The Simulation of the VAPS XT Cockpit Display and Control System Based on the Integrated Data Distribution Network

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Abstract—**Focus on the problems existed in the topologies of the traditional VAPS XT cockpit display and control, we propose the simulation of VAPS XT cockpit display and control system based on the integrated data distribution network in this paper. This simulation uses the integrated data distribution network replacing the nCom communications network. By using this method, we can separate the business logic and the data communications mechanism of the simulation modules. Therefore, each simulation module only has to interact with the data distribution network. And the data distribution network transfers data with the VAPS XT simulation software by the nCom data communications gateway. It is demonstrated that this is an efficient way to reduce the programming work of the nCom communications and improve the scalability and flexibility of the Cockpit display and control simulation system.**

Index Terms—**Cockpit display and control system, data distribution network, VAPS XT.**

I. INTRODUCTION

The cockpit display and control system is the HMI (human machine interface) of avionics system of the aircrafts. It is in charge of centralized display and mission management of the human-machine interaction information. The avionic systems of newly developed aircraft platforms are demanded to be a fully integrated avionics system of enhanced functions supporting the operator for successful mission operations [1]. The avionics system is the significant component of the aircraft design. The complexity and information comprehension of the modern avionics system have been increased greatly [2]. The goal of advanced cockpit display systems is to present large amounts of information quickly and in an understandable format, enabling the aviator to improve the mission performance [3]. It may be possible to extend that efficiency to lower weather conditions if pilots are able to perform the same separation tasks by reference to a Cockpit Display of Traffic Information (CDTI) in lieu of visual contact out-the-window (OTW) [4]. Therefore, the design of this system will affect the judgments and decisions made by the pilots, as well as the appropriate operation. The traditional design cannot realize the centralized data management and all the modules have to develop the nCom communication interfaces. The simulation of VAPS XT cockpit display and control system based on data distribution

network links the distributed simulation computers, nCom gateway and VAPS XT simulation nodes by the gigabit switch. The network nodes deploy the DDS environment, realizing the integration, binding and code generation of data and display elements through the nCom gateway code generation software. By this way, the simulation system can get the better management and increase the scalability and flexibility.

II. COCKPIT DISPLAY AND CONTROL SIMULATION TECHNOLOGIES

A. VAPS XT HMI Development Tool

Using the assembly language, C language and OpenGL to implement the software of the cockpit display and control system will lead to the large amount of coding work and low efficiency. Otherwise, the use of sophisticated graphical development tools of HMI software design will improve development efficiency and greatly reduce the programming work.

VAPS XT is a full-featured and advanced software tool for the rapid development of dynamic, interactive graphical interfaces for safety and mission-critical avionics and embedded displays. VAPS XT simulation tools will fundamentally change the development process of human-machine interface, and can reduces the design costs and shortens the design cycle [5]. VAPS XT offers unparalleled control and flexibility in the design of dynamic, interactive, real time HMI. It is widely used in the complicated development of cockpit display and control system, auto meter display panel, communications products display screen and so on. Meanwhile, it is ideal for the design of all types of embedded display graphics ranging from digital and analog instrumentation to next-generation menu-based displays. Users can build the customized electronic instrumentation graphics by VAPS XT, set the corresponding behaviors to complete the fast prototype design and implement the external data connection through data communication mechanism. Since VAPS XT is the only embedded graphics tool that allows users to define both object appearance and display logic in one easy graphical editor, it is now widely used in the aviation instrumentation and auto instrument industry.

Working together and using the automatic code generator CODE nGEN – developers and Human Factors Experts can define the look and feel of an object or group of objects, assign behavior, and subsequently generate a stand-alone executable of their applications. Through a flexible porting

approach, VAPS XT applications can be easily deployed to virtually any embedded target with excellent performance [6].

B. Simulation of Cockpit Display and Control System

Build a display interface simulation system interface to digitally simulate the HMI can evaluate and test at the design phase [7]. After a satisfied result, the developers will begin the detailed design of hardware and software, which can reduce design costs and shorten the design cycle.

The cockpit display and control system receives and displays the real-time status of various types of airborne devices. Meanwhile, it should also response to the pilots' operations to realize the control of the avionics system. Therefore, the simulation of cockpit display and control system not only contains the VAPS XT simulation design but also the simulation modules of all the avionics subsystems.

