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European Strategy Study

Operational Scenarios

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1 Introduction

1.1 Purpose of Document

The objective of this report is to illustrate from a high-level, non-technical perspective how the Aeronautical Telecommunication Network (ATN) will operate. This will be done in the form of a guided tour through the interior of the ATN along a typical use case. The use case will describe an example flight scenario including flight planning and preparation and will involve different user groups including air traffic services (ATS) providers, airline operators and pilots. Along this use case the fundamental mechanisms, procedures and principles of ATN-internal operation in response to user requests and in support of user activities will be presented.

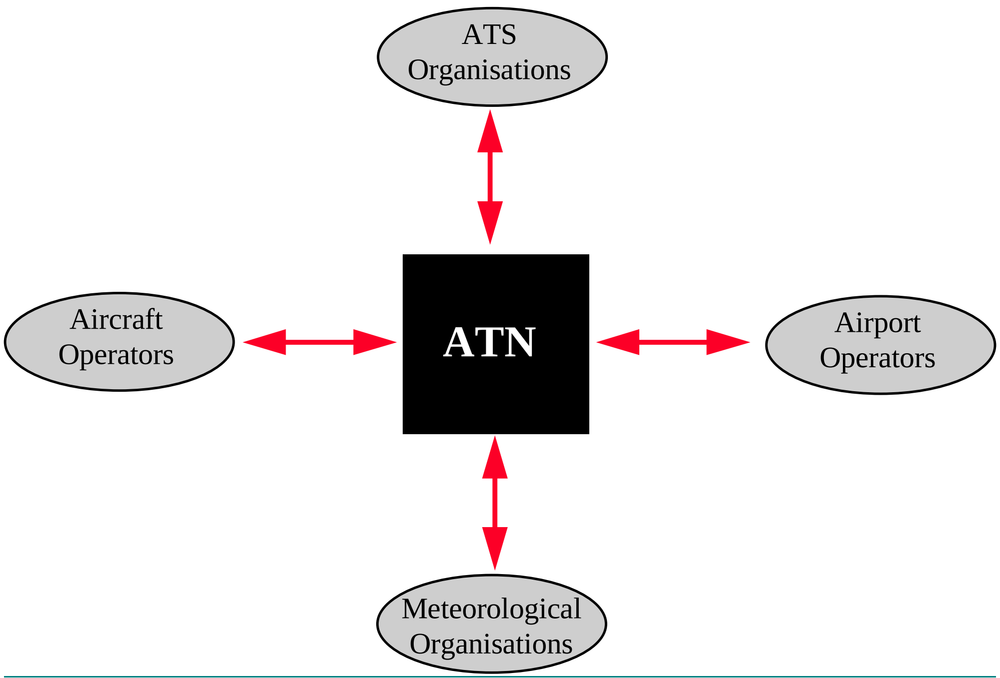

Figure 1: High Level ATN Context Diagram

Figure 1 presents these users in the context of the ATN. At the same time, this figure is a realistic illustration of the users' perspective of the ATN in general. The user' s view of the ATN is basically a black box which includes complex mechanisms in order to shuffle data from one end of the box to the other. It is the intention of this report to make this box more transparent without going into the technical details of the ATN. Consequently this report can be seen as a tutorial that provides some insight into the operation of the ATN and provides a basic understanding of the interaction of the users with the ATN.

1.2 Scope

The scope of this report covers a flight scenario in a European ATN environment that consists of the elements presented in [A204] and [A205], and implements a routing architecture as described in [A203].

It is not targeted to a particular point in time. However, it assumes full ATN deployment, both ground/ground and air/ground, along the considered flight route, whereas the level of ATN deployment outside this area is irrelevant for the reflections in this report. Furthermore, it assumes an air traffic environment which is similar to today's one with respect to ATS and airline operational procedures, ATS organisation, flight information region (FIR) boundaries, etc., but that fully integrates the above ATN infrastructure and the ATN data link services defined in [A202] into this environment. This is in order to avoid major speculations on a potential future air traffic environment when defining the flight scenario as the basis for the presentation of the ATN operation. Due to the nature of the ATN, being an enabling technology and a supporting infrastructure, the ATN-internal operation is supposed to be largely independent from the procedures and operations of the respective air traffic environment anyhow.

The flight scenario does not comprise an exhaustive compilation of each individual air traffic control (ATC) and airline operation during a normal flight but focuses on those events which are appropriate to demonstrate fundamental ATN operation in the context of a typical flight in the European Region.

1.3 Selected Form of Presentation

An event-driven presentation has been selected which demonstrates the operation of the ATN along the actual sequence of key events occurring in the defined use case. These key events are triggering ATN operations which are presented in a descriptive and intuitive manner without diving into the technical details of each individual operation. The ultimate objective of this presentation is to give a basic understanding of the principles and mechanisms of ATN operation.

Figure 2 offers a generic illustration of the proposed approach.

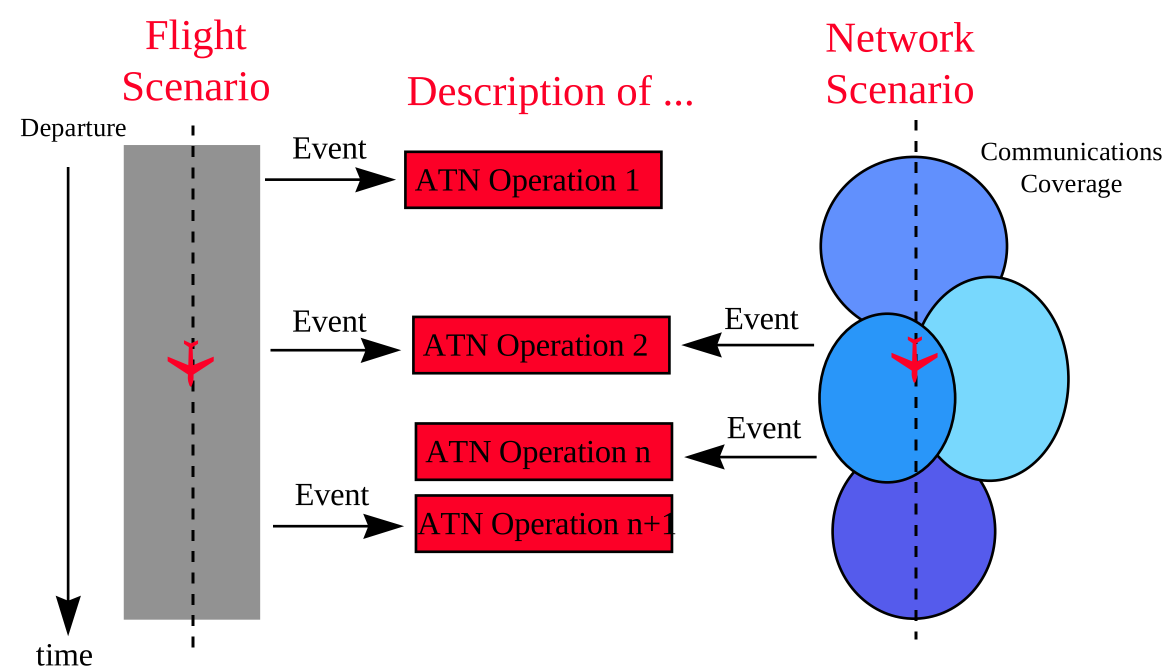

Figure 2: Generic Illustration of Proposed Approach

In progressing by time through the defined use case, the key events will be reported in its sequence of occurrence and used as trigger for a description of the associated ATN operation. The key events can be grouped into:

- actions invoked by ATN users as part of regular ATC and airline operations, which will result in ATN air/ground and/or ground/ground communications, such as filing of flight plan, controller instructions to aircraft, reporting of aircraft' engines status; and events resulting from changes in ATC responsibilities, e.g. at boundaries in the ATC topology scenario;

- network events resulting from changes in the connectivity of the aircraft with respect to the ground portion of the ATN as part of the flight, such as entrance/leaving mobile subnetwork coverage.

The ATN operation is demonstrated in a single run through the example use case, which combines events from the different user groups (e.g. ATS, airline operation), instead of re-iterating the scenario for the different user perspectives.

1.4 Document Structure

The document is composed of the following sections:

Chapter 1 defines the purpose and the scope of this document, and explains the form of presentation selected for illustrating the operation of the ATN.

Chapter 2 defines the flight scenario and the network scenario which constitute the example ATN use case for subsequent demonstration of ATN operation.

Chapter 3 illustrates the ATN operation based on the defined flight scenario and network scenario. Section 3.1 summarises the flight events and the network events which result in ATN operations. These ATN operations are then described in detail in section 3.2.

Appendix A compiles a list of acronyms and a glossary of the technical terms used in this report.

Finally, Appendix B provides some additional technical background information on the ATN (and ATN routing in particular) for those readers who are not very familiar with the ATN concept and architecture.

1.5 References

Reference	Title
[A202]	ACCESS WP202 - ATN Data Link Services in the ACCESS Area, Version 2.0, March 1998
[A203]	ACCESS WP203 - Definition of the European ATN Routing Architecture - Option 1, Version 2.0, March 1998
[A204]	ACCESS WP204 - Ground/Ground Subnetworks, Version 1.0, April 1998
[A205]	ACCESS WP205 - Air/Ground Subnetworks, Version 2.0, April 1998
[EAT7]	ENOC - European Network Operating Concept, Draft 3.1, December 1994
[SSV1]	ATN SARPs - Subvolume 1 - Introduction and System Level Requirements, Version 2.2, 16 January 1998
[SSV5]	ATN SARPs - Subvolume 5 - Internet Communications Service, Version 2.2, 16 January 1998

2 Scenarios

This chapter defines a flight scenario and a network scenario which, in their totality, constitute the example ATN use case for subsequent demonstration of ATN operation.

2.1 Flight Scenario

The operation of the ATN applications and the ATN network is demonstrated along the route of a transatlantic flight. As many of the events and ATN operations experienced during the first phases of the flight repeat during the later flight phases only the portion of the flight within the European ATC environment is described in the following sections[1].

2.1.1 Flight Route

The Lufthansa (LH) flight selected for illustrating the ATN operation starts from the international airport of Frankfurt am Main (Germany) and is destined to the international JFK airport in the U.S.

The flight scenario starts about one hour prior to departure, covers the departure at Frankfurt, the aircraft's route through the responsibilities of the en-route centres of Frankfurt, Düsseldorf, Maastricht, London and Shannon, and continues until the aircraft has reached the hand-over point between the oceanic centres of Shanwick and Gander. The European part of the flight and the crossed en-route centres are illustrated in .

The flight scenario covers the following flight phases:

- Pre-flight phase (including short-term flight planning and flight preparation)
- Pre-Taxiing and Taxiing phase
- Departure phase
- En-route phase.

2.1.2 ATC Organisation

For the flight scenario, an ATC organisation like today is assumed, where each European country forms its own national air traffic control region. These national regions are divided into FIRs which are controlled by an en-route ACC and in terminal areas around each airport controlled by an approach control center. In the same way, the Maastricht UACC operated by Eurocontrol is responsible for the upper air space of Northern Germany and Benelux. The FIRs crossed by the flight are illustrated in .

[1] Alternatively a gate-to-gate flight scenario in the European airspace may be selected, but it is believed that the later flight phases do not add a lot to the demonstration of ATN operation.

