Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

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an HLA based approach

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Summary

Traditionally the Flight Simulation Department of the National Aerospace Laboratory NLR is strong in high fidelity human-in-the-loop flight simulation. In order to open up more possibilities for NLR flight simulators as participants in networked simulation exercises, NLR started the project MAPLESIM. During the first part of this project a high-performance network has been created between several of NLR's military flight simulations in combination with computer generated forces using the simulation package ITEMS. This network makes use of NLR's deterministic reflective memory network (SCRAMNet) for real-time distribution of the critical data. This enables data to be distributed at high rates (50 Hz). The next step in this project is a connection between this high performance network and "external" simulations. Two different approaches are followed to realise this connection with the outside world. The first has been a DIS(Distributed Interactive Simulation)-based connection. This DIS gateway has been developed in the summer of 2000. For the second gateway to external simulations an HLA (High Level Architecture) protocol interface unit will be developed. This will make it possible to integrate the NLR simulation environment into a complete synthetic environment, together with Command & Control systems, tactical wargaming tools and exercise observation and evaluation tools. SmartFED, an in-house developed tool that facilitates that proprietary simulators at various geographic locations participate in a joint simulation, will control this environment.

Contents

(18 pages in total)

1 Introduction

The National Aerospace Laboratory NLR operates at its Amsterdam establishment a versatile flight simulation facility for research in various areas. This is a high-quality modular research and development facility, capable of simulating both fixed-wing and rotary-wing aircraft. It is used in military and civil research programmes for national and international customers.
NLR's research flight simulation facility consists of a set of advanced hardware and software components, structured in a modular fashion to allow virtually any vehicle to be simulated. The simulator equipment consists of many modules, such as cockpits, visual, motion and computer systems, and a large set of simulation software modules and tools. The simulator's modular and versatile set-up enables efficient interchange of aircraft models, environment models, equipment, etc.

The NLR Flight Simulation department currently operates the following flight simulators:

- The National Simulation Facility (NSF), primarily assigned to military simulation projects (F-16MLU, helicopter etc.) mounted on a six degrees-of-freedom (6-dof) motion platform.
- The Research Flight Simulator (RFS) with a generic dual pilot cockpit for civil simulation projects mounted on a four degrees-of-freedom motion platform.
- Two fixed-base Pilot Stations (currently fighter and helicopter, see Figure 1).
- AIRSIM, a civil aircraft desktop research flight simulator.
- AVIATOR, a fighter aircraft desktop flight simulator.

Beside these flight simulators NLR operates some additional sophisticated simulations, such as an ATC research simulator, the Traffic Manager, and the scenario generator ITEMS. This opens up possibilities to integrate these NLR simulations into a complete, flexible synthetic environment, perfectly suited for research to distributed simulation techniques, distributed mission training and simulation based acquisition.

