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Results of IDRP Large Scale Simulations

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SUMMARY

This working paper presents results of a simulation study which was part of the ATN validation activity. The objectives were to evaluate the ATN routing concepts related to the handling of mobiles, and to assess the performances of the IDRP in this context.

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1. Introduction

The modelling and simulation project presented here takes place in the frame of the ATN validation programme. It is a joint project of Eurocontrol and CENA.

A network model, called the IDRP Convergence Model has been developed using the OPNET modelling and simulation tool. The purpose of this model is to simulate the operation of the IDRP for what concerns the propagation of routes to airborne systems within the fixed part of the ATN. It implements the ATN routing concepts developed for the support of mobile systems. The simulation exercises carried out with this model aimed at:

- checking that the propagation of routes to mobiles within the ground part of the ATN converges when the ATN routing concepts specified in the SARPs are applied,

- assessing the performances of the IDRP regarding the propagation of routes to mobiles.

This working paper stresses the main results of this study, and gives an overview of the simulated conditions. For more details, such as the description of the modelling assumptions, or the different simulation scenarios which were run, it is recommended to refer to the Final Report of the IDRP Convergence Modelling Study [Ref. 5].

2. Overview of Simulation Exercises

The main characteristics of the simulation exercises carried out with the IDRP Convergence Model are summarised in this section.

2.1 Indicators of Convergence

To assess whether ATN routing concepts are valid or not, three main measurements of the performances of IDRP were defined as indicator of the routing convergence. They are:

- The **Convergence Delay**, which is the delay after which a stable state is reached for the routing information in the simulated ground network, after the operation of IDRP has been triggered by a routing event generated by the mobility of aircraft.

- The **Route Unavailability Period**, which is the period of time a route to a mobile is not available to at least one of the backbone BISs, so that during this period, the network would not be able to forward data NPDUs destined to that mobile.

- The **Route Update Rate**, which is the frequency at which each selected route to an aircraft is replaced by an alternative route to that aircraft within each router of the Backbone RDC. It reflects the stability of the route to that aircraft.

These measurements were made on the propagation of routes with the empty Routing Information Base Attribute (RIB-Att), because these routes must be supported by all the routers.

2.2 Main Input Parameters

The values of the perfomance measurements were compared for simulation runs with different input parameters. Among the selected set of input parameters for simulations, those which proved to have the greatest impact on the indicators of convergence were:

- the topology of the ground ATN network, which implicitly includes the simulated ATN transit policies,

- the value of the minRouteAdvertisementInterval timer used by IDRP instances.

The two topologies on which simulations were made are possible options for ATN implementations over the area represented by the European Civil Aviation Conference (ECAC). In both cases, the ground network consists of 27 air-ground BISs and corresponds to a single ATN Island. In the **Centralised Topology**, the backbone RDC consists of a single Routing Domain (RD), and all the other modelled RDs are off-backbone Transit Routing Domains (TRDs). In the **Distributed Topology**, the backbone RDC consists of 6 fully inter-connected RDs, and all the other modelled RDs are off-backbone TRDs.

A different transit routing policy characterises each modelled class of RDs. Off-backbone TRDs re-advertise routes to mobiles to only one adjacent RD, which is either a backbone RD, or an off-backbone TRD which is used as a next hop to the backbone RDC. Members of the backbone RDC re-advertise to each others all the routes to mobiles, but do not re-advertise them to adjacent off-backbone TRDs. Each RD in the Backbone RDC may act as the "Home" for a group of mobiles, but this is not exercised in the simulations as only one ATN Island is modelled.

Both topologies are logical topologies, not physical ones. So far, the study has not addressed any aspect related to the dependability of the networks. The modelling does not represent possible redundancies of actual links or nodes.

The effect of the minRouteAdvertisementInterval IDRP timer is to slow down the propagation of routes, when a route with the same Network Layer Reachability Information (NLRI) has already been propagated. It is important to assess the trade-off between the reduction of the generated number of route updates, and the increase of the Route Unavailability Period and of the Convergence Delay which are expected when this timer is increased.

Among other input parameters, simulation runs were carried out with varying numbers of aircraft, and different characteristics of aircraft mobility.

Regarding the number of aircraft simultaneously moving their points of attachment to the ground network, the analysis of simulations with a single aircraft proved the most significant. Indeed, with the current model it is not possible to check the influence of the number of aircraft in all the conditions. For example, there is no limitation to the capacity of the BISs in terms of the numbers of BISPDUs they can handle per unit of time, nor to the length of queues within the subnetworks or to those of the connection-less network protocol. It was thus preferred to make performance measurements on the mobility of one aircraft, with the hypothesis that measurements made on several aircraft are mostly independent.