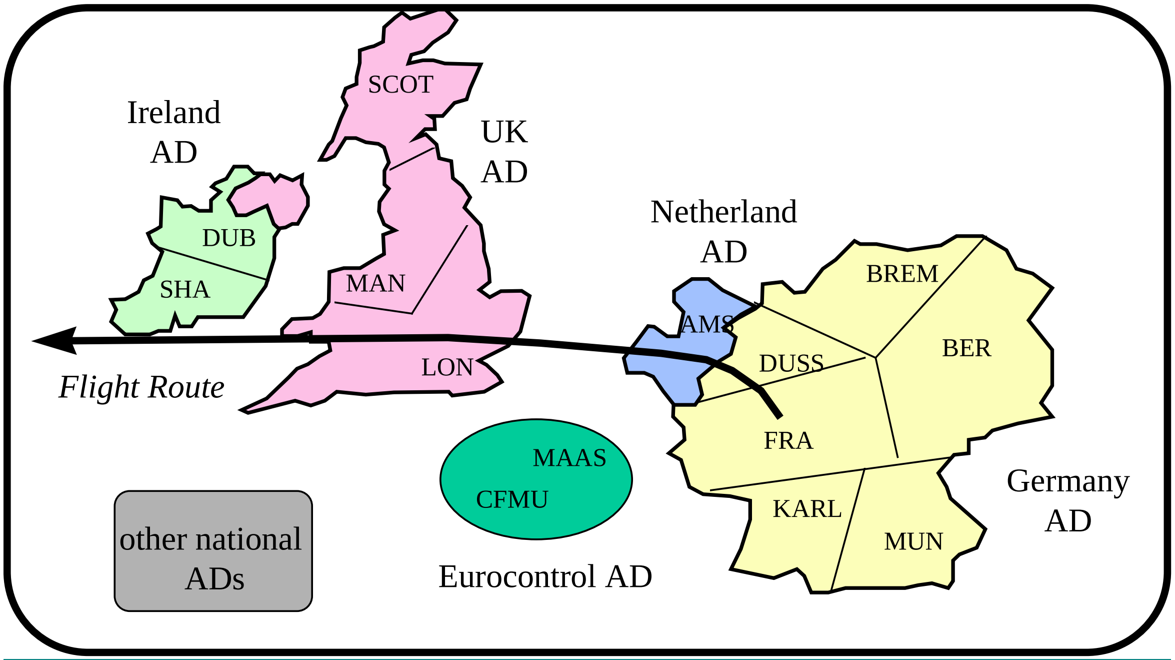

Figure 3: Illustration of the Flight Route and the traversed Flight Information Regions

The described flight is controlled by the ground controller and the tower controller at the Frankfurt airport, the departure controller and the en-route controller in the Frankfurt ACC, and the en-route controllers of all the other transited FIRs.

Figure 4 shows the sequence of control authorities along the flight route. This figure is detailed in section 3.2 into several figures illustrating the occurrence of the events along the flight route resulting in ATN operations.

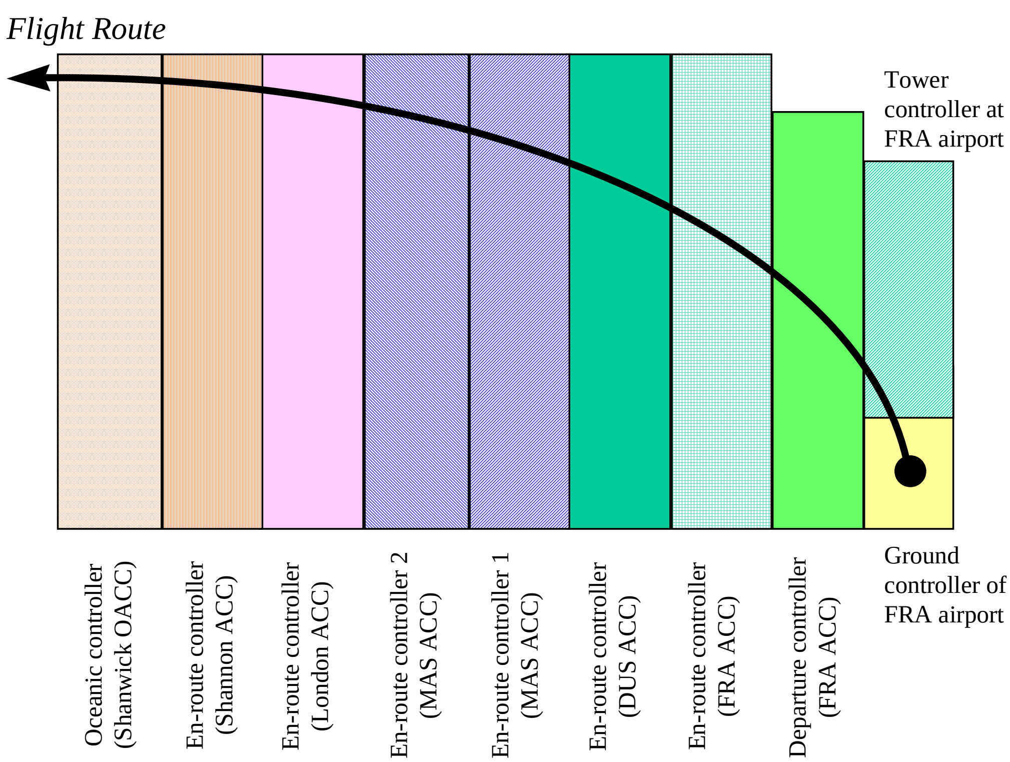

Figure 4: Control Sectors passed by the Aircraft

In addition to the ATS-related communications (ATSC) both air-ground and ground-ground, the flight scenario also includes some examples of aeronautical operational control (AOC) / aeronautical administrative communications (AAC) and aeronautical passenger communications (APC). From an end user perspective ATSC and AOC/AAC are transparently passed across the same ATN network. However, each data packet is internally labelled by the type of traffic it contains. Based on this label the switching nodes of the network (i.e. the ATN routers) make a deliberate decision concerning the path which they select to forward the data packets to their destination. This mechanism allows to respect some restrictions in the use of subnetworks (e.g. the Mode S subnetwork is allowed to carry traffic related to the safety and regularity of flight only), or to forward traffic along preferred routes (e.g. via less expensive links or links which are certified for a given class of traffic) while reaping the benefits of sharing network resources by different types of communications in general.

APC is currently not specified as a user of the ATN. However, APC, ATSC and AOC/AAC share for example the resources of air/ground data links for those data links which are open to all these traffic types (e.g. the aeronautical mobile satellite service, AMSS). ATSC and AOC/AAC data are transferred across these data links as ATN user data whereas the APC data are exchanged as native APC data. This common use of network resources is transparent to both the end users and the ATN. However, it ensures efficient use of network resources and consequently contributes to economies of scale.

2.2 Network Scenario

The Network Scenario outlines the communication coverage arrangement provided by the individual air/ground subnetworks and the ATN routing organisation. Furthermore, it maps these structures onto the ATC organisation presented in the previous section.

The Network Scenario is a regional snapshot from the overall European ATN topology and organisation proposed in other ACCESS work packages, including [A203], [A204] and [A205]. It is based on a pan-European X.25 network (see section 2.2.1), which is overlaid by the European ATN internetwork.

2.2.1 Ground Subnetworks

The private (multi-) national X.25 based Packet Switched Networks (PSNs) which are operated by ATS authorities are used for the interconnection of the ATN boundary routers within the countries. For the discussed scenario, this is the RAPNET in the area of Germany and Benelux, the CAPSIN in the UK, and the OLDI network in Ireland.

These (multi-) national PSNs are interconnected to a pan-European ATSO network (e.g. by the use of X.75 gateways). This allows, for example, that systems attached to the RAPNET can directly communicate with systems attached to the CAPSIN, and vice versa, without using the routing and relaying functions of the ATN internetwork.

2.2.2 Mobile Subnetworks

The data communication between the aircraft and the ground systems is provided through the following mobile subnetworks:

- a Gatelink installation while the aircraft is parked at the Frankfurt airport
- a local VDL subnetwork operated by the Frankfurt APO
- VDL and Mode S subnetworks over Germany (FIR Frankfurt and FIR Düsseldorf),
- VDL and Mode S subnetworks over Benelux (FIR Maastricht) and the UK (FIR London)

- VDL subnetwork over Ireland
- an AMSS subnetwork over Europe and the NAT area operated by an IACSP.

Whereas the Mode S subnetwork is restricted to ATSC traffic only, the Gatelink, VDL and AMSS subnetworks are allowed for all types of aeronautical traffic.

In this document, the architecture and the functions of the individual mobile subnetworks (Mode S, VDL, AMSS) do not need to be considered in order to describe the operation of the ATN. Therefore, the internal architecture of the mobile subnetworks is transparent for the sake of clarity. Instead of the mobile subnetworks themselves, the internetwork links between an A/G-BIS and an A-BIS over a particular mobile subnetwork is reflected in the scenario. The coverage of these mobile subnetworks is assumed to be sufficient to get in contact with the aircraft as long as it is in the region of responsibility of the associated ATSU.

2.2.3 Overall European ATN Routing Organisation

The assumed ATN Routing Organisation of the European ATN internetwork is based on the Routing Organisation defined in [A203]. This Routing Organisation is used for routing and relaying of all types of aeronautical traffic including aeronautical passenger communication (APC).

The European ATN is divided into two major entities:

- an European Region ATN Island RDC and
- an independent separate European Homes RDC.

The European Region ATN Island RDC comprises the RDs of the national ATC authorities and the European Region Island's Backbone RD; it is primarily dedicated to ATSC traffic.

The European Homes RDC comprises the other European ATN ground systems. It is structured into the Home Routing Domains of the different European Airline Operators (AOs), the RDs of the airport operators[2] (APOs), the RDs of the international aeronautical communications service providers (IACSPs), and the European Homes' Backbone RD.

The aircraft are neither contained in the European Region ATN Island nor in the European Homes RDC, but form their own independent RDs.

2.2.4 ATS Routing Organisation of the European Region Island RDC

The European Region Island RDC is divided into national ATS RDCs and the European Region Island's backbone RD as illustrated in Figure 5 for the considered flight scenario.

Each national European ATS Organisation[3] forms its own Administrative Domain which more or less overlaps with the region for which the ATS Organisation has ATC responsibility. An Administrative Domain has a one-to-one relationship to a national ATS

[2] A situation may exist, whereby, an ATSO will be providing ATN services (ATC and AOC/AAC) at an airport.

[3] Eurocontrol is assumed to be an RDC connected to the backbone in the same way as the states having access to the pan-European ATS WAN.

RDC[4].

A national ATS RDC consists of one or several Routing Domains which are centred around each ACC. Therefore, the geographical extent of a RD corresponds to that of a FIR. For example, the flight crosses the Frankfurt ATC RD and the Düsseldorf ATC RD which are both nested in the Germany RDC.

In addition to these national ATS RDCs, the European Region Island's Backbone RD forms part of the European Region Island RDC. The European Region Island's Backbone RD consists of several Backbone BISs (BB-BISs)[5].

The BB-BISs have two main tasks: they relay traffic from and to BB-BISs located in other BB RDs, and they relay traffic to the aircraft currently not attached to the A/G-BIS of the RD in which the traffic is generated (e.g. from an ATN ES in the London RD through the UK BB-BIS to the Frankfurt A/G-BIS which is in contact with the aircraft to which the message is destined). In addition, the BB-BISs may support the relaying of ground-ground traffic within an ATN Island RDC.