C. Data Distribution Network

The information network is an important carrier of application data transfer. According to difference of business and application, the data stream represents the significant convergence. However, the traditional information network is only used as a data transmission channel, which owns the static path, speed, quality and other characteristics. So that it is unable to adapt initiatively of the changes for the network data stream convergence. Building a data distribution network with intelligent management capabilities can improve the efficiency of the information application for the whole network.

The middleware is currently one of the key technologies to achieve transparent access for the heterogeneous systems. It shields the differences of the hardware environments, operating systems and programming languages among the distribution systems. The current middleware technology faces the new challenges in the avionics systems: real-time, reliability, and dynamical expansibility. However, the traditional middleware, for example CORBA (Common Object Request Broker Architecture), cannot handle these problems. Therefore, OMG (Object Management Group) published DDS (Data Distribution Service for Real-time Systems) in 2004 to define a series of standard interfaces and behaviors for the DDS middleware. The DCPS (Data-Centric Publish-Subscribe) provided a data distribution model which is platform independent. Meanwhile, DDS is also strongly concerned about the support of QoS (Quality-of-Service), which defines a lot of QoS policies so that can make DDS better allocation and utilization of system resources, balance the predictability and execution efficiency, as well as support for complex data stream requirements [8].

D. Traditional VAPS XT Simulation of Cockpit Display and Control System

In the simulation of the cockpit display and control system, the simulation data communications network design is the key. VAPS XT supports three types of network communication protocols: TCP/IP, UDP/IP and shared memory. And it provides a communication tool library called nCom to apply for the development of VAPS XT simulation and external communication program.

The topology of the traditional VAPS XT cockpit display and control simulation system is shown in Fig. 1. The

topology is simple in the network structure and can achieve the fast generation of small-scale simulation system. Each avionics subsystem simulation model develops the nCom communications module to communicate with VAPS XT simulation software. The nCom can be realized by TCP, UDP or shared memory so that can support to build the network connection among the modules of the different terminals.
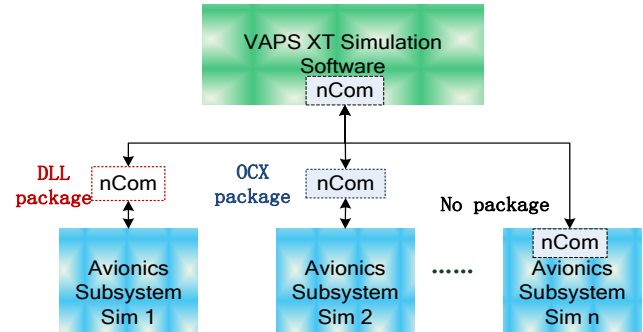

Fig. 1. Topology of the traditional VAPS XT cockpit display and control simulation system.

When each simulation model establishes the nCom connection and communications, it will usually separate the business logic related processes from the unrelated processes and partly package the nCom in order to reduce the coupling and unnecessary dependencies among modules. Since the avionics modules are made by different companies, the packaging processes may be very different. The nCom communication tool library is a set of C ++ library.

Based on the analysis above, the topology of the traditional VAPS XT cockpit display and control simulation system exists the following problems:

1) Each simulation module communicates with the VAPS XT independently so that it is no good for the centralized data management;
2) Each simulation module has to develop the nCom which costs the repetitive work. Meantime, every module is implemented by different forms resulting the difficult module management;
3) The simulation system has a poor scalability and flexibility. When the HMI development tool changes, all the simulation modules have to make the corresponding modification.

III. COCKPIT DISPLAY AND CONTROL SYSTEM SIMULATION BASED ON THE INTEGRATED DATA DISTRIBUTION NETWORK DESIGN

A. DDS Network

OMG released DDS as a standard of the data distribution in the real-time systems. It is the publish/subscribe communications model centered on the data and standardizes the interfaces and behaviors of data release, transmit and receive in the real-time distributed system [9]. Compared with the traditional TCP/IP protocol, DDS middleware helps to shield many basic problems in network communications and reduce the period from design to simulation [10].

