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WIRING OF AVIONIC SYSTEMS

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ABSTRACT

Avionic systems become more and more complex and are increasing rapidly. Flight assistant and entertainment systems need higher bandwidth. As a result, the information flow inside of an aircraft is growing. Consequently, one of the main issues is the wiring to connect the systems and the different aircraft zones with each other in an optimal way. Therefore, a method is required to keep the amount of cabling low and to get it more structured, lighter, cheaper and energy-efficient.

***Index Terms*—** Avionic, photionic, network, inflight entertainment

1. INTRODUCTION

Flight assistants systems become more complex, in order to facilitate the pilots of an airplane. *In-Flight Entertainment* (IFE) is used to make the flight more comfortable regarding passengers and cabin crew. These kind of systems are required to establish a human-machine interface. This affects the bandwidth, weight and wiring of avionic networks which is claimed more and more by flight systems. The use of higher bandwidth is recommend for the new generation of airplanes.

This paper describes the development of a new avionic network architecture in order to reduce the weight, cost and energy consumption and the possibility to increase the bandwidth by using photonic components. Therefore, a complete network model according to IFE requirements will be generated and evaluated/tested in several simulation steps.

2. MODEL BASED ENGINEERING

System modelling and simulation is getting more important for automotive or aircrafts and it improves the several design steps. *Model Based Engineering* (MBE) with executable specification provides the ability to analyse parameters at system level such as network architecture, energy consumption and costs [1]. Therefore, different tools are available for research and development, e.g. Matlab/Simulink, MLDesigner, Ptolemy, OPNET or VPI. Other tools like CORE, MEGA or SimProcess support to define the model including requirements and/or specifications and do not allow simulations (executable model).

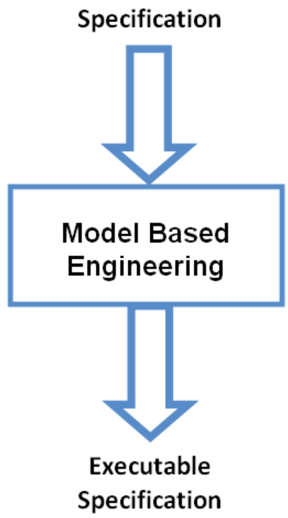

Fig. 1. MBE

Therefore, the design steps are located on an abstract level concerning tight time schedules and missing complex system details because of confidentiality at level of development. However, specifications of systems, subsystems or components have to be defined at the beginning of the development process. This is required to sketch out an initial preliminary draft proposal of the behaviour inside the system. Accordingly, to implement the specifications and requirements is the first step in order to develop an executable model.
Additonaly, MBE also support performance testing and optimisation of a system at a high level of detail. This allows to make first suitable assumptions about the architecture at the beginning of the development stage. The main issue described in this paper is to develop an executable model by using MLDesigner, concerning to analyse the architecture regarding several parameters. Summing up, a model based approach enables to describe complex relations of a system at a high level of detail, to fill the models with information by the use of predefined specifications and requirements.

3. AVIONIC NETWORKS

Avionics describes the electric devices, units and electronics on board of an aircraft, including:

- Flight instruments
- Flight assistance systems
- Navigation
- Collision-avoidance system
- Weather system and
- Aircraft management system.

Avionic network, in this context, defines the whole network of an aircraft which comprises all communication systems and how they are interconnected and established. Most of the systems are located in the avionics bay in front of an aircraft, below or near the cockpit. In order to get an overview of how the connection is implemented, there were different standards specified as a guide to set up an avionic network. The networks are mostly connected by an avionic data bus system. Accordingly, the bus systems can be split up into different standards like AFDX, ARINC 429, MIL-STD-1553 or STANAG 3910.
To reduce the amount of control units and computer systems, *Integrated Modular Avionics* (IMA) were developed [2]. The IMA is capable to support different applications and proposes an integrated architecture. The architecture layout can be designed in different ways, because of the ability of portable software application across common hardware modules. The IMA concept faciliates the development process of avionics software and provides a united structure of network modules.
Considering the increasing bandwidth, a new network architecture is needed. This paper will describe the first steps towards a new high level architecture, regarding cabin system based on the example of the In-Flight Entertainment.
The IFE system transmits a high amount of information such as video, audio, telephony and passenger service controls. Accordingly, the developing process of a model based approach will be described in the next chapters with focus on IFE.

3.1. In-Flight Entertainment

To establish communication inside the cabin, communication systems are needed, which are part of the avionics. They supply e.g. the communication between cabin, crew, flight management system and collision detection. IFE provides different services, such as telephone, internet, video and audio. In order to examine communication and its layout inside the cabin, like transmitting data, failure rates and topology, the In-Flight-Entertainment system was chosen. Therefore to provide higher bandwidth a new network architecture has to be set up as part of the work described in this paper. The IFE shows the data flow inside of an aircraft cabin, regarding uplink, downlink and bit rates of each component.
IFE could have different architectures, on the one hand a decentralised data storage, e.g. server based information flow. On the other hand a centralised data storage, where all data is stored near seats or seat groups of a cabin.
To manage all the functions, an optical network will be studied with focus on reducing cost, weight and energy consumption.

3.2. The Advantage of Fibre Optic

The advantage of fibre optic is distinguished by electromagnetic interference immunity, low weight and high bandwidth. The use of fibre optic components become increasingly important for aviation industries in order to develop communication systems which are able to handle the high amount of information flows [3]. Additionally, photonic networks use light to transport information. In this case, optical transmitters are represented by laser or LED source.