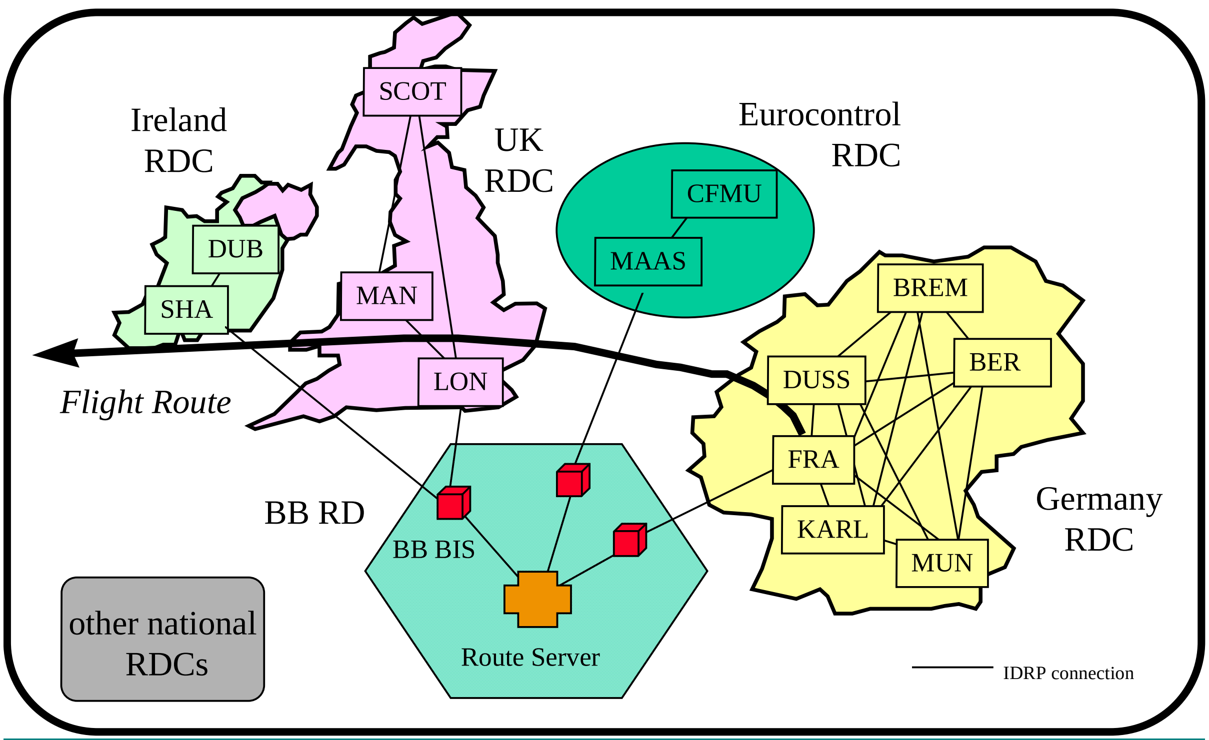

Figure 5: ATS Routing Organisation for the ATN Scenario

2.2.5 Routing Organisation of Airline Operators

An AO may operate its own BIS(s) and then form its own RD, or it may make use of the services provided by an IACSP. For the scenario, it is assumed that LH operates its own G-BIS in its headquarters in Frankfurt that has IDRP connections to the A/G-BIS of the Frankfurt APO and to the Germany BB-BIS of the European Homes RDC operated by an

[4] An AD describes the "ownership" of (i.e. who administers this) part of the network, whereas the RDC relates to the "technical" aspects like route calculation and distribution.

[5] One of the BB-BISs may be configured as a dedicated Route Server (see Glossary).

IACSP.

2.2.6 National ATS Routing Organisation

Within a national RDC, an ATC Routing Domain is formed around each ACC. It encompasses the A/G-BIS of the ACC[6], the ATS ground BIS of each airport in the Routing Domain, and the BISs of other possible ATS sites in the FIR like MET offices.

The routing organisation of an ACC is illustrated in Figure 6 for the Frankfurt ACC. The Frankfurt ATC RD contains the Frankfurt ACC A/G-BIS, the ACC G-ESs (CWPs) of the departure / approach controllers (see section 3.2.5.3 for description of ATN operation) and the en-route controllers (see section 3.2.6.1), as well as the ATC G-BIS and the G-ESs at the Frankfurt Airport. The Frankfurt ACC A/G-BIS is connected to all other ACC A/G-BISs in the Germany ATS RDC, in particular to the Düsseldorf ACC A/G-BIS (see section 3.2.6.4), and to the Germany BB-BIS, as well as to a BIS of an IACSP who provides the satellite link to the aircraft.

The Frankfurt ACC A/G-BIS has attached a Mode S subnetwork (restricted to ATSC traffic) and a VDL subnetwork (available for both ATSC and non-ATSC traffic).

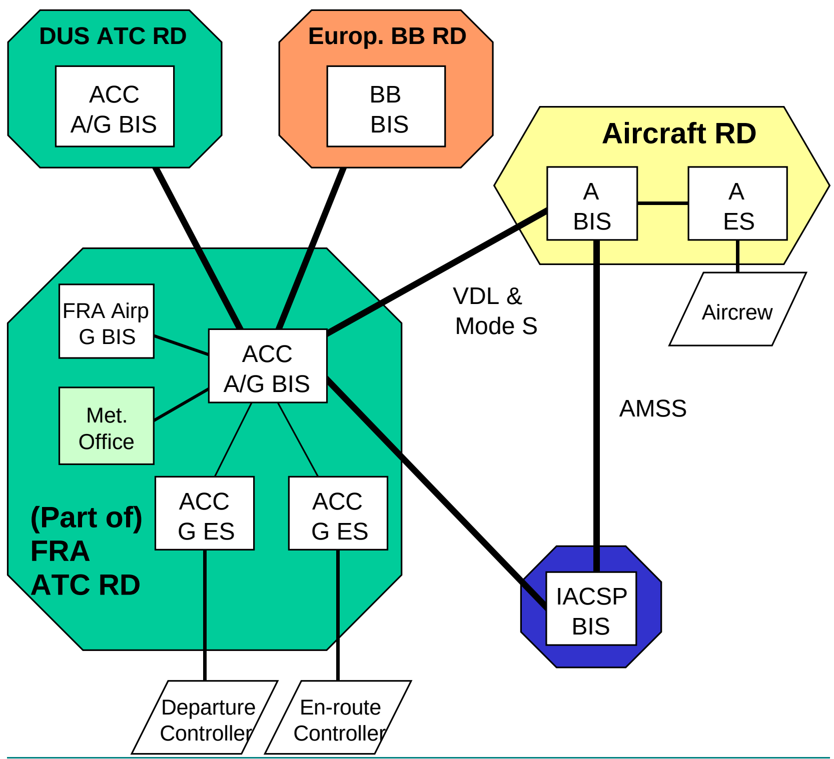

Figure 6: ATN Routing Organisation of Frankfurt ACC

In addition to the ATS systems, also the ATN End Systems of Meteorological organisations are located within the routing domains of the national ATSO. As illustrated in the figure, the Meteorological office of the German DWD is directly connected to the Frankfurt ACC A/G-BIS (see section 3.2.1 for description of ATN operation).

Note: This does not restrict airlines to request and receive meteorological reports from the

[6] The ATS A/G-BIS is provided in fault tolerant manner, possibly consisting of a set of A/G-BISs.

Meteorological organisations.

The routing architecture from the point of view of the ATC G-BIS at the Frankfurt Airport is described in the following section.

2.2.7 Routing Organisation of Airport Operators and Aircraft Operators

An airport operator (APO) of a main airport forms its own Routing Domain centred around the APO's A/G-BIS[7]. It comprises the APO's ESs and the ESs of other local non-ATM organisations having a requirement for ATN communication.

The routing organisation of an airport is illustrated in Figure 7 for the Frankfurt Airport. The figure depicts

- the Frankfurt APO's RD which contains the APO's A/G-BIS and G-ESs (see section 3.2.2 for description of ATN operation),
- the part of the Frankfurt ATC RD that is located at the Frankfurt airport and that contains the ATC G-BIS and ATC G-ES of the ground controller (see section 3.2.3) and the tower controller (see section 3.2.4), the ATC Log-on Server, and the connection to the FRA ACC A/G BIS,
- the LH Headquarters RD which forms the Home for the LH aircraft (see section 3.2.6.16)
- the RD formed by an aircraft (with the ATN ESs of the aircrew), and
- the RD of an IACSP.

The APO's A/G-BIS is interconnected over ground links with the adjacent G-BISs, and over Gatelink and a local VDL network with the airborne BISs (when powered-on) of all ground-located aircraft.

[7] Please note that this relates to one network scenario. Among other options, APOs could also be interconnected to an ATSO-owned A/G-BIS.

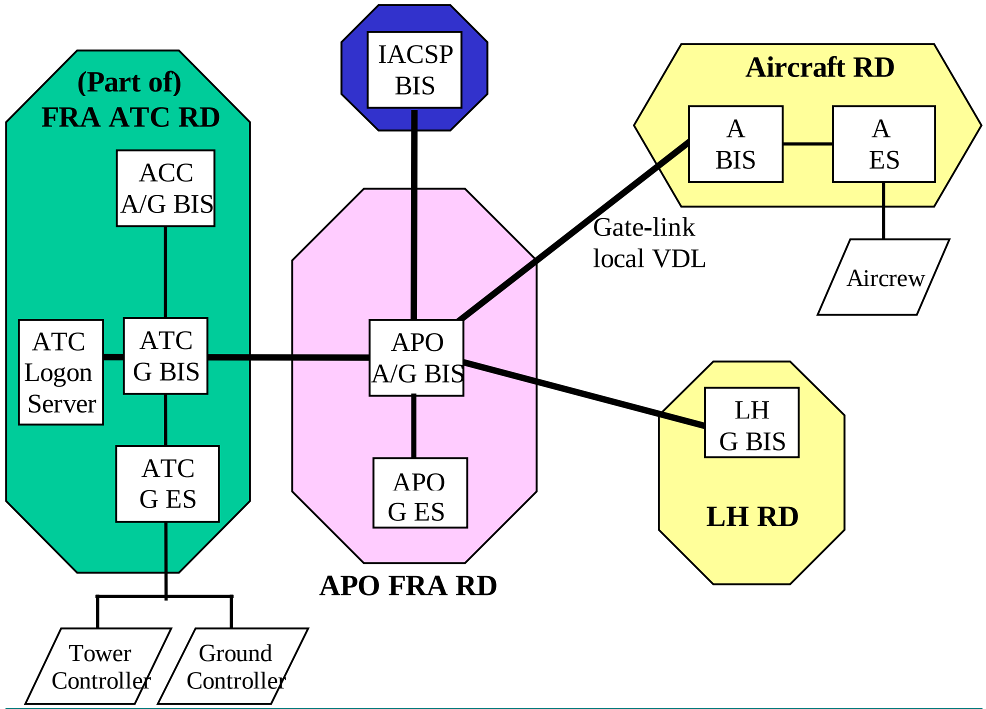

Figure 7: ATN Routing Organisation at Frankfurt Airport

3 Example ATN Use Case

This chapter demonstrates the operation of the ATN for the flight scenario defined in section 2.1 and the network scenario defined in section 2.2.

The table in section 3.1 lists the flight-related events and network events and the resulting ATN operations, section 3.2 describes the ATN operations in detail.

3.1 Events

In the following table, the relevant events that are triggered by the aircrew, the controller or another human user, or by an ATN application are called flight-related events and are listed in the second column. The network events (which do not require any human input) are listed in the forth column. The flight-related events and the network events are reported in their sequence of occurrence. A short description of the ATN operation resulting from either the flight-related event or the network event is given in the third column. The first column provides a reference to the detailed description of the ATN operation which is presented in section 3.2.