The scenarios applied to study the operation of IDRP are not communications scenarios (i.e. exchanges of messages) but events generated by the aircraft mobility and triggering IDRP operation. These events are JOIN and LEAVE events sent by airborne BISs to air-ground BISs. They trigger the propagation of UPDATE PDUs over the ground part of the modelled ATN. The parameters of these scenarios were mostly the average duration of IDRP connections (i.e. the duration of physical adjacencies between a mobile RD, and a ground RD), and that of overlap between successive connections. All the simulation runs concerned « make before break » mobility scenarios. This ensures that there are many cases of alternative routes to a single aircraft that co-exist in the ground network for a period of time.

3. Main Results and Conclusions

3.1 Conclusions

The analysis of the results led to the following main conclusions:

1. The modelled networks always converged to stable routing patterns in which all Backbone routers can select a route to every aircraft in the simulation.
   This is a key indicator that the ATN Island architecture is valid.
2. It was verified that the routing information was correct, i.e. that in stable states, there are no false routes in any router's Loc-RIB.
3. The modification to the specification of IDRP presented in [Ref. 4] is necessary to ensure a correct withdrawal of routes in multiply connected backbone RDCs consisting of more than 4 RDs.
   Indeed, simulations showed that truncated routes may remain in the Loc-RIBs of the some backbone BISs if routes that would close a routing loop are propagated, even though they are discarded upon reception. The modification imposes to check that routes are re-advertised to an adjacent RD only if its RDI, or that of any RDC it belongs to, is not already in the RD_PATH of the route.
4. The instability is significantly worse for the topology with a distributed backbone RDC than for the centralised topology.
   It means that measured Convergence Delays, Route Unavailability Delays, and Route Update Rates are higher on the distributed topology than on the centralised topology for the same aircraft mobility scenario.
5. The minRouteAdvertisementInterval IDRP timer must be chosen strictly smaller than one minute, around 30 seconds. Higher values served only to increase the Route Unavailability Period, whilst contributing little to lowering the Route Update Rate.

3.2 Results

Simulations showed that:

The **worst performances** were measured on simulations on the distributed topology with a high value of the minRouteAdvertisementInterval timer (6 minutes), where

- the mean Convergence Delay is around 1.5 minute,
- the mean Route Unavailability Period is around 2.5 minutes,
- the mean Route Update Rate is less than 6.10^{-3} updates per second.

The **best performances** were measured on simulations on the centralised topology with the reference value of the minRouteAdvertisementInterval timer (1 minute), where

- the mean Convergence Delay is less than 2 seconds,
- the mean Route Unavailability Period is around 0.14 seconds,
- the mean Route Update Rate is around than 3.10^{-3} updates per second.

For the simulated mobility scenarios, the mean numbers of **received as well as transmitted UPDATE PDUs per second by each backbone BIS** range between **$2.7*10^{-3}$** and **$8.2*10^{-3}$** per aircraft in the scenario. As routes to the different mobiles are not aggregated, these figures are to be multiplied by the number of aircraft to account for more that one aircraft connected to the ground systems. For backbone BISs in the distributed topology, the numbers of transmitted and received PDUs are almost equal. This is due to the fact that the exchanges of UPDATE PDUs within the backbone are pre-dominant over routes received or withdrawn by BISs adjacent to the backbone RDC.

The figures 1 and 2 illustrate the influence of the value of the minRouteAdvertisementInterval ("Tma") on the performances of IDRP measured for the same aircraft mobility scenario on the Distributed Topology. The notation "i,jEn" on the ordinate axis must be understood as "i.j*10^n"

Delays measured in seconds are presented in Figure 1 : CD is the Convergence Delay, and RUP is the Route Unavailability Period.