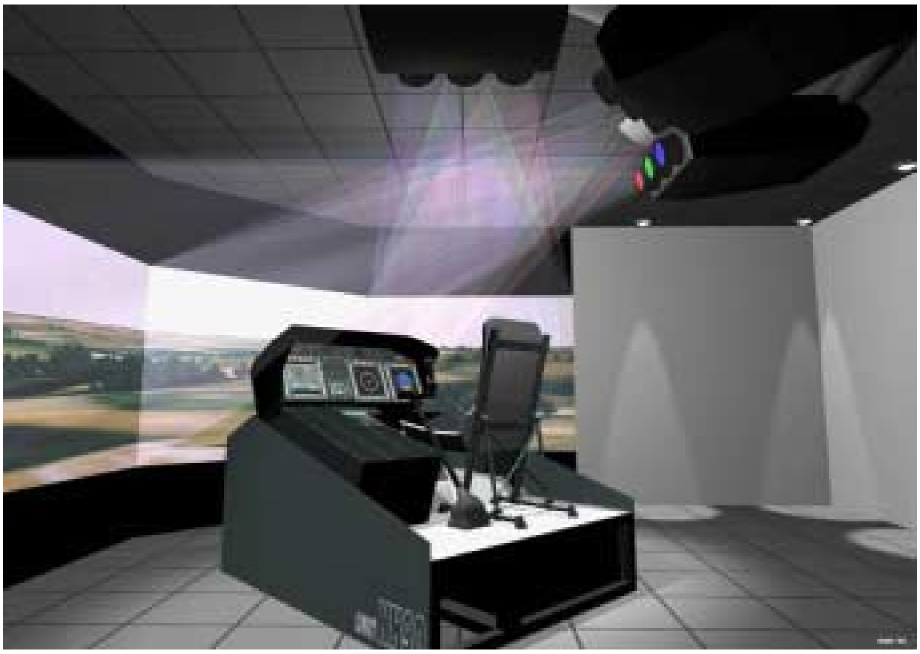

Figure 1: NLR Fixed-base Pilot Station

Therefore the MAPLESIM project was started. During the first part of this project a high-performance network has been created between several of NLR's military simulations in combination with computer generated forces (CGF) using ITEMS. This network makes use of a deterministic reflective memory network (SCRAMNet) for real-time distribution of critical data. This enables data to be distributed at high rates (50 Hz) to allow not only Beyond Visual Range (BVR) operations but especially Within Visual Range (WVR) operations such as dog-fighting, formation flying and Close Air Support. The second part of the project is a gateway to external simulators and simulation environments. Two different approaches have been determined. First a DIS gateway has been developed and second an HLA protocol interface unit will be created. In the last part of the project we will derive guidelines in order to make a choice between the different solutions for projects making use of a distributed synthetic environment.

In the first section of this paper we briefly outline the technical issues of the National Simulation Facility NSF, the computer systems and the high-performance network. We then describe the objectives and approach to set-up a high-performance network of our military simulation facilities and shortly describe the implementation of the DIS gateway. Next, the design and implementation issues of the HLA protocol interface unit will be outlined. Finally the lessons learned and the next phase of the MAPLESIM project, guidelines for use of the different simulation environments, will be discussed.

2 National Simulation Facility

The National Simulation Facility (NSF) is a six degrees-of-freedom (dof) motion platform simulator with a dome projection visual system, see Figure 2. It uses a three-channel ESIG-3000 computer image generator; two channels are used for the Out-of-the-Window scene and one for sensor displays such as IR and radar. A head-tracked projection system is mounted inside the 17-ft dome, which gives a total possible Field of Regard of nearly 360°. The head-slaved image consists of an oval background Field of View of 140° horizontal by 110° vertical, in the centre of which is a high-resolution inset with a Field of View of 50° horizontal by 35° vertical. The 6-DoF synergistic motion platform is characterised by a high bandwidth (45 degrees phase lag at 4 Hertz) and movements of ±29° in pitch, ±30° in roll, ±41° in yaw, total 2.1 m heave, ±1.4 m sway and +1.7/-1.3 m surge. The high-frequency response makes this system well suited for fighter and helicopter applications.

Figure 2: National Simulation Facility

A multi-processor Silicon Graphics Challenge computer functions as the simulation host. Simulator systems are connected via Ethernet or via SCRAMNet. Ethernet has a gross throughput of 10 Mbits/second and is used as a cost effective communication media for computers that generate graphic displays. With a throughput of 6 Mbytes/sec SCRAMNet is used for connecting more demanding simulator systems. Figure 3 gives an overview of the Simulator systems and their connection.