Event	Flight-related Event	Resulting ATN Operation	Network Event
3.2.1	*Flight preparation*		
Ev1	Weather report	transfer of messages between AO and MET office	
Ev2	Flight plan co-ordination	transfer of messages between AO and CFMU	
3.2.2	*Pre-flight phase*		
Ev3		establish Gatelink exchange network addresses distribute routes to airborne systems	Power-on of airborne communication equipment (ATN Log-on)
Ev4		DLIC log-on dialogue	DLIC log-on
Ev5	Departure D-FIS ATIS	D-FIS dialogue	
Ev6	Aircraft placed under ATC	establish CPDLC dialogue with ground controller	
Ev7	Pre-departure clearance	using established CPDLC dialogue	
3.2.3	*Pre-Taxiing phase*		
Ev8	Push back clearance	using established CPDLC dialogue	
Ev9		update routing tables in APO's A/G-BIS and A-BIS	VDL link established
Ev10		update routing tables in APO's A/G-BIS and A-BIS	Gatelink terminated

Event	Flight-related Event	Resulting ATN Operation	Network Event
3.2.4	*Taxiing phase*		
Ev11	Transfer of Control (Ground to Tower)	forward DLIC information to tower terminate CPDLC dialogue with Ground Controller establish CPDLC dialogue with Tower Controller	
Ev12	Taxiing clearance	using established CPDLC dialogue	
Ev13	Departure clearance	using established CPDLC dialogue	
Ev14	Take-off clearance	using established CPDLC dialogue	
3.2.5	*Departure phase*		
Ev15		update routing tables in ACC A/G-BIS and A-BIS, distribute routes	VDL (ACC FRA) available
Ev16		update routing tables in ACC A/G-BIS and A-BIS	Mode S (ACC FRA) available
Ev17	Transfer of Control (Tower to Departure)	AIDC dialogue for forwarding DLIC information to ACC terminate CPDLC dialogue with Tower Controller establish CPDLC dialogue with Departure Controller	
Ev18		update routing tables in APO's A/G-BIS and A-BIS, distribute routes	leaving APO's VDL SN
Ev19	Status report to LH office at JFK	deliver status report through the backbone RDs	
3.2.5.6	*En-route phase*		
Ev20	Transfer of Control (Departure to FRA ACC)	terminate CPDLC dialogue with Departure Controller, establish CPDLC dialogue with en-route Controller	
Ev21		update routing tables; distribute routes (for Mode S: ATSC traffic only)	AMSS available; Mode S (DUS) available
Ev22		update routing tables distribute route for all traffic types	VDL (DUS) available
Ev23	Transfer of Control (FRA to DUS)	AIDC dialogue for forwarding DLIC information to DUS ACC terminate CPDLC dialogue with FRA en-route Controller establish CPDLC dialogue with DUS en-route Controller	

Event	Flight-related Event	Resulting ATN Operation	Network Event
Ev24		update routing tables, distribute routes	VDL (FRA) unavailable
Ev25		update routing tables, distribute routes	Mode S (FRA) unavailable
Ev26	ADAP CAP	establish ADAP CAP dialogue with MAS ACC	
Ev27	Transfer of Control (DUS to MAS#1)	AIDC dialogue for forwarding DLIC information to MAS ACC terminate CPDLC dialogue with DUS en-route Controller establish CPDLC dialogue with MAS en-route Controller #1	
Ev28		update routing tables distribute routes	VDL, Mode S (MAS) available
Ev29		update routing tables distribute routes	VDL, Mode S (DUS) unavailable
Ev30	Transfer of Control (MAS#1 to MAS#2)	terminate CPDLC dialogue with MAS en-route Controller #1 establish CPDLC dialogue with MAS en-route Controller #2	
Ev31	ADAP CAP	establish ADAP CAP dialogue with London ACC	
Ev32	MET report	generated on request by on-board systems and sent to MET office, aircrew not involved	
Ev33	Status report to LH office at JFK	deliver status report through the backbone RDs	
Ev34	Information from LH office at JFK airport to aircraft	deliver instruction through the aircraft's home	
Ev35	Passenger e-mail (air initiated)	deliver e-mail created onboard using IACSP and ISP services	
Ev36	Passenger e-mail (ground initiated)	deliver e-mail to onboard passenger using IACSP and ISP services	
Ev37	METAR report	request and deliver METAR report from Shannon weather database	
Ev38	periodic ADS contract	establish periodic ADS contract with Shanwick Oceanic controller	
Ev39	ADS event contract	replace periodic ADS contract with ADS event contract	
Ev40	Downstream clearance	request flight level change from GAND oceanic Controller being the Downstream Data Authority	

Event	Flight-related Event	Resulting ATN Operation	Network Event
Ev41	Transfer of Control (Shanwick Oceanic to Gander Oceanic)	AIDC dialogue for forwarding DLIC information to ACC terminate CPDLC dialogue with SHAN oceanic Controller establish CPDLC dialogue with GAND oceanic Controller	

Table 3.1: Overview of sequence of Events and resulting ATN operations

3.2 ATN Operation

3.2.1 Short-term flight planning

[Ev1]: The LH operations centre requests the current weather report for the scheduled flight from the German MET office using the ATN communication services. The LH application server forwards the request to the LH headquarters G-BIS, which knows the optimum route the MET office application server. The response is sent back the same way to the LH application server which provides the received weather information to the human user, e.g. via a display. Taking into account the received weather information, the preferred route for the scheduled flight is determined by the LH application server.

[Ev2]: The short-term flight plan for the flight is submitted by the LH operations centre to the CFMU, requesting the preferred route. The suitability of the preferred route is checked by the CFMU and a revised flight plan is returned. Thereby the information about the current availability of usually restricted flight areas is taken into account. This information is provided by military ATN ESs[8] to the CFMU whenever a change of the usability of restricted flight areas occurs.

The pre-filed flight plan is accompanied by the actual aircraft identification (its unique 24-bit aircraft address) and activated by the LH airline. The corresponding messages are sent by the CFMU to all involved Flight Management Positions at the ATC units and are acknowledged by them.

All the above messages are sent through the ATN ground internetwork on the optimum paths using the AMHS services. As already mentioned, the messages that flow between ATN systems in the European Region ATN Island RDC and ATN systems in the European Homes RDC need not pass the Backbone routers but can be relayed along the optimum paths.

3.2.2 Pre-flight phase

3.2.2.1 Establish Gatelink

[Ev3a]: Initially, the LH aircraft is parked at a gate of the Frankfurt airport. On power-up, the communication systems are activated and a Gatelink subnetwork connection between the communication systems on board the aircraft and the communication systems of the

[8] A military ATN ES is a secure gateway providing interconnection to the civil ATN. The civil part of a military ATN ES looks like a "normal" ATN ES whereas the military part is not known to the civil ATN.

Frankfurt airport is established. Physically, the Gatelink may be a cable or an infra-red link. Due to its high bandwidth (compared with other mobile subnetworks), Gatelink allows the exchange of large amounts of data between the airborne and the ground communication systems like flight plan updates, MET reports or address tables, as described below.

3.2.2.2 Establish IDRP connection

[Ev3b]: After the subnetwork connection has been established, the airborne BIS announces its presence to the air/ground BIS operated by the Frankfurt (FRA) APO. The BISs identify themselves by exchanging their network addresses[9] and establish an IDRP connection between them[10].

3.2.2.3 Route advertisement

[Ev3c]: After the availability of the Gatelink is indicated to the airborne BIS, it advertises to the FRA APO's A/G-BIS a route to all the ATN ESs on board the aircraft. This route can be used for all traffic types.

The FRA APO's A/G-BIS processes this route and, using the network infrastructure illustrated in Figure 7, it distributes

- a route available for all traffic types to the ATC G-BIS of the FRA ATC RD (at FRA airport),
- a route available for all traffic types to the G-BIS of the LH RD which forms the aircraft's Home,
- a route available for all traffic types to the IACSP G-BIS it is attached to.

The ATC G-BIS at the FRA airport processes the route received from the FRA APO's A/G-BIS and distributes

- a route available for ATSC traffic only to all other BISs within its RD, in particular to the A/G-BIS of the FRA ACC.

The A/G-BIS (FRA ACC), which forms the point of contact to the Backbone, processes this route and, using the network infrastructure illustrated in Figure 6, it distributes

- a route available for ATSC traffic only to all other A/G-BISs in the Germany ATC RDC, in particular to the A/G-BIS in Düsseldorf ACC, which distribute the route within their RD
- a route available for only ATSC traffic to the Germany BB-BIS.

Note: At that moment, the FRA ACC A/G-BIS is not directly connected to the aircraft.

Within the European ATN Island Backbone, the optimum route to the aircraft is distributed

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[9] In this document, the term network address always refers to the ATN NSAP (internetwork) address which is unique within the global ATN. Using this address and assuming the correct implementation of the routing procedures, every ATN system can be reached world-wide. The ATN NSAP internetwork address has to be distinguished from the subnetwork address, e.g. an X.25 address or an Ethernet LAN address.

[10] Note that only a single IDRP connection is established between the airborne BIS and the A/G-BIS. The subsequent route advertisement and distribution (see following subsection) by the A/G-BIS is performed using the quasi-permanently established IDRP connections between the ground BISs.

to all BB-BISs which do not re-distribute this route to their national RDCs.

In the opposite direction, the APO's A/G-BIS advertises

- a default route for all traffic types towards all the ATN ground systems to the airborne BIS.

After the routing information has been propagated as explained above,

- the airborne systems know a (default) path to all the ground ATN systems (through the airborne BIS and the FRA APO's A/G-BIS)
- all ground ATN systems in the Germany ATC RDC have a (direct) path to the airborne systems
- all ground ATN systems in the other European ATC RDCs have a path to the airborne systems through their BB-BIS
- the LH Home BIS knows the direct path to the airborne systems, and
- all other ground systems can forward messages via the aircraft's home to the airborne systems.

3.2.2.4 DLIC Log-on

[Ev4]: After the network connectivity has been established, the aircraft contacts the FRA ATC Log-on Server (see Figure 7), which provides the Directory Service for ATN applications[11] and initiates an DLIC[12] Log-on request. After completion, the application dialogue is closed again.

The LH aircraft ATN ES informs the Log-on Server, along with flight plan information, about the ATN applications (identified by name, version number, and airborne address if it can be ground initiated) which it supports on board and which it intends to use. In response, the Log-on Server informs the aircraft ATN ESs for the reported ATN applications if they are supported on the ground (applications are identified by name, version number, and ground address if it can be air initiated).

After that Log-on procedure, both the LH aircraft ATN ESs and the FRA ATC Log-on Server have loaded or updated the name/address tables for all peer systems of interest and can provide this information on request to other airborne or ground located ATN applications, like ADS, D-FIS, CPDLC.

From now onwards, whenever a data-link application wants to establish an association to a peer application, it queries the local DLIC application for the network address to identify the computer system on which the peer application is currently hosted, and the application address to contact the application. The DLIC application retrieves these addresses from the loaded name/address tables and returns it to the querying application.

3.2.2.5 Departure D-FIS

[Ev5]: Before departure, the pilot initiates a D-FIS - ATIS request in "Demand mode" for the Frankfurt airport identified by its ICAO location code. The airborne ATIS application

[11] The application address of the Log-on Server is known statically to the airborne application, whereas all the other application addresses may change dynamically during the course of time.

[12] DLIC services use the Context Management (CM) Application defined in the ATN SARPs, Subvolume 2.

retrieves the network address of the ground ATIS application by a query to its local DLIC application which has downloaded the address table from the FRA Log-on Server. Using the retrieved address, the airborne ATIS application establishes an association to the ground ATIS application at the central German FIS server (through the APO's A/G-BIS) and receives the ATIS information. After the information is delivered, the D-FIS application context is terminated.

3.2.2.6 Establishing ATC Communication

[Ev6]: By pilot initiation, the aircraft ATN ES retrieves the address of the FRA ATC communication management application from the local DLIC application and establishes a connection with the FRA ATC communication management application. The LH aircraft ATN ES identifies itself by its unique ICAO 24-bit aircraft address, and the flight plan that has already been associated to the aircraft's address is correlated to the aircraft network address.

The FRA ATC communication management application determines the ground controller responsible for the aircraft based on the parking position of the aircraft and the current work load of the individual ground controllers, and triggers the CPDLC application to initiate a CPDLC dialogue to the aircraft. The aircraft that has initially no Current Data Authority link established, accepts the ground controller as Current Data Authority (CDA) and is put under ATC. As the CDA, the ground controller is now the only one whose clearances will be accepted by the airborne ATN applications until he hands over the authority to the next controller (i.e. the Next Data Authority, NDA).

The CPDLC messages are sent by the aircraft ATN ES to the A-BIS, over the Gatelink to the APO's A/G-BIS, and to the ATC ATN ES on which the CPDLC application is hosted, and vice versa.

3.2.2.7 Pre-departure Clearance

[Ev7]: When ready, the pilot requests the Pre-departure clearance from the ground controller over the established CPDLC application context, which is given by the controller and acknowledged again by the pilot. The exchange of these messages is supported to the utmost extend by the applications, requiring minimum input or just a "mouse-click" by the pilot and the controller.

3.2.3 Pre-Taxiing phase

3.2.3.1 Push back clearance

[Ev8]: Finally, the pilot requests the push back clearance from the ground controller, which is given by him, and acknowledged again by the pilot, still using the established CPDLC association over the Gatelink.

3.2.3.2 Establishing VDL subnetwork link

Note: All the communication from and to the aircraft described above was done over the Gatelink. When the aircraft leaves its parking position, the Gatelink can no longer be used and another mobile subnetwork is to be made available instead.

[Ev9]: Before push-back, a VDL subnetwork link is established between the A-BIS and the APO's A/G-BIS. The routing tables in these two BISs are updated to reflect the change in subnetwork connectivity.