The application programs can use a topic name to specify the wanted DDS network data and read/write data directly by the DDS function interfaces.
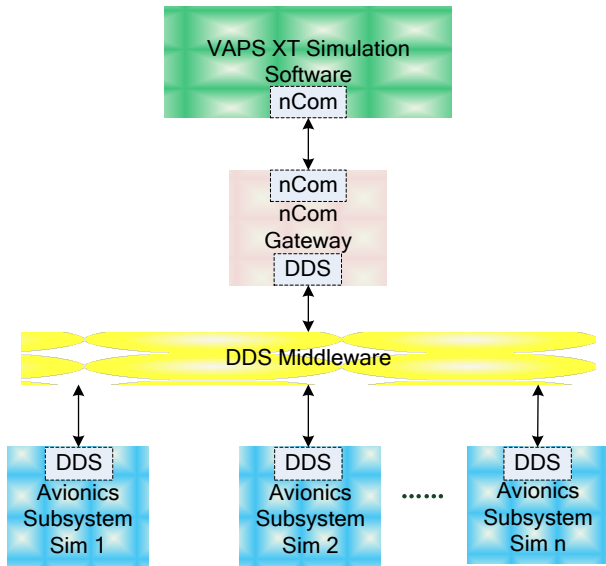
Fig. 2. Topology of the VAPS XT cockpit display and control simulation system based on DDS.

The topology of the VAPS XT cockpit display and control simulation system based on DDS is shown in Fig.2. The uplink communications data flow from the avionics subsystems to the VAPS XT software is:

1) Each simulation module releases data to the DDS network by the certain DDS Topic through the DDS interfaces;
2) The nCom gateway assigns the DDS topics of subscribed data to achieve the data read/write;
3) The nCom gateway sends data to VAPS XT simulation software via the nCom interfaces.

The downlink communications data flow from the VAPS XT software to the avionics subsystems is:

1) VAPS XT sends the data to the nCom gateway through nCom interfaces;
2) The nCom gateway releases data to the DDS network by the assigned DDS topics;
3) The simulation modules assign the DDS topics of subscribed data to achieve the data read/write.

The establishment process of the nCom connection and communications of the nCom gateway is shown in Fig. 3.

1) Build nCom connection manager, transmitter and receiver

nCom gateway needs to define 3 objects: connection manager, transmitter and receiver.

2) The nCom connection manager establishes the connection.

The connection manager loads the configuration files and establishes the connection. When design the display and control interface, the configuration files is produced by VAPS XT software, including connection name, type (TCP/UDP/Shared Memory) and so on.

3) nCom transmitter initialization

nCom transmitter sends data of nCom gateway to VAPS XT simulation software. During the initialization, the loaded output data description files are made by VAPS XT.

4) nCom receiver initialization

nCom receiver receives data sent by VAPS XT simulation software to the nCom gateway. During the initialization, the loaded input data description files are made by VAPS XT.

5) nCom receiver receives data

The receiver begins to receive data when the VAPS XT simulation software sends data. And nCom gateway receives data passively.

6) Transmission to the data distribution network

nCom gateway inquires the modules addresses from topic subscription list according to the topics of the data waiting to be sent. Then it sends data to the simulation modules based on the addresses.

7) Receive data from the data distribution network

nCom gateway receives data from the topic buffer according to the unique number in a fixed period.

8) nCom transmitter sends data

After receiving data from the data distribution network, the nCom gateway calls the transmitter to send data to the VAPS XT software.
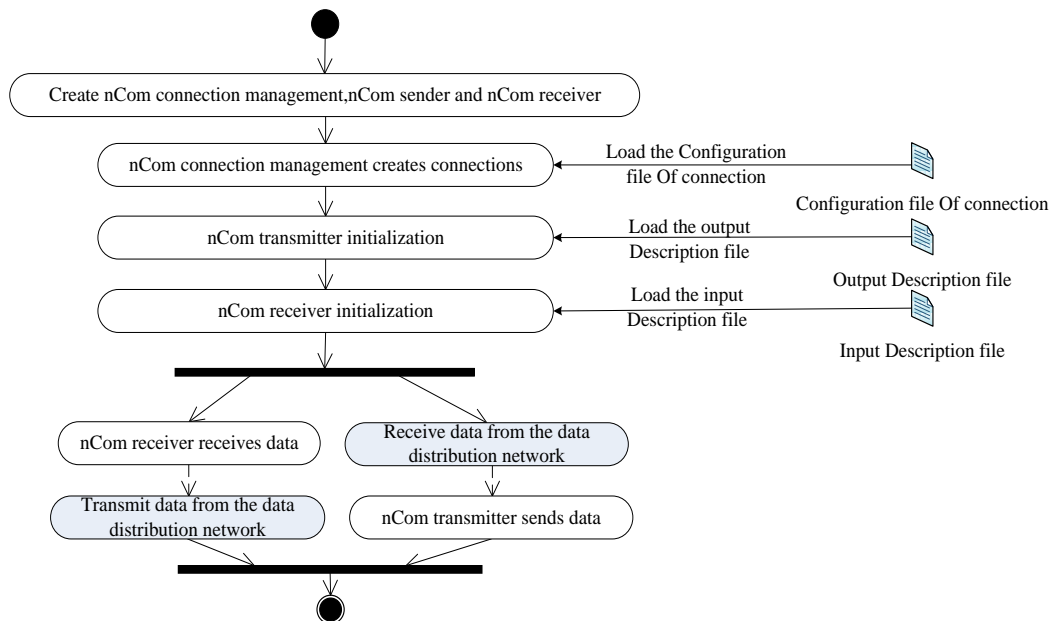

Fig. 3. General process of building the nCom connection.