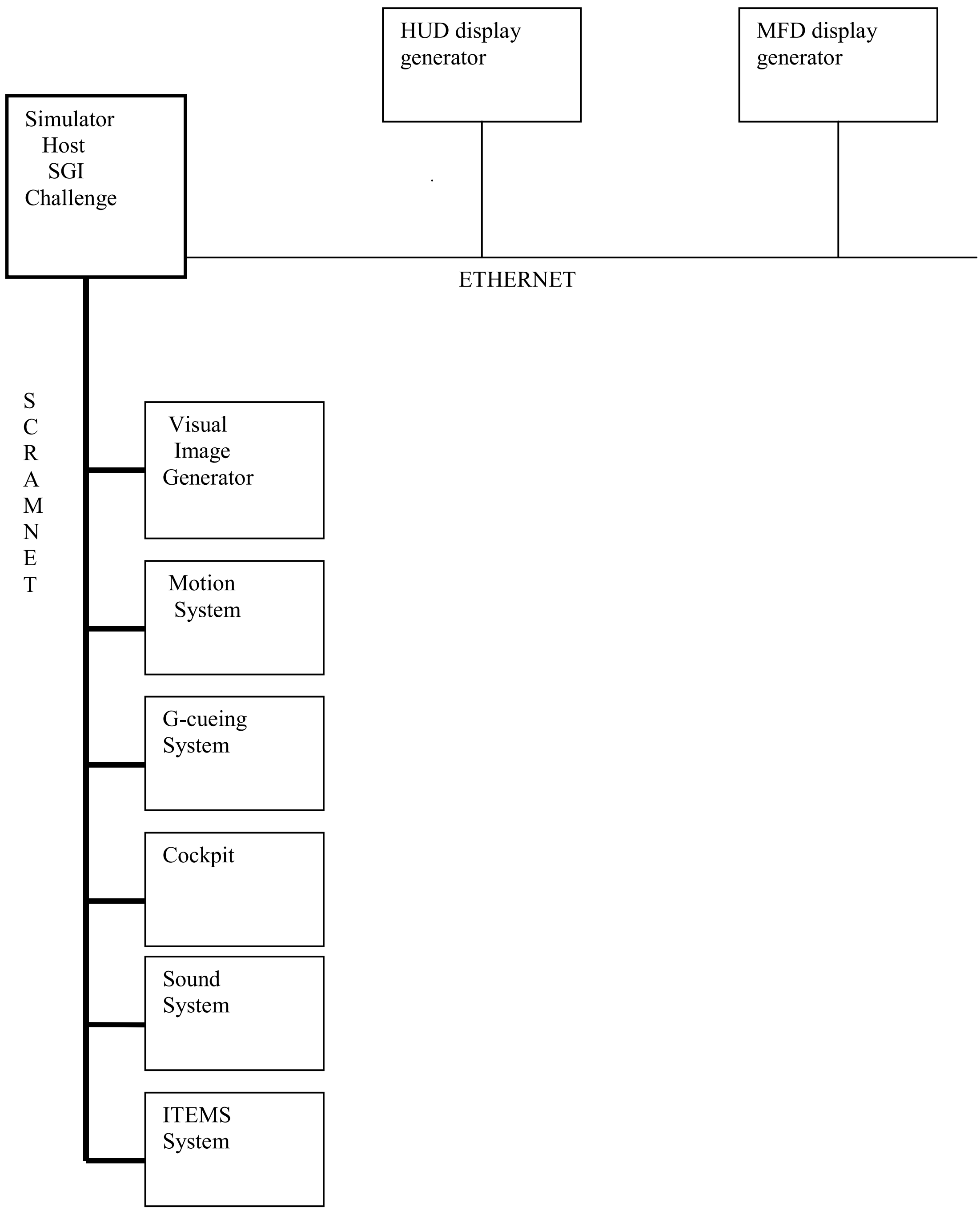

Figure 3: NSF simulation systems

3 The project MAPLESIM

3.1 Phase 1: a high-performance internal network

3.1.1 Objectives

In order to expand the versatility of NLR's Flight Simulators, especially in networked simulation scenario's, the MAPLESIM project was started in 1998. The main objectives are to couple NLR's Fighter Aircraft simulators in such a way that even the most demanding Within Visual Range scenario's can be demonstrated. Also the coupling will act as a baseline for future work and to which "external" simulations can be coupled using DIS, HLA and other (dedicated) distributed simulation technologies.

3.1.2 Simulation Architecture

The participating NLR simulators in the first phase of the MAPLESIM project are:

- NSF full mission simulator in F-16 MLU configuration
- Fighter Pilot Station, fixed base F-16 simulator
- AVIATOR, desktop based F-16 simulator
- ITEMS for computer generated players (CGF).

These simulators are all located at one site and have been linked together for this project.

The decision was soon made to exchange data between the simulators through one datapool and to distribute this datapool over the simulators. Also several internal simulation modules in each simulator make use of this datapool. Use of one central datapool assures modularity. Preparations for and first implementations of this datapool started already in 1996. Basically the datapool comprises of blocks of variables that need to be shared amongst simulators and simulation modules. Conversion routines are added to close the gap between suppliers of data and the consumers of the data, whom often need the data in slightly different form or units. Next mechanisms and agreements are included on who is allowed to deliver or modify data in the datapool and also when. Together we call these the MEID (Mission Environment Interface Driver). Figure 4 gives an overview of the architecture. The implementation and performance of this architecture has been described in [Kuiper00].