Figure 8 zooms into Figure 4. It depicts the areas of ATC responsibility, the coverage of the mobile subnetworks that provide data links to the aircraft, and the events along the flight route after the VDL subnetwork is established. The numbers in the small circles identify the relevant events and correspond to the numbering scheme introduced in Table 3.1.

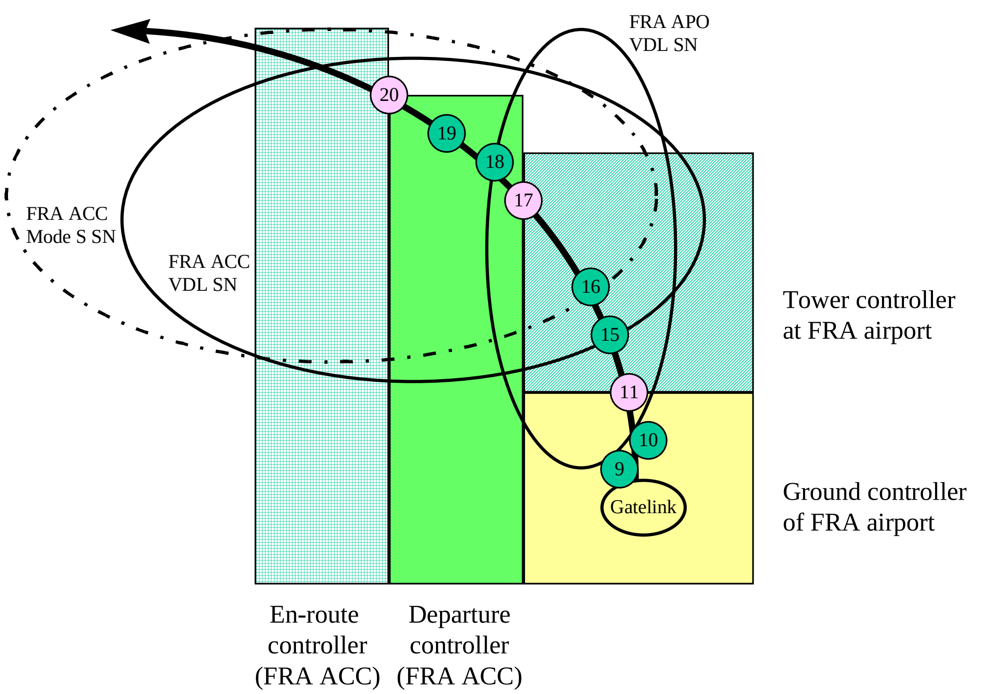

Figure 8: Flight Route from Leaving Parking Position to Handover to FRA Departure Controller

3.2.3.3 Terminating Gatelink

[Ev10]: During push-back, the Gatelink is disconnected. This disconnection is indicated by the ATN communication protocols to the A-BIS and the APO's A/G-BIS which update their routing tables accordingly.

As an alternate subnetwork connection (i.e. the VDL subnetwork connection) is still available to the aircraft (see [Ev9]), the IDRP connection between the A-BIS and the APO A/G-BIS is not terminated. The APO A/G-BIS propagates that change in subnetwork connectivity to its adjacent BISs.

The switch from the Gatelink to the VDL subnetwork is transparent to the pilot and the ground controller, as all active application associations (e.g. the CPDLC dialogue between the controller and the pilot) are kept established during that change in subnetwork connectivity.

3.2.4 Taxiing phase

3.2.4.1 Transfer of control (Ground controller - Tower controller)

Note: When the aircraft enters the taxi-way, the ATC authority is given from the ground controller to the tower controller.

[Ev11]: When the aircraft is to enter the taxi-way, the ground controller initiates a notification from his application to the tower controller's application about the forthcoming transfer of control authority. As both the ground controller's application and the tower controller's application are hosted in the same ATC G-ES, all relevant information is already available to the tower control application and does not have to be exchanged. In addition, the CPDLC link that has been established by the ground controller can be re-used by the tower controller, and no transfer of data link communication has to be initiated. The transfer of control authority is indicated to the aircraft and the CPDLC application association between the aircraft and the ground controller's application is replaced by the CPDLC application association with the tower controller's application.

Voice frequency is changed in accordance with the transfer of data authority. This is assisted and monitored by the ATC Communications Management application, i.e. the frequency to which the pilot has to change, is displayed on the pilot's screen, and the currently set frequency is remotely monitored by the responsible controller.

The messages between the aircraft and the controllers at FRA airport are transmitted over the ATC G-BIS (at FRA airport), the APO's A/G-BIS, the local VDL subnetwork and the A-BIS.

3.2.4.2 Taxiing clearance, Departure clearance, Take-off clearance

[Ev12], [Ev13], [Ev14]: At the appropriate time, Taxiing clearance, Departure clearance, and Take-off clearance messages are requested by the pilot and given by the tower controller using the established CPDLC dialogue over the FRA airport's local VDL subnetwork. In addition to the clearance itself, additional parameters may be transmitted during that dialogue.

3.2.5 Departure phase

Note: For this scenario, it is assumed that the departure controller position is located in the ACC, thus the communication paths is over the ACC A/G-BIS.

3.2.5.1 Entering the coverage of the FRA ACC VDL Subnetwork

[Ev15]: At latest after take-off, the aircraft enters the coverage of the VDL subnetwork of the FRA ACC A/G-BIS. Automatically, an IDRP connection is established between the ACC A/G-BIS and the A-BIS, and routes are exchanged between them (in the same way as described in section 3.2.2.2 for the IDRP connection between the A-BIS and the FRA APO’s A/G BIS).

As the new route is different from the former one to the airborne systems (the ACC A/G-BIS has now a direct connection to the A-BIS, whereas before the connection was through the FRA APO's A/G-BIS), the FRA ACC A/G-BIS distributes the route to adjacent BISs in the following way:

The FRA ACC A/G-BIS distributes

- a route available for ATSC traffic only to all BISs within its RD, e.g. to the ATC G-BIS at the Frankfurt airport
- a route available for ATSC traffic only to all other A/G-BISs in the Germany ATC RDC
- a route available for ATSC traffic only to the Germany BB-BIS.
- a route available for all traffic types to the IACSP G-BIS it is attached to (which distributes the route to the LH G-BIS forming the LH's Home),

The ATC G-BIS (at FRA airport) processes the route received from the FRA ACC A/G-BIS and distributes a route available for ATSC traffic only to the FRA APO's A/G-BIS.

The new route learnt by the FRA APO's A/G-BIS does not overwrite and delete the already known route of the BIS to the LH aircraft. Contrarily, as the old route is more direct to the LH aircraft (and thus calculated as the "best" one to the airborne systems), it is used as long as the aircraft is within the coverage of the airport's VDL subnetwork.

Note that although the data connection through the FRA ACC A/G-BIS is available, it is not used for ATS communication by the tower controller until the aircraft is handed over to the departure controller located at the ACC. The connection through the FRA ACC A/G-BIS may be used for MET data, AOC/AAC traffic, etc. and as backup path for ATSC traffic.

3.2.5.2 Entering the coverage of the FRA ACC Mode S Subnetwork

[Ev16]: Short time afterwards, the aircraft also enters the coverage of the Mode S subnetwork attached to the FRA ACC's A/G-BIS. Immediately after the aircraft has been detected by the Mode S interrogator, a subnetwork connection is established and indicated to the ACC's A/G-BIS and the A-BIS. This subnetwork forms an additional link between these two BISs and increases the overall capacity. The route to the aircraft is re-distributed on the ground indicating the availability of a Mode S link[13].

According to the routing policy implemented in the FRA ACC's A/G BIS, the Mode S subnetwork link is preferred for ATSC traffic against the "parallel" VDL subnetwork. On the other hand, the Mode S subnetwork is restricted to ATSC traffic and is not offered for other traffic types.

3.2.5.3 Transfer of control (Tower controller to Departure controller)

[Ev17]: Some time later the aircraft has progressed along its flight path to a point where a hand-over from the tower controller to the departure controller is initiated. The addressing information previously received from the aircraft is passed from the ATC Log-on Server to the ACC Log-on Server by means of the DLIC Ground Forwarding service. The FRA ACC addressing information is passed to the aircraft by means of a DLIC Update service. The forthcoming hand-over is notified to the departure controller by means of the AIDC notification and to the aircraft by sending a NDA message identifying the FRA ACC as the NDA. The ACC G-ES initiates a CPDLC dialogue with the aircraft, which accepts the dialogue.

When the aircraft crosses the agreed boundary, the tower controller sends the AIDC Transfer message to the departure controller, who confirms the transfer. Now, the tower controller instructs the LH aircraft that it is now under the control of the NDA by terminating the CPDLC link. The NDA becomes the CDA. At that time, the transfer of control is completed.

The G/G connection is established from the tower controller's ATC G-ES, to the ATC G-BIS at the FRA airport, over the private ATS WAN to the ACC A/G-BIS at the FRA ACC to the departure controller's ACC G-ES, as illustrated in Figure 9.

Note: The data-link connection between the A-BIS and the ATC G-BIS at FRA airport (depicted in the figure by a dotted line) passes the APO's A/G BIS.

[13] The Mode S link will be identified by an additional Mode S A/G subnetwork security tag in the UPDATE PDU advertising the route to the aircraft.

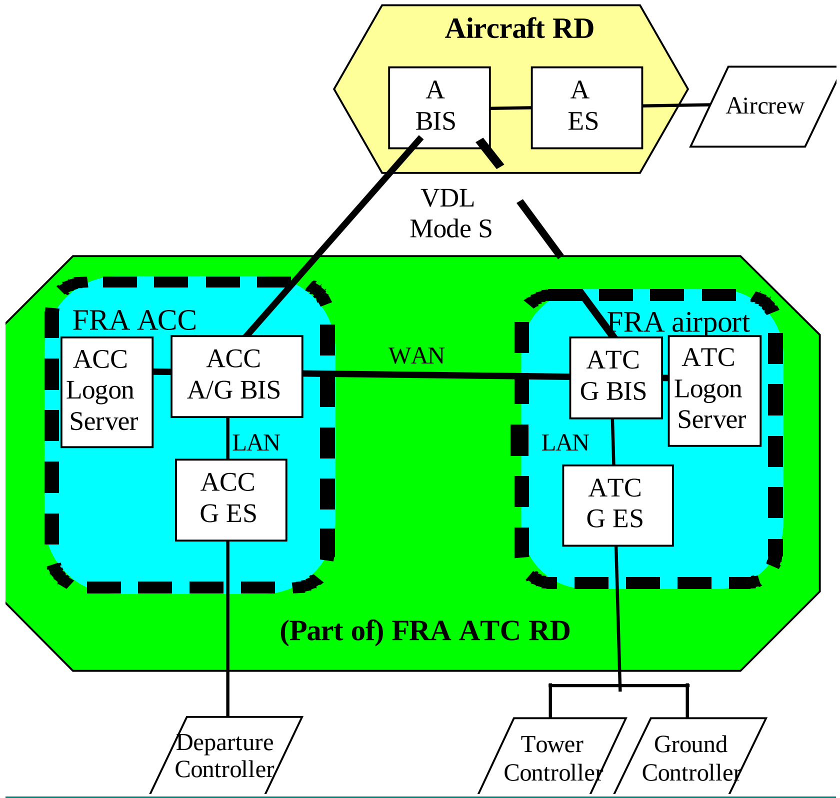

Figure 9: Detailed Network Scenario for Transfer of Control from FRA Tower Controller to FRA Departure Controller

The data connection between the FRA airport's A/G-BIS and the A-BIS is kept established until the coverage of the FRA APO's VDL subnetwork is left. However, that connection is no longer used for ATS CPDLC communication, except for back-up.

The transfer of data authority is synchronised with the transfer of control executed over voice communication, as the operational principle has to be retained that there is only one controlling authority (for voice and data) that is properly and unambiguously defined. In addition, this voice communication guarantees the required operational awareness of the aircrew to which currently responsible Air Traffic Service Unit (ATSU) it is communicating with.