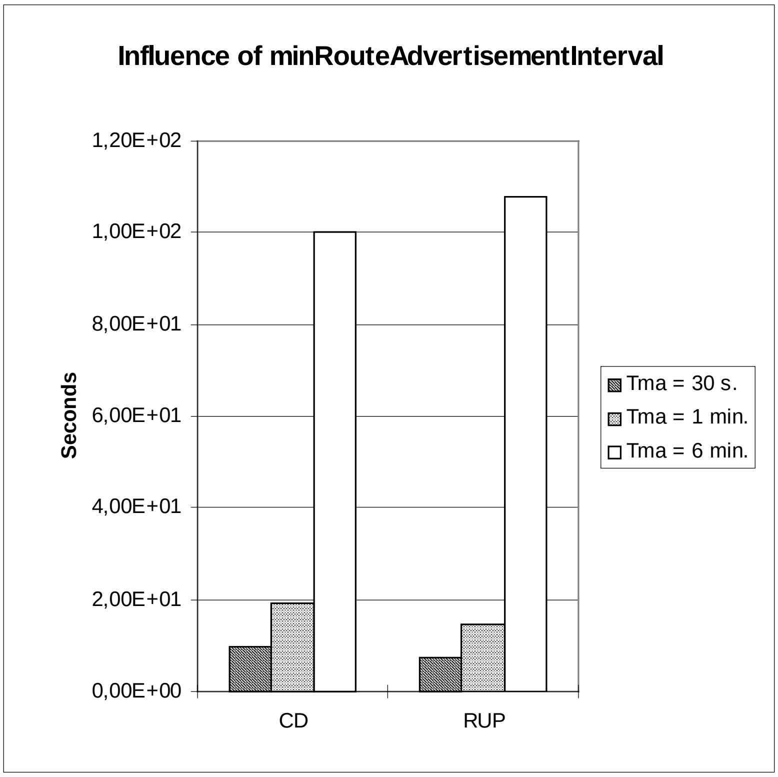

Figure 1 : Influence of Tma on Convergence Delay and Route Unavailability Period

The Figure 2 presents the mean Route Update Rate (RUR) in number of route updates (i.e. selection of a new route) per second, and the mean number of UPDATE PDUs received ("PDU in") and transmitted ("PDU out") per second by the backbone BISs.

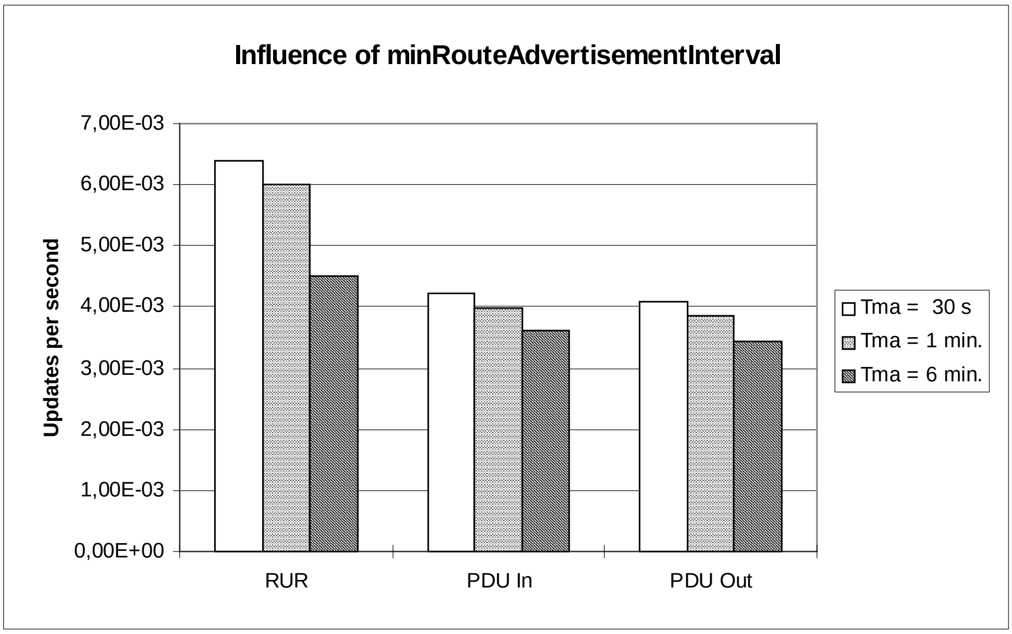

Figure 2 : Influence of Tma on Route Update Rate, and number of received and transmitted UPDATE PDUs per second

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5. Glossary

ATN Aeronautical Telecommunication Network

BIS Boundary Intermediate System

ECAC European Civil Aviation Conference

IDRP Inter-Domain Routing Protocol

ISO International Standards Organisation

PDU Protocol Data Unit

RIB Routing Information Base

RIB-Att Routing Information Base Attribute

RD Routing Domain

RDC Routing Domain Confederation

RDI Routing Domain Identifier

TRD Transit Routing Domain