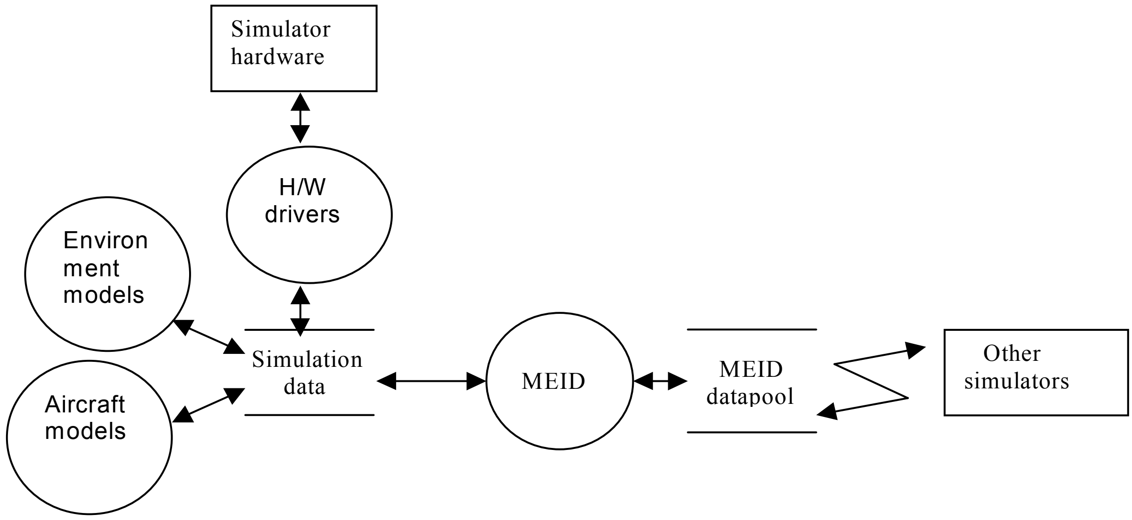

Figure 4: Simulation Architecture

3.2 Phase 2: Gateway to external simulation networks

The next phase of the MAPLESIM project is the development of a gateway to external simulation networks, which will be connected to the central datapool MEID. This phase started in the beginning of 2000 the design and first implementation of a DIS interface. The implementation of this interface has been finished in the summer of 2000. In the beginning of 2001 a start has been made with the design and implementation of an HLA interface. In the next paragraphs the main design and implementation issues of these interfaces are discussed.

3.2.1 Objectives

The main objective of this phase is to develop a gateway to external simulations in a way that the NLR simulation facilities can take part in distributed simulation exercises. Due to the current use of different methods for networking simulators (DIS, HLA) the gateway must be compliant to the most common networking protocols (DIS, HLA) and must be extensible for future methods. In this way the interface can be adapted to different requirements for specific purposes of the simulation exercises. For example closely coupled simulation is required for Within Visual Range (WVR) operations while Beyond Visual Range (BVR) operations can be operated with loosely coupled simulations. This will lead to different requirements for latency and that can influence the choice of the networking protocol.

3.2.2 Design issues

One of the major requirements for the design of the DIS interface was that in a later phase of the project the simulation environment must support both the DIS gateway and the HLA architecture. This leads to the requirement that the DIS gateway must be extendible to HLA with a minimum of effort and without significant modifications.

The proposed solution was to split up the gateway into two separate subsystems. The first will keep the simulation application away from the underlying communication infrastructure and will provide the application programmer with an easy-to-use interface. This saves instructions of DIS and HLA techniques to the application programmers, mostly people who are specialised in aeronautical instead of network engineering. The second subsystem will be an object-server. This object server is responsible for the exchange of object and event information with other simulation applications.