That change of the voice frequency is assisted and monitored by a data-link application, i.e. the frequency to which the pilot has to change, is displayed on the pilot's screen, and the currently set frequency is remotely monitored by the responsible controller.

3.2.5.4 Leaving the coverage of the APO's VDL Subnetwork

[Ev18]: When the LH aircraft leaves the coverage of the FRA APO's VDL subnetwork, no more subnetwork link between the A-BIS and the FRA APO's A/G-BIS is available. The FRA APO's A/G-BIS distributes this information to all BISs within the FRA RD, which remove the entry associated with this route to the LH aircraft from their routing tables[14].

[14] If a data packet destined to an airborne system arrives in the meantime at the APO's A/G-BIS, the APO's A/G-BIS forwards it to the FRA ACC A/G-BIS which is in contact to the aircraft and which announced that route before to the APO's A/G-BIS.

3.2.5.5 Status report to LH office at JFK airport

[Ev19]: Some time after take-off, an LH-specific AAC application is automatically triggered to send a status report to the LH office at the JFK airport. It informs the office, amongst others, about the actual take-off time and the estimated arrival time.

The message (created by the ATN ES and categorised as AOC traffic) is sent from the A-BIS over the VDL link to the FRA ACC A/G-BIS. The FRA ACC A/G-BIS forwards the message to a BB-BIS of the European Homes RDC as the routes to the Germany BB-BIS of the European Region BB RD are restricted to ATSC traffic. The BB-BIS of the European Homes RDC forwards the message to a BB-BIS of the North American Region RDC, which forwards it to the LH office at JFK airport[15].

3.2.5.6 Establishing an AMSS link

When the aircraft has reached its cruising altitude it activates the AMSS equipment and initiates an AMSS connection between its A-BIS and an A/G-BIS of an IACSP in order to allow for communication services to the aircraft's passengers (see sections 3.2.6.17 and 3.2.6.18)[16]. The IACSP's A/G-BIS distributes the received route to the airborne ESs to the adjacent FRA ACC A/G BIS and towards the LH aircraft's home.

In addition, the AMSS link constitutes a back-up path for ATC communication over continental airspace with alternative links (VDL, Mode S), and will be used for ATSC over oceanic airspace (see section 3.2.6.20).

3.2.6 En-route phase

3.2.6.1 Transfer of control (FRA Departure controller to FRA ACC en-route controller)

[Ev20]: The Transfer of control from the FRA departure controller to the FRA en-route controller in the FRA ACC is performed in the same way as the Transfer of control from the FRA TWR to the FRA departure controller. No ATN routes are changed or distributed as the LH aircraft keeps attached to the FRA ATC RD; the communication for both controllers is through the FRA ACC A/G-BIS. As the address information about the ATN systems on board of the LH aircraft is already available at the FRA ACC, this information need not be forwarded or retransmitted by the LH aircraft respectively.

Figure 10 continues the illustration of the flight route of Figure 8 and shows the events after the transfer of control to the FRA ACC en-route controller.

[15] As this message is transferred from one ATN Island to another, it has to pass through both a BB-BIS of the European and a BB-BIS of the North American Homes RDC.

[16] If there is a need for it, the AMSS link may be established anytime before (after power-up of the aircraft).

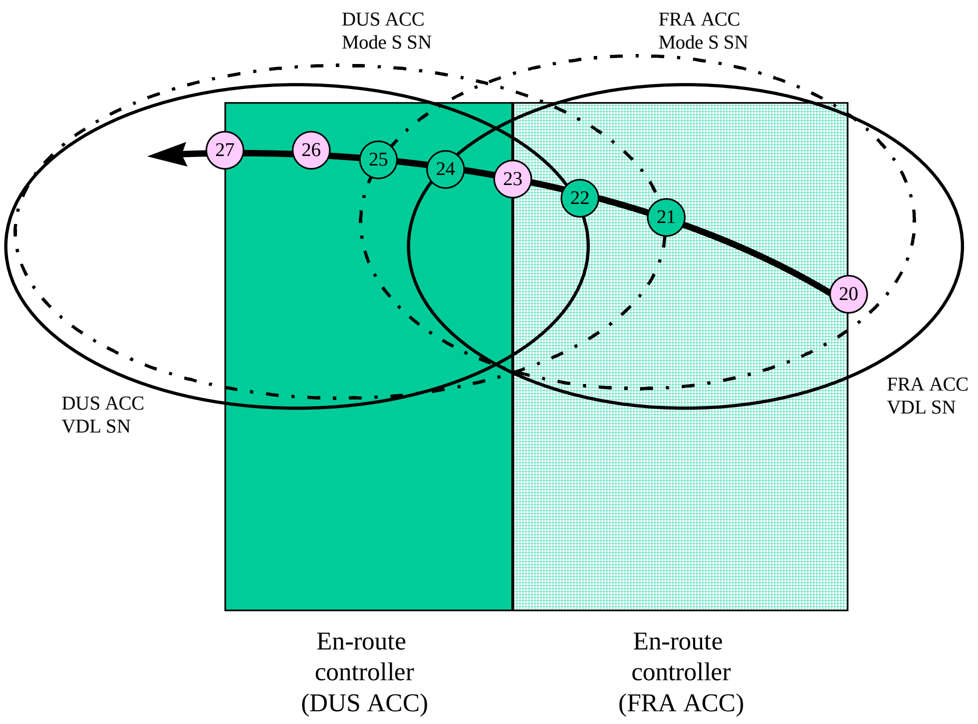

Figure 10: Flight Route from FRA ACC to DUS ACC En-route Controller

3.2.6.2 Entering the coverage of the DUS ACC Mode S Subnetwork

[Ev21]: On its flight, the aircraft enters the coverage of the Düsseldorf (DUS) ACC Mode S subnetwork and an IDRP connection is automatically established between the DUS ACC A/G-BIS and the A-BIS. Like described in section 3.2.5.1, the DUS ACC A/G-BIS creates a route (available for ATSC traffic only) and distributes it to all BISs within its RD, to all other RDs within the Germany RDC, and to the Germany BB-BIS which distributes the route to all BB-BISs. The BB-BISs re-calculate the routes to the aircraft, e.g. the Benelux BB-BIS and the UK BB-BIS can forward data packets destined to the airborne systems directly to the DUS ACC A/G-BIS.

3.2.6.3 Entering the coverage of the DUS ACC VDL Subnetwork

[Ev22]: When the aircraft enters the coverage of the VDL subnetwork attached to the DUS ACC A/G-BIS, an additional subnetwork link is established between the DUS ACC A/G-BIS and the A-BIS. This new link constitutes a change in non-ATSC traffic connectivity and new routes are distributed to the attached BISs advertising the VDL subnetwork link available for all traffic types.

3.2.6.4 Transfer of control (FRA controller to DUS controller)

[Ev23]: The transfer of control from the FRA controller to the DUS controller is performed in the same way as the transfer of control from the FRA TWR to the FRA departure controller. No routes are changed or distributed, as the connectivity to the aircraft still exists through both the FRA ACC A/G-BIS and the DUS ACC A/G-BIS.

3.2.6.5 Leaving the coverage of the FRA ACC VDL Subnetwork

[Ev24]: When the aircraft leaves the coverage of the FRA VDL subnetwork, the FRA ACC A/G-BIS looses the only available route to the LH aircraft for non-ATSC traffic. Consequently, it informs all BISs in its RD, all RDs in the Germany RDC and the BB-BIS of its loss of the direct route for non-ATSC traffic.

3.2.6.6 Leaving the coverage of the FRA ACC Mode S Subnetwork

[Ev25]: When the aircraft leaves also the coverage of the FRA Mode S subnetwork, the FRA ACC A/G-BIS has no longer a direct route to the airborne ATN systems available, and informs again the adjacent BISs about the loss of the direct route (see section 3.2.6.6).[17]

3.2.6.7 ADAP CAP by Maastricht

[Ev26]: When the LH aircraft appears on the radar screens of the Maastricht ACC, the ADAP CAP (Automatic Downlink of Aircraft Parameters - Controller Access to Aircraft Parameter) application of the MAS ATN ES initiates a periodic contract with the airborne ADAP CAP application[18,19]. After the CAP service has been initiated, the airborne application creates periodically messages containing parameters like airspeed, heading, flight level, vertical rate and wind velocity and transmits these messages to the Maastricht ACC and all other ATSUs which requested the service. The ground applications receive these parameters, process them and improve the display of the aircraft and its extrapolated flight route on the radar screens of the affected controllers (i.e. not only of the currently responsible controller (C-ATSU) but of all screens on which the aircraft is displayed).

The ADAP CAP service does actively involve neither the aircrew nor the controllers. The contract is terminated when the LH aircraft leaves the monitored airspace of the Maastricht ACC.

3.2.6.8 Transfer of control (DUS controller to MAS controller #1)

[Ev27]: From the operational point of view, the transfer of control from the DUS controller (ATSU) to the Maastricht (MAS) controller #1 (ATSU) is performed in the same way as the transfer of control from the FRA TWR to the FRA departure controller (see section 3.2.5.3).

However, as Maastricht ACC controls the upper air space of Northern Germany, the best connection between the Maastricht controller and the aircraft at the time of the transfer of control is done over a Mode S (or VDL) link attached to the DUS ACC A/G-BIS. Therefore, the communication path is from the controller's working position to the Maastricht ACC A/G-BIS, to the Benelux BB-BIS, to the DUS ACC A/G-BIS, to the A-BIS, and to the aircraft ATN ES (see Figure 11)[20]. In the opposite direction, the communication path is from the aircraft ATN ES to the A-BIS, to the DUS ACC A/G-BIS, to the Germany BB-BIS, to the Maastricht ACC A/G-BIS, and to the controller's working position. Note that the data transmission through the DUS ACC A/G BIS is only a technical matter that is perceptible to neither the controller nor to the pilot.

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[17] It still can reach the aircraft over the DUS ACC A/G-BIS from which it learnt a route to the aircraft.

[18] The scenario assumes that Maastricht ACC has no Mode S coverage. In areas where there is a Mode S coverage, the transmission of the CAP message may be better provided by the Mode S Specific Services than by the ATN. This does not affect the presentation of the received information to the controller as described hereafter.

[19] The ATSUs know from the DLIC Log-on that the aircraft is equipped with the ADAP CAP application and which airborne address to use.

[20] The Germany BB-BIS is not involved, as the Benelux BB-BIS knows the direct path to the DUS ACC A/G BIS.

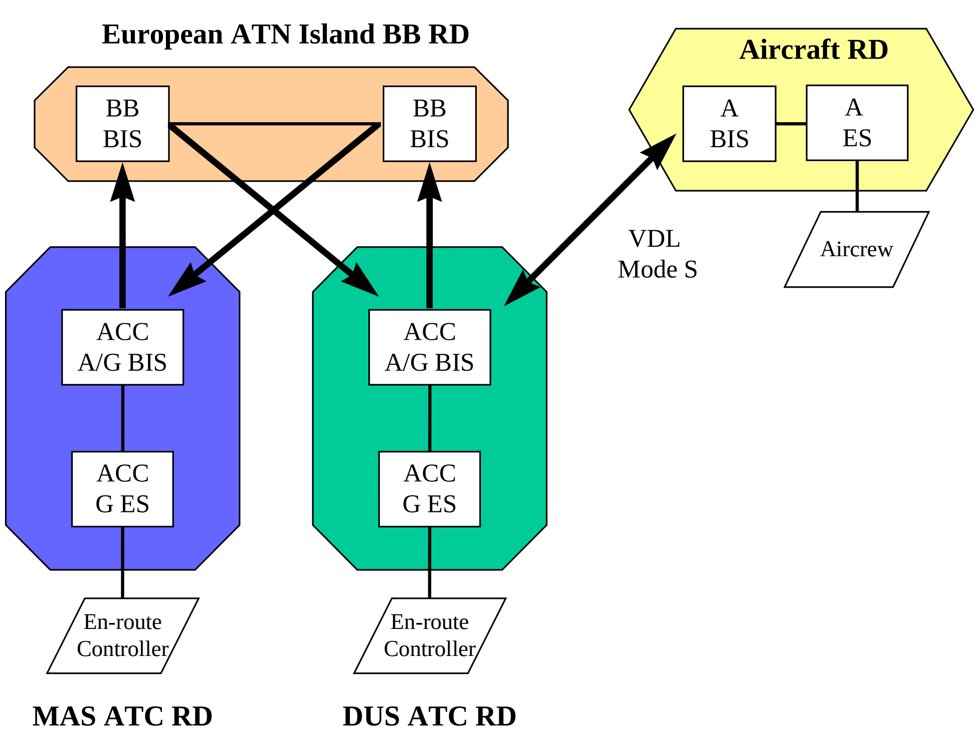

Figure 11: Data communication path for aircraft over Northern Germany controlled by MAS ACC En-route Controller

Figure 12 continues the illustration of the flight route and shows the events after the transfer of control to the FRA ACC route controller.