B. nCom Gateway Code Generation Software Based on the DDS Middleware

We developed the nCom gateway code generation software based on DDS, which supported binding the data of simulation modules sending or receiving from DDS with the display factors generated by VAPS XT using graphically design. By this way, the code can be generated automatically.

The process of the implementation is:

1) The developers use VAPS XT software to develop the display and control system and generate the connection configuration files as well as the I/O data description files;

2) nCom gateway code generation software resolves the connection configuration files and the I/O data description files. Then it collects the elements to display, such as altimeter height indicator, heading device and so on;

3) The avionics subsystems simulation modules save the data in XML format interacting with VAPS XT simulation software;

4) nCom gateway code generation software resolves the XML files of all the simulation modules and displays the exchanged data between all the modules and the VAPS XT simulation software, such as the height data of the Air Data Computer module, longitude/altitude of the Navigation module and so on.

5) Bind the elements of display and control interface with the simulation modules through the nCom gateway code generation software;

6) nCom gateway code generation software generates the data exchange code with the VAPS XT and DDS network according to the standard nCom and DDS communication interface. It assigns the modules data to the interface elements based on the binding information or assigns to the modules data source code from the interface elements.

7) The source code generated by the nCom gateway code generation software contains many .h files and .cpp files, as well as a makefile file of the windows console program. It compiles and links to the nCom tool library of VAPS XT and DDS communications function library.

8) nCom gateway receives and sends data from the DDS network. Then, it calls the nCom interface function to achieve the data exchange between VAPS XT and simulation modules.

IV. IMPLEMENTATION

According to the design of the cockpit display and control simulation system, the realization contains three parts. They are VAPS XT design, nCom gateway development and the avionics subsystems modules design.

A. VAPS XT Design

Use VAPS XT software to design and develop the cockpit display and control interfaces, including PFD (primary function display) and MFD (multi-function display) and the connections with the corresponding output data from the nCom gateway. The PFD and MFD design interfaces are shown by Fig. 4.
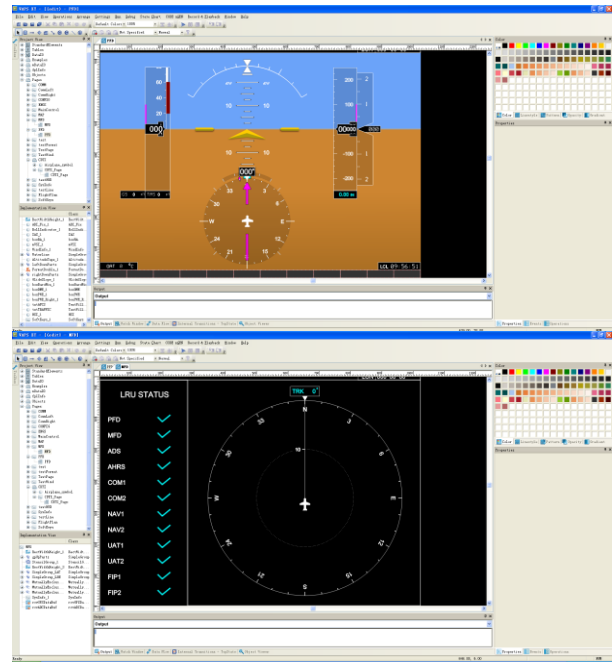

Fig. 4. PFD and MFD design interfaces.