The first subsystem, called DISCOM, is a protocol-independent layer that provides an interface to the simulation application. It reflects the up-to-date status of the simulation objects and events and it contains the current status of all simulation objects and events in the simulation application. It gathers the data from FORTRAN COMMON blocks. This simulation application can be one of the NLR simulations but also the whole high-performance network of NLR simulations. In this first case these blocks were part of the MEID datapool and the application was the National Simulation Facility.

The data from the MEID datapool will be converted to the right format for filling the DIS PDU parameters. This information will be stored in structs. These structs will contain exactly the information of a specific DIS PDU. These structs will be the input for the second subsystem, the object server.

For this subsystem the choice has been made to make use of the COTS tool VR-Link release 3.4 of M K Technologies. VR-Link is an object-oriented library of C++ classes, functions, and definitions that minimise the effort required creating networked simulators [VR-Link99]. VR-Link contains a protocol-independent API referring to a set of classes that allows the user to create an application that will work in both DIS and HLA without significant modification. This means that later the DIS implementation can be upgraded to an HLA interface with minimal effort.

This leads to the structure given in Figure 5.

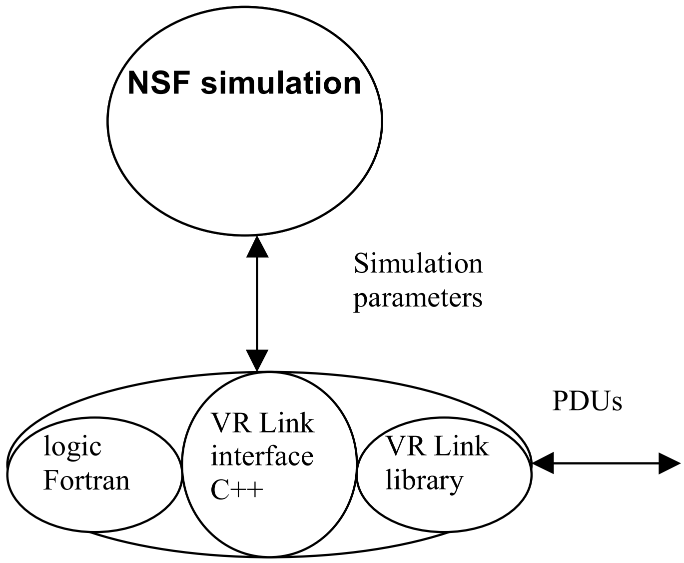

Figure 5: Structure DIS interface implementation

At this moment a subset of the PDUs from the DIS 2.0.4 standard [IEEE1278] have been implemented. The following PDUs can be issued by DISCOM: Entity State PDU, Fire PDU, Detonation PDU, Electromagnetic Emission PDU and the Comment PDU. Only the project relevant fields of the PDUs (i.e. this is the information which is available in the current simulation application) will be filled, but this can be expanded in a simple way.

The next step in the project was to build a first implementation of an HLA gateway. To have the same functionality (data exchange) as for the DIS gateway, the RPR (Real-time Platform Reference) FOM has been chosen as the Federation Object Model (FOM). The RPR FOM [RPRFOM99] is a reference FOM to facilitate a priori interoperability among HLA simulations to about the extent the DIS standard provided.

In figure 6 an outline of this gateway is presented. VR-Link has built-in support for the RPR FOM. With this functionality only small modifications have to be made to develop an HLA application. One of the major modifications that has to be made is due to the different way objects are identified in DIS and HLA. In DIS, entities are identified by a triplet (site:application:entity) that is unique in the DIS exercise. In HLA, all objects have an object handle and an object name. The object handle is an integer that an application uses to identify a particular object in RTI service calls. An object handle is meaningful only to a particular federate and this object can be known to different federates by different object handles.

This HLA implementation is able to send and receive the same data as the original DIS gateway. This data is at this moment a subset of the RPR FOM. There are no constraints to extend this gateway to the complete RPR FOM, however this is only useful if the simulation application, the federate, can provide and handle all this data.

One of the reasons for using HLA instead of DIS is the possibility and flexibility to extend the contents of the sent data beyond the RPR FOM functionality. For this specific data a second subsystem beside DISCOM has been developed (see Figure 6). This application is part of the protocol-independent layer and provides an interface for the HLA specific data to VR-Link.