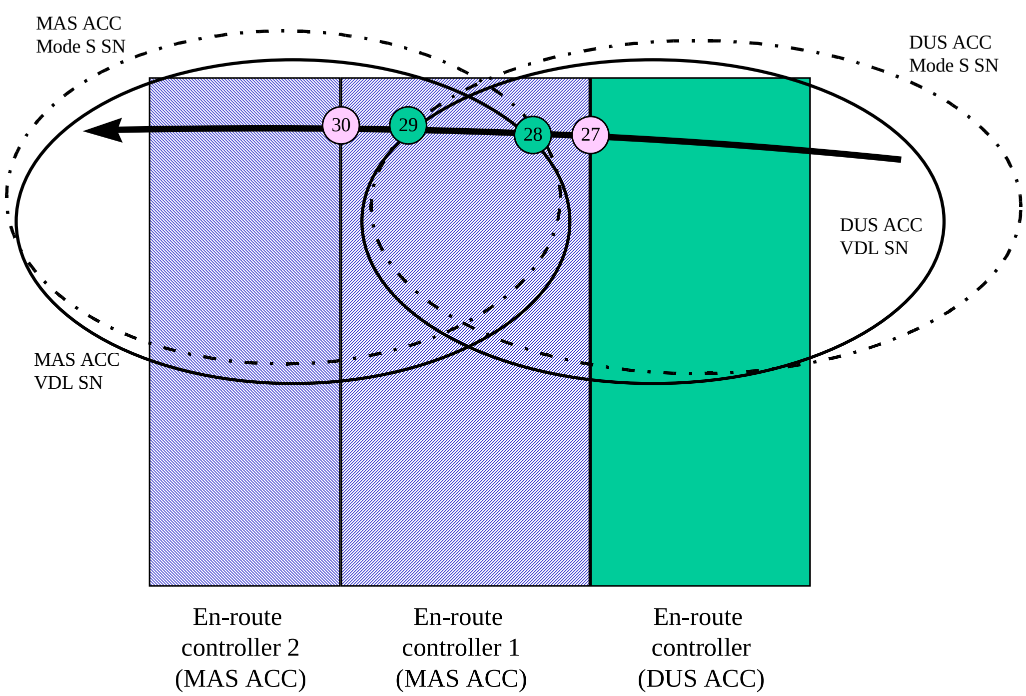

Figure 12: Flight Segment Controlled by MAS ACC En-route Controllers

3.2.6.9 Entering the coverage of the MAS ACC VDL/Mode S Subnetworks

[Ev28]: On its flight, the aircraft enters the coverage of the Mode S subnetwork and the VDL subnetwork of the MAS ACC and an IDRP connection is automatically established between the MAS ACC A/G-BIS and the A-BIS. As described in section 3.2.5.1, the MAS ACC A/G-BIS creates a route and distributes it to all BISs within its RD, to all other RDs within the Eurocontrol RDC, and to the Benelux BB-BIS which distributes the route to all BB BISs. The BB-BISs re-calculate the routes to the aircraft, e.g. the Germany BB-BIS and the UK BB-BIS can forward data packets destined to the airborne systems directly to the MAS ACC A/G-BIS.

After that direct connection between the MAS ACC A/G-BIS and the A-BIS is established, the data communication between the Maastricht controller and the pilot flows along that direct path, i.e. from the CWP to the Maastricht ACC A/G-BIS, to the A-BIS to the aircraft ATN ES, and vice versa. That change in the communication path is made autonomously by the network entities and is perceptible to neither the controller nor to the pilot.

3.2.6.10 Leaving the coverage of the DUS ACC Mode S and VDL Subnetworks

[Ev29]: When the aircraft leaves the coverage of the DUS Mode S and VDL subnetwork, the DUS ACC A/G-BIS informs all BISs in its RD, all RDs in the Germany RDC and the BB-BIS of its loss of the direct route to the aircraft.

3.2.6.11 Transfer of control (MAS controller #1 to MAS controller #2)

[Ev30]: The transfer of control from one controller to another controller in the MAS ACC is performed in the same way as described above for the transfer of control between different ACCs. The LH aircraft address information is already available in the ATN ES of the MAS ACC (see section 3.2.6.4 for example).

No routes are changed or distributed, as the connectivity to the aircraft still exists through MAS ACC A/G-BIS and over the directly attached subnetworks.

3.2.6.12 ADAP CAP by London ACC

[Ev31]: When the aircraft appears on the radar screens of the London ACC, the ADAP CAP application of the London ACC ATN ES initiates also a periodic contract with the LH aircraft, in addition to the one by the Maastricht ACC. The contract is terminated when the aircraft leaves the airspace controlled by the London ACC.

3.2.6.13 Subsequent Changes in Subnetwork connectivity and Transfers of control

Along its further flight, the aircraft is handed over from the MAS controller to the London controller, to the Shannon controller, and to the Shanwick oceanic controller. Thereby it repeatedly enters and leaves the coverage of mobile subnetworks attached to the A/G-BISs of these centres. The procedures always correspond to the ones described above (see sections 3.2.6.2 through 3.2.6.6 for example) and need not be described here again.

3.2.6.14 MET report

[Ev32]: When the aircraft is in the London FIR, it receives a request by the UK MET office to report the current weather data. That request is received by the airborne application which automatically gathers the available weather information (e.g. temperature, pressure, wind vector), creates the response message and sends it back to the UK MET office, which updates its weather database. This communication is done completely without involving the aircrew.

The communication takes place in two subsequent dialogues as the application in the UK

MET office initially does neither know which aircraft are currently in the airspace nor the addresses of those aircraft which are equipped with data link applications.

So, as the MET ATN ES can not directly contact an aircraft, it sends first a request to a server application at the London ACC to which it is connected through the London ACC A/G-BIS. The server application receives the request and replies with a set of application addresses for those aircraft which are equipped with the airborne weather reporting application (this information is retrieved from the AIDC dialogue) and their current positions (this information is retrieved from the RDPS application).

Based on this information, the application in the UK MET office selects one of the aircraft and sends the weather information request through the London ACC A/G-BIS and the A-BIS to the airborne ES, using the VDL link between the London ACC A/G-BIS and the A-BIS. The airborne ATN ES sends its reply directly to the address of the MET office, which it retrieves from the received request. The reply is sent over the VDL link to the London ACC A/G-BIS which knows a direct ground route to the ATN ES in the UK MET office.

3.2.6.15 Status report to LH office at JFK airport

[Ev33]: About one hour after take-off when the aircraft is in the London FIR, the airborne application sends again a status report to the LH office at the destination airport. It informs about the current engine status and other data for maintenance purposes, about the current weather status as well as the estimated arrival time (which may be delayed for half an hour), the currently consumed fuel and estimated fuel consumption.

The message (categorised as AOC traffic) is sent from the A-BIS to the London ACC A/G-BIS, to a BB-BIS of the European Homes RDC, to a BB-BIS of the North American Homes RDC, and to the LH office at JFK airport. This assumes that the aircraft knows the current address of the ATN application at the LH office at JFK airport.

3.2.6.16 Instruction to aircraft by LH office at JFK airport

[Ev34]: The LH office at JFK airport acknowledges the status report and informs the aircrew about the expected delays of the connecting flights of passengers onboard of the LH flight..

The return path differs from the path of the status report as the G-BIS to which the LH office at JFK airport sends the reply does not know the current position of the aircraft[21]. Therefore the LH ATN ES sends the message on the default path, i.e. to the nearest BB-BIS of the North American Homes RDC. The BB-BIS neither knows the direct route to the aircraft as it is not (yet) over the North American Region, but still over Europe. So it sends the message towards the aircraft's home RD (i.e. the LH headquarters in Frankfurt) to a BB-BIS of the European Homes RDC. However, that BB-BIS knows the direct route to the aircraft and forwards it to the London ACC A/G-BIS, which delivers it over its VDL link to the A-BIS.

3.2.6.17 Passenger communication (air initiated)

Note: Data communication is getting more and more important for the business people flying as passengers in an aircraft. Thus, it is assumed that in the considered time-frame the airline will offer to its passengers an e-mail service like they presently offer a telephone service onboard.

[Ev35]: When the aircraft is on its flight over London FIR, a passenger plugs his laptop into

[21] More technical speaking, it does not know which is the A/G-BIS that is in direct contact to the aircraft.

the socket at his seat, logs on to the aircraft's passengers LAN and sends an e-mail to a colleague in his company office notifying him about the flight number of his flight and requesting some information. This message is sent on the aircraft LAN to the A-BIS. The A-BIS identifies the message as APC traffic and forwards it over the AMSS subnetwork to the A/G-BIS of the IACSP. The SMTP gateway of the IACSP forwards the message to an attached internet service provider (ISP) who forwards it finally to the mailbox of the colleague.

3.2.6.18 Passenger communication (ground initiated)

[Ev36]: Some time after the passenger sent his e-mail, the colleague reads it and creates the reply. At that time, neither he nor his ISP knows the current position of the aircraft (nor even the position at the time when the first message was sent). However, this is not necessary; the colleague simply sends the reply to the address consisting of the following components: passenger's name, flight number, airline. The ISP forwards the message to a message gateway at the airline's home. The airline messaging application is always informed about the current position of its aircraft and the connections to it. Based on the APC traffic type and the flight number as well as the current connectivity to the aircraft (which is now in the Shannon FIR), it forwards the message through an IACSP over the AMSS subnetwork to the A-BIS identified by the flight number in the e-mail address. The A-BIS receives the message, extracts the passenger's name and relays the message on the internal LAN to the passenger's computer.

3.2.6.19 METAR report

[Ev37]: On its flight over Shannon FIR, the pilot requests a METAR report for its destination aerodrome JFK for flight planning and for the information of the passengers. The request is sent by the aircraft ATN ES to the connected A/G BIS, i.e. the Shannon ACC A/G-BIS which forwards it to its local weather database application. This application holds a copy of all the current METAR reports for the aerodromes in this database which are distributed world-wide using the AMHS services.

The METAR ground application identifies the requested METAR report by its ICAP location identifier and sends the response back to the aircraft's weather application whose address it retrieved from the request through the Shannon ACC A/G-BIS and the A-BIS. After receipt, the airborne application displays the METAR information to the aircrew. With the successful delivery of the response message, the data link service between the airborne application and the ground METAR application is implicitly closed.

3.2.6.20 Periodic ADS contract

[Ev38]: When the LH aircraft is leaving the continental airspace, the Shanwick oceanic controller initiates a periodic ADS contract with the aircraft over the AMSS subnetwork. As this AMSS subnetwork is provided by an IACSP, the messages are sent from the ATN ES in the Oceanic ACC (OACC) to the Shanwick OACC A/G-BIS, through the ground subnetwork of the IACSP to his GES and via the satellite to the AES, the A-BIS and the airborne ES, and vice versa.

After the airborne ADS application has acknowledged the contract, it issues every 15 minutes its position (latitude, longitude, altitude) and the time of the reported position to the ground application, whereby the position and the time are derived from the GNSS application. On the screen of the oceanic controller’s CWP, the aircraft is displayed similar to data received from radar. Note that the aircrew is involved neither in creating the contract nor in providing the requesting parameters; this is executed autonomously by the airborne ADS application.

