surveillance
COCR	Communications Operating Concept and Requirements
COTS	Commercial-Off-The-Shelf
CPDLC	Control Pilot Data Link Channel
DFS	Deutsche Flugsicherung
DiffServ	Differentiated Services
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DSCP	Differentiated Services Code Point
EC	European Commission
EMMA	European Airport Movement Management by A-SMGCS
E-OCVM	European Operational Concept Validation Methodology
ETSI	European Telecommunications Standards Institute
ES	End System
ESA	European Space Agency
FAA	Federal Aviation Administration
FCS	Future Communication Study
FCI	Future Communication Infrastructure
FMIPv6	Fast Handovers for Mobile IPv6
FRQ	Frequentis
GACSP	Global Aeronautical Communication Service Provider
HA	Home Agent

HO	Handover
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv4/IPv6	Internet Protocol version 4 / version 6
IPS	Internet Protocol Suite
ISL	Inter Satellite Links
ISO	International Organization for Standardization
ISP	Internet Service Provider
L-DACS	L-band Digital Aeronautical Communication System
LEO	Low Earth Orbit
LFN	Local Fixed Node
LMA	Local Mobility Anchor
MANET	Mobile Ad-hoc Network
MAG	Media Access Gateway
MAGIC	Manager of Air-Ground Interface Communications
MEO	Medium Earth Orbit
MEXT	Mobility EXTensions for IPv6
MIHF	Media Independent Handover Function
MINERVAA	Mid-Term Networking Technologies In-Flight and Rig Validation for Avionic Applications
MIPv6	Mobile IPv6
MIRON	Mobile IPv6 Route Optimization in NEMO
MN	Mobile Node
MONAMI	Mobile Nodes and Multiple Interfaces in IPv6
MOWGLY	MObile Wideband Global Link sYstem
MPLS	Multiprotocol Label Switching
MR	Mobile Router
N/A	Not Applicable
NEMO	Network mobility
NETLMM	Network-based local mobility management
NexSAT SG	NexSAT Steering Group
NEWSKY	NEtWorking the SKY
NIS	Network Infrastructure and Security
OSI	Open Systems Interconnection
PEP	Performance Enhancement Proxy
PM	Person Month / Progress Meeting
PMIPv6	Proxy MIPv6
QoS	Quality of Service
RO	Route Optimization
RRM	Radio Resource Management
SAG	Security Access Gateway
SESAR JU	Single European Sky ATM Research Joint Undertaking
SOA	Service Oriented Architecture
SWIM	System Wide Information Management
TAS	Thales Alenia Space
TCP	Transmission Control Protocol
TGS	TriaGnoSys
TM	Traffic Management
TP4	Transport Protocol Class 4

UAS	Unmanned Aircraft System
UDP	User Datagram Protocol
UniSBG	University of Salzburg
VDL2	VHF Data Link Mode 2
VoIP	Voice over IP
WG	Working Group
WiMAX	Worldwide Interoperability for Microwave Access
WP	Work Package
QQ	QinetiQ

----------- END OF DOCUMENT -----------