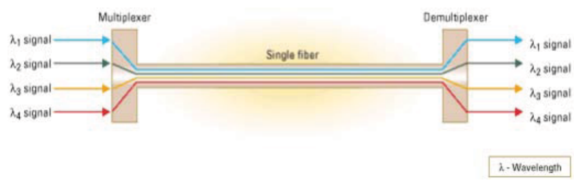

Fig. 2. WDM [4]

Another advantage is the Wavelength Division Multiplexing (WDM), in order to transmit different information by using different wavelengths over one fibre. This increases the number of channels by adding different wavelength with coarse channel width of 1nm to 20nm. That provides the opportunity to transmit different information over one fibre by using the whole bandwidth and to design networks smaller regarding their wiring.

4. EXAMPLE OF AN EXECUTABLE SPECIFICATION

4.1. Architecture Design

The architecture describes the characteristic structure of a system, computer or a network. It implies description of the interaction between hardware, software, functional concept, usability and peripheral components. A network architecture consists of processing units, network components like switches, router, server/clients and routing or multiplexing techniques. Most common architectures are e.g. Open Systems

Interconnection (OSI) or IBM-network architecture SNA. Therefore, to build network maps to get an overview of all network components and and their interconnection and information flow is well suited in order to define a new architecture.
The design of an architecture passes several design steps. At first, the requirements have to be defined in a certain way. Hence, services, nodes and connection between nodes need to be listed up. Based on this information a generic network map can be developed in order to describe the information flow between the nodes and to define the location and their distances. The second step is to select several network topologies and if their are suitable for use of fibre optic.

4.2. Network Map

A network map describes all network components as nodes and how they are connected to each other. This is a simple form to get a first overview of all information flow inside a network and the amount of nodes. Figure 3 shows a generic network map which consits of nodes and the connection between them, represented as edges. Each node presents network component regarding fibre optic, which is used in this paper. Optical network components are:

- Transmitter/ Receiver
- Splitter
- Coupler
- Switch and
- Multiplexer/Demultiplexer (WDM).

The network mapping could also include network requirements like topology and data flow information, e.g. uplink, downlink, min/max data rates or BER.

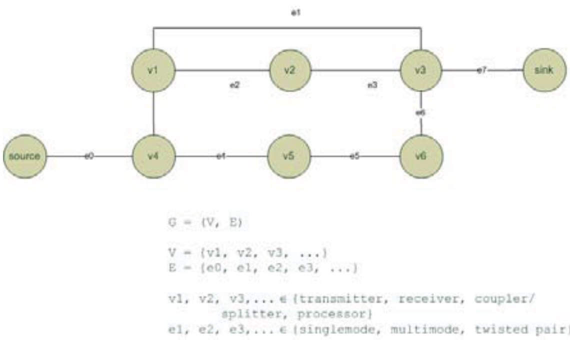

Fig. 3. Generic Network Map

4.3. MLDesigner Model

Based on the network map a model is created with MLDesigner. The goal is to find an optimal architecture with focus on reducing weight, energy consumption and costs. The model includes several nodes and connections. It also implements WDM/CDWM. This is realised by using different types of transmitter/laser sources with an own wavelength. The data goes into different transmitter, then the information is carried by different wavelengths. Therefore, different connection

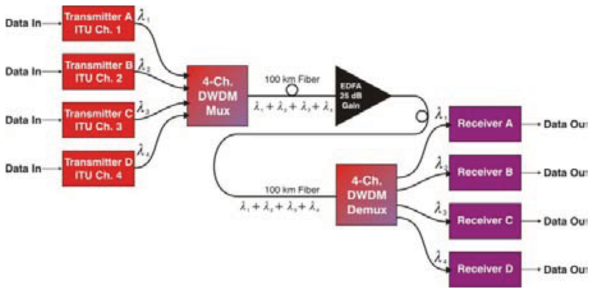

Fig. 4. DWDM

types can be studied, e.g. to combine groups of seat groups to receive the information via one wavelength and use different topologies like bus or tree. The model consists of a tunable transmitter (IFE server) in order to simulate WDM behaviour and receiver (seat groups).

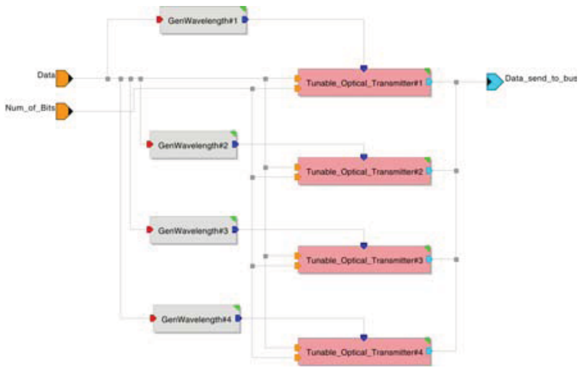

Fig. 5. Transmitter

However, a DWDM Mux multiplexes the different wavelengths to send the information over one cable. At the receiver side the signals need to be demultiplexed. Another way is to use receiver with only one acceptable wavelength. Therefore, the information needes to be splitted before. The target is to examine what type of connection is the best. Accordingly, different connection methods can be set up and simulated. In this paper two topologies are examined by using MLDesigner, bus and tree. The next step towards architecture design is to create an interface between MLDesigner and other tool in order to exchange the simulation results. That would effort to evaluate/analyse the results by using other tools and to make them visible in an optimal way. For example the data could also be useed as an input, e.g. to show the layout