Every hour, the airborne ADS application sends in addition to these position parameters meteorological data (wind direction, wind speed, temperature, and turbulence) to the ground. These meteorological data are processed both by the ground OACC and are also forwarded to the central meteorological office using AMHS services.

3.2.6.21 ADS event contract

[Ev39]: After the aircraft has flown some time and no changes of the intercontinental flight route are to be expected, the Shanwick oceanic controller replaces the periodic ADS contract with an ADS event contract. The aircraft ADS application reports from then on every deviation of its level, its airspeed, its heading and its track angle whenever it may occur.

These messages are transmitted over the AMSS subnetwork as described in the section above for the periodic ADS contract.

3.2.6.22 Downstream Clearance to Gander controller

[Ev40]: Some time before the LH aircraft enters the control region of the Gander oceanic controller, the pilot informs the Gander oceanic controller that he wants to change his flight level after he will have entered the Gander oceanic control region. This request is sent as a Downstream Clearance message over the established AMSS subnetwork link.

The Gander oceanic controller receives the request, prepares for the flight level change, and replies with a Downstream clearance, which is sent back over the AMSS subnetwork to the LH aircraft.

Although the downstream clearance is given to the pilot at that time, it comes into effect not before the Gander oceanic controller has become the current data authority.

3.2.6.23 Transfer of control (Shanwick controller to Gander controller)

When the LH aircraft enters the coverage of the satellite operated from a North American GES, an AMSS subnetwork link and subsequently an IDRP connection are established between the A-BIS and the A/G-BIS of the IACSP operating this AMSS subnetwork.

The IACSP's A/G-BIS advertises to the airborne BIS a default route to all ATN ESs. In the opposite direction, the airborne BIS advertises to the IACSP's A/G-BIS a route to all the ATN ESs on board the aircraft which can be used for all traffic types.

The IACSP's A/G-BIS processes this route and distributes

- a route available for all traffic types to the ATC G-BIS of the Gander OACC A/G-BIS, which distributes the route according to its local routing policy,
- a route available for all traffic types to a BB-BIS of the North American Region ATN Island, which distributes the route over a BB-BIS of the European Region ATN Island to the LH RD in Frankfurt which forms the aircraft's Home.

[Ev41]: The Transfer of control from the oceanic controller in Shanwick OACC to the controller in the Gander OACC is performed in the same way as described above.

Before the Transfer of control from the oceanic controller in Shanwick OACC to the controller in the Gander OACC is executed, a NDA data link connection is established between the airborne CPDLC application and the CWP of the oceanic controller in Gander OACC. The messages for this connection are sent from the ATN ES in the Oceanic ACC (OACC) to the Gander OACC A/G-BIS, over ground links to the GES of the IACSP, via the satellite to the AES, the A-BIS and the airborne ES, and vice versa.

The G/G connection for the AIDC dialogue is established from the Shanwick controller's ES, to the A/G-BIS at the Shanwick OACC, to the UK BB-BIS, to a North American ATN Island BB-BIS, to the A/G-BIS at the Gander OACC, and to the oceanic controller's ES.

No routes are changed or distributed due to the transfer of control, as the connectivity to the aircraft still exists through the Shanwick OACC A/G-BIS and the Gander OACC A/G-BIS, over the directly attached AMSS subnetwork links.

As mentioned in section 2, the flight scenario stops at this point in time as the events and activities in the subsequent flight phases are similar to those described above. Consequently, a description of the resulting ATN operations would be a repetition of those explained before and does not help to provide further insight into ATN operation.

Appendix A - Acronyms and Glossary

Acronyms

A/G	Air / Ground
AAC	Aeronautical Administrative Communications
ACCESS	ATN Compliant Communications European Strategy Study
ACM	ATC Communication Management
ADAP	Automated Downlink of Aircraft Parameters
ADS	Automatic Dependent Surveillance
AIDC	ATS Inter-facility Data Communications
AINC	Aeronautical Industry Communications
AIS	Aeronautical Information Service
AMHS	ATS Message Handling System
AO	Aircraft Operator
AOC	Aeronautical operational control
APO	Airport Operator
APR	Automatic Position Reporting
ATC	Air Traffic Control
ATSC	Air Traffic Services Communication
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information Services
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
ATSO	ATS Organisation
ATSU	ATS Unit
CAP	Controller Access Parameter
C-ATSU	Controlling ATSU
CFMU	Central Flow Management Unit
CPDLC	Controller Pilot Data Link Communications
CWP	Controller Working Position
DAP	Downlink Aircraft Parameters
DCL	Departure Clearance
D-FIS	Datalink Flight Information System
DFS	Deutsche Flugsicherung GmbH (German ATC authority)
DLIC	Data Link Initiation Capability
DWD	Deutscher Wetterdienst (German weather services)
ES	End System
FDPS	Flight Data Processing System
FIR	Flight Information Region

G/G	Ground / Ground
GNSS	Global Navigation Satellite Systems
IACSP	International Aeronautical Communications Service Provider
ISO	International Organization for Standardization
ISP	Internet Service Provider
LH	Lufthansa
METAR	Meteorological Reports
OACC	Oceanic Area Control Center
OSI	Open Systems Interconnection
PSN	Public Switching Network
RDPS	Radar Data Processing System
SARPs	Standards and Recommended Practices
SN	Subnetwork
UACC	Upper area control center
VDL	VHF Data Link
VHF	Very High Frequency

Glossary

Administrative domain *[SSV1]:* A collection of end systems, intermediate systems and subnetworks operated by a single organization or administrative authority. An administrative domain may be internally divided into one or more routing domains.

Aeronautical administrative communication (AAC) *[SSV1]:* Communication used by aeronautical operating agencies related to the business aspects of operating their flights and transport services. This communication is used for a variety of purposes, such as flight and ground transportation, bookings, deployment of crew and aircraft or any other logistical purposes that maintains or enhances the efficiency of overall flight operation.

Aeronautical mobile-satellite service (AMSS) *[SSV1]:* The AMSS comprises satellites, aeronautical earth stations (AESs), ground earth stations (GESs) and associated ground facilities such as a network coordination center. It uses the satellite subnetwork to provide aeronautical communication services between aircraft and ground users. Technical requirements for the AMSS are contained in Annex 10, Volume III, Part I, Chapter 4. The ATN supports the packet-mode data exchange provided by the AMSS.

Aeronautical operational control (AOC) *[SSV1]:* Communication required for the exercise of authority over the initiation, continuation, diversion or termination of flight for safety, regularity and efficiency reasons.

Aeronautical passenger communication (APC) *[SSV1]:* Communication relating to the non-safety voice and data services to passengers and crew members for personal communication.

ATN Island RDC *[A203]:* An ATN Island is simply an ATN region comprising a number of Routing Domains, some of which support air/ground datalinks. The ATN Island exists for the exclusive purpose of supporting routing to mobiles.

ATS communication (ATSC) *[SSV1]:* Communication related to air traffic services including air traffic control, aeronautical and meteorological information, position reporting and services related to safety and regularity of flight. This communication involves one or more air traffic service administrations. This term is used for purposes of address administration.

Boundary intermediate system (BIS) *[SSV1]:* An intermediate system that is able to relay data between two separate routing or administrative domains (running the ISO 10747 inter-domain routing information exchange protocol).
An ATN BIS is a router whose protocol implementation is in conformance with the ATN Internet SARPs [SSV5].

Home Routing Domain *[A203]:* Aircraft for which inter-Island communications are required must have a « Home » domain. The role of the « Home » Domain is to advertise a default route to all aircraft belonging to an airline, or the General Aviation aircraft of a given country of registration. This default route is advertised to all other ATN Island’s backbone routers.

Internetwork *[SSV1]:* A set of interconnected, logically independent heterogeneous subnetworks. The constituent subnetworks are usually administrated separately and may employ different transmission media.

Mobile subnetwork *[SSV1]:* A subnetwork connecting a mobile system with another system not resident in the same mobile platform. These subnetworks tend to use free-radiating media (e.g. VHF/UHF radio, D band satellite or D band secondary surveillance radar) rather than contained media (e.g. wire or coaxial cable); thus they exhibit broadcast capabilities in the truest sense.

Mode select (Mode S) *[SSV1]:* An enhanced mode of secondary surveillance radar (SSR) which permits the selective interrogation of Mode S transponders, the two-way exchange of digital data between Mode S interrogators and transponders and also the interrogation of Mode A or Mode C transponders.

Network service access point (NSAP) address *[SSV1]:* A hierarchically organized global address, supporting international, geographical and telephony-oriented formats by way of an address format identifier located within the protocol header. Although the top level of the NSAP address hierarchy is internationally administered by ISO, subordinate address domains are administered by appropriate local organizations.

Next data authority *[SSV1]:* The ground system that provides for the establishment and maintenance of a transport connection for the purposes of conducting a CPDLC dialogue pertaining to the services of the receiving ATS unit (R-ATSU).

Relaying *[SSV1]:* The process of transferring packets across subnetworks including any necessary packet conversion.

Route *[SSV1]:* The set of addresses that identifies the destinations reachable over the router and information about the route’s path including the QoS and security available over the route.

Router *[SSV1]:* The communication element that manages the relaying and routing of data while in transit from an originating end system to a destination end system. A router comprises an OSI intermediate system and end system supporting a systems management agent.

Route Server *[A203]:* A Route Server is a system that participates in IDRP, but doesn't participate in the actual CLNP packet forwarding. A Route Server is a BIS dedicated to the processing of routes: it acquires routing information from all the BISs connected to a common WAN, performs decision process over this information, and then redistributes the results to the routers. When a Route Server acquires a route from a BIS, and passes the route to other BISs, the Route Server specifies the direct subnetwork address of the router from which the route was acquired. This way CLNP traffic bypasses the Route Server, and flows directly between the routers without going through the Route Server.

Routing *[SSV1]:* A function within a layer that uses the address to which an entity is attached in order to define a path by which that entity can be reached.

Routing domain (RD) *[SSV1]:* A set of end systems and intermediate systems that operate the same routing protocols and procedures and that are wholly contained within a single administrative domain. A routing domain may be divided into multiple routing subdomains.

Routing domain confederation (RDC) *[SSV1]:* A set of routing domains and/or RDCs that have agreed to join together. The formation of a RDC is done by private arrangement between its members without any need for global coordination.

Very high frequency (VHF) digital link (VDL) *[SSV1]:* Packet data communication to aircraft and ground users comprised of airborne VHF data radios (VDRs), VHF ground stations and connectivity to routers on the aircraft and the ground.

Appendix B - Technical Background Information on ATN Operation

The ATN is an internetwork overlaid to existing ground (packet switching) networks and mobile subnetworks. The internet routing and relaying functions are provided by the Inter-domain Routing Information Exchange Protocol (IDRP) defined in the ISO/IEC standard 10747 and profiled in [SSV5]. The main task of the IDRP in the ATN is to enable world-wide reachability between any pair of ATN systems thereby restricting the amount of routing information exchange in order to avoid overload and instability of the global ATN internetwork. The routers which implement the IDRP are called Boundary Intermediate Systems (BISs). The ATN distinguishes between BISs that are installed onboard an aircraft (A-BIS), BISs that provide connectivity over ground links only (G-BIS), and ground located BISs that provide connections both to ground located BISs and to A-BIS (A/G-BIS). Backbone BISs (BB-BISs) are dedicated G-BIS used for interconnection of larger routing regions.

BISs distribute the information about the current paths to ATN systems in a controlled manner by distributing routes. The main elements of a route are the network addresses of reachable ATN ESs (the destinations of the route), the type of traffic that is allowed to travel along this route, and the routing domains (RDs) that are to be traversed.

Processing this information, a BIS can forward a data packet (i.e. an ATN CLNP packet) towards the ATN ESs, it is destined for[22]. Based on the traffic type indicated in data packet and the local routing policy, different routes may be selected for relaying packets carrying for example ATSC or AINC traffic, even if they are destined to the same system, e.g. onboard an aircraft.

Note: An explanatory description of the terms "Administrative Domains", "Routing Domains", "Routing Domain Confederations", "ATN Island", "ATN Island Backbone", "Home Routing Domains" can be found in section 3 of [A203].

[22] Note that the direction for route advertisement is opposite to the direction for data transportation.