The VAPS XT defines many data buffers corresponding to the interfaces elements. Mapping the output data from the nCom gateway with the interfaces elements is the key for the cockpit display and control development. The data connection approach is shown by Fig. 5.
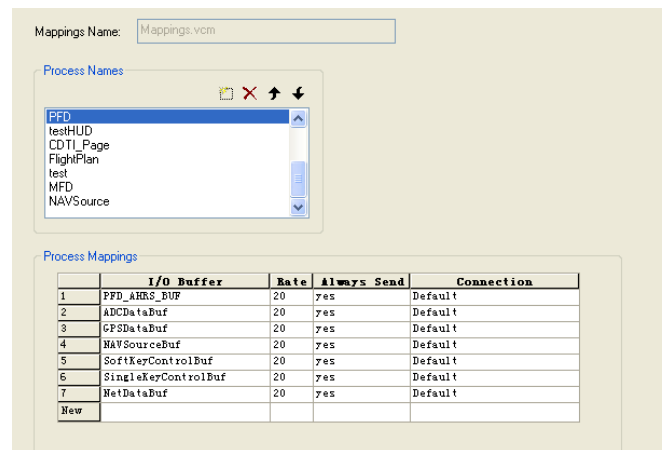

Fig. 5. Data connection.

B. nCom Gateway

NCom gateway software collects the simulation data from the DDS network and sends the corresponding data to the VAPS XT project. The main process includes initialization (DDS, nCom libraries and sender), simulation data acquisition from DDS and the data transmission to the VAPS XT project through the nCom sender. The core C++ code is shown by the Table I.

C. Avionics Subsystems Modules Design

Use Rhapsody software to develop the avionics subsystems modules, which designs DDS interface with ICD. The process is as following:

1) Get the original data block list from DDS receiver;
2) Detailed process the all data blocks from the list;
3) Get the DDS identifiers of the data blocks;
4) Assign the DDS identifiers, length and message according to the data structure of DDS data blocks;
5) Send DDS data blocks to DDS network.

The core C++ code is shown by the Table II.

TABLE I: C++ CODE OF THE nCOM GATEWAY

```
while(!finishFlag)
  {
     // simulation data acquisition from DDS
     read_FIP1_422_PFD_ADC_from_dds();
     read_FIP1_422_PFD_AHRS_from_dds();
     // data transmission to the VAPS XT project through the
nCom sender
     SenderADC.SetData(andpfd_adc, sizeof(pfd_adc));
     SenderAHRS.SetData(andpfd_ahrs, sizeof(pfd_ahrs));
  }
```

TABLE II: C++ CODE OF THE AVIONICS SUBSYSTEMS MODULES

```
DDS data receiver interface
// Get the original data block list from DDS receiver
SIL_msgSeq_var msgs;
int ret = takeSIL(msgs);

if( (0==ret) andand (0!=msgs->length()) ){
   // Detailed process the all data blocks from the list
   for (unsigned int j = 0; j < msgs->length(); j++){
      // data blocks buffer
      char *buffer_dds = new char[msgs[j].payload.length()];
      memcpy(buffer_dds, (unsigned char
*)msgs[j].payload.get_buffer(), msgs[j].payload.length() );
      // Get the DDS identifiers of the data blocks
      unsigned int key_dds = msgs[j].id;
      //Invoke the business logic process program according to
the DDS identifiers
      if(key_dds == 600056){
         receiveNAV2_422_AHRS_0(buffer_dds);
      }
      else if(key_dds == 100009){
         receiveADC_429_TS(buffer_dds);
      }
   }
}
DDS data sender interface
//Define the identifier of the data block
unsigned int key_dds = 600003;
//Create and define the DDS data block about the DDS identifiers,
length and message
SIL_msg msg;
msg.id = key_dds;
msg.length = sizeof(Block_AHRS_422_FIP1);
msg.payload.replace(msg.length,msg.length,(unsigned
char*)andblock_AHRS_422_FIP1);
//Send DDS data blocks to DDS network
writeSIL(msg);
```

V. CONCLUSION

In this paper, we proved that the simulation of VAPS XT cockpit display and control system based on the integrated data distribution network took the following advantages:

1) The simulation modules and the data distribution network achieve the data exchange with VAPS XT simulation software through the nCom gateway. Therefore, it can avoid the display elements duplication or data missing assignment caused by the decentralized management.
2) All the simulation modules need not to develop the nCom communications interfaces. The nCom gateway can realize the communications protocols conversion between the nCom and the data distribution network. Since the interfaces are standard and the source code has certain regularity, the nCom gateway can automatically generate code by the graphical assignment method and reduce the work of realization.
3) Reducing the dependency of simulation systems with the nCom tool library of VAPS XT, as well as using the data distribution network to decrease the data coupling, can enhance the system scalability.
4) Using the integrated data distribution network will reduce the system complexity and redundancy.

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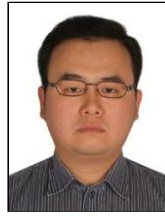
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