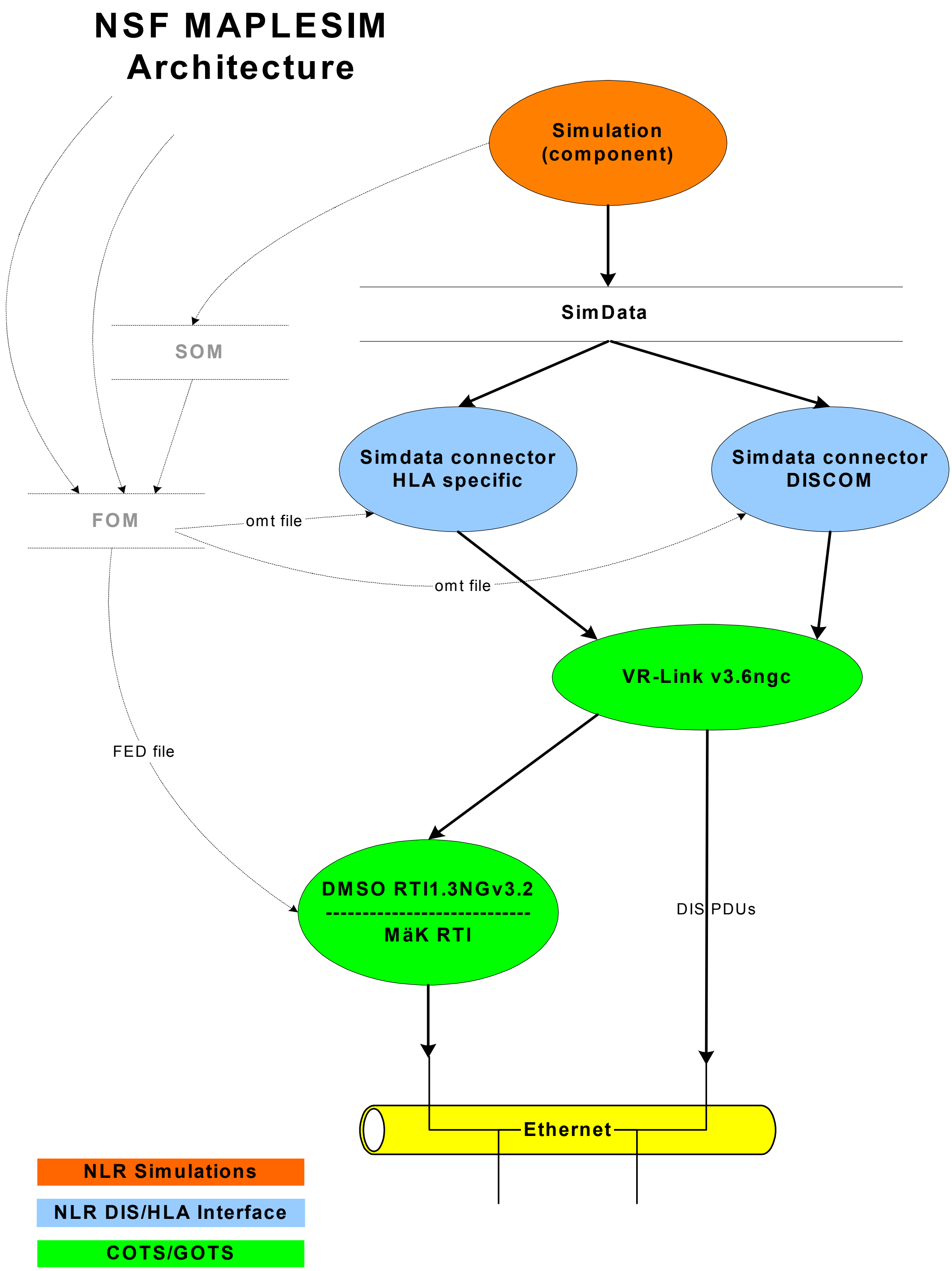

Figure 6: NSF MAPLESIM Architecture

Real-time performance is one of the most demanding characteristics of high-fidelity fighter simulations. For this reason latency is a key issue for the NSF MAPLESIM architecture. The first implementation of the HLA gateway will therefore make use of the M K RTI 1.3.1, because this RTI has much lower latencies than the DMSO RTI-NG [Burks01]. However the M K RTI implements only a subset of the HLA Interface Specification and the attribute size is limited. The implemented services are: Federation Management, Declaration Management, Object Management and Ownership Management. Data Distribution Management (DDM) and Time Management services are not supported.

At this moment it is not possible to use the M K RTI and the DMSO RTI in the same HLA federation. Due to the fact that many organisations work with the free available DMSO RTI, also an implementation has been developed for the DMSO RTI1.3NGv3.2. The latency of this first, rather simple implementation is significantly larger than the M K RTI implementation and it is at this moment not acceptable for closely coupled real-time fighter simulations. At the other side the DMSO RTI has implemented all the HLA Management services and usage of Data Distribution Management could give a significant performance boost [Lorenzo01].

The SmartFED tool-suite [Keuning01] will be used for the distributed exercise management. At present the SmartFED tool-suite consists of three distinct tools: a federation manager tool, a federation monitor tool and a scenario definition and execution manager tool. The SmartFED federation manager provides central control over the distributed real-time simulation. The SmartFED federation monitor provides information about simulation objects within an entire federation. The scenario definition and execution manager has two tasks: scenario definition and scenario execution. The scenario definition component enables the user to specify a scenario prior to simulation execution and gives the user the possibility to play predefined training exercises. The scenario execution manager component supports this capability by allowing the exercise manager to generate events that are defined in the FOM.

4 Conclusions and lessons learned

- The high-performance network of NLR’s simulations has been expanded with a gateway to external simulation networks. This gateway has been realised for both the DIS protocol and HLA. This gives opportunities for the NLR Flight simulation facilities to take part in distributed simulation exercises.
- The gateway exists of two subsystems: a protocol-independent layer and an object server. The protocol-independent layer keeps the application (aeronautical) programmers away from the, for them unfamiliar, DIS and HLA techniques. For the object server the COTS tool VR-Link of M K Technologies has been used.
- An implementation has been developed for both M K RTI and DMSO RTI1.3NG. M K RTI has better latency characteristics, but only subset of HLA services implemented. Latency of DMSO RIT1.3NG is still a problem for closely coupled simulation, but significant improvement can be expected by the usage of DDM. With these RTI options the HLA interface can be tailored to the meet the different requirements of the distributed exercises.
- Use of SmartFED tool-set for automated exercise management. This proves to be a useful tool-set in setting up distributed simulations.

5 Future work

The next activities in the MAPLESIM project will be an effort in testing and measuring the latency and performance of the RTI implementations in varying conditions. Also tests to extract the requirements for the bandwidth of the network in these conditions will be performed. Also some experiments will be executed to investigate the benefits of this implementation for the internal simulator architecture. Several components will be separated and will communicate via this distributed architecture with the other parts of the simulator. This will enlarge the possibilities for reuse of simulator components like weapon models, avionics models, radio, etc. From the results of these tests guidelines will be derived to indicate which technique and implementation is best for which type of simulation and which type of components can be used in this distributed environment without any significant loss of fidelity, functionality or performance.

Future research is foreseen to investigate the benefit of data distribution management and time management services in order to optimise the network communications. Other investigations will be performed to the suitability to expand this architecture to NLR’s civil simulations. This will connect the major NLR traffic research simulation facilities including the NLR Air Traffic Control and Tower (NARSIM/TRS) and the NLR Research Flight Simulator (RFS) on the ground side as well as the NLR Cessna Citation II Laboratory Aircraft on the airborne side.

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Abbreviations

API	Application Protocol Interface
ATC	Air Traffic Control
BVR	Beyond Visual Range
CGF	Computer Generated Forces
COTS	Commercial Of The Shelf
DDM	Data Distribution Management
DIS	Distributed Interactive Simulation
dof	degrees-of-freedom
FOM	Federation Object Model
GOTS	Government Of The Shelf
HLA	High Level Architecture
MEID	Mission Environment Interface Driver
MLU	Mid-Life Update
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium
NSF	National Simulation Facility
PDU	Protocol Data Unit
RFS	Research Flight Simulator
RPR FOM	Real-time Platform Reference FOM
RTI	Run-Time Infrastructure
TRS	Tower Research Simulator
WVR	Within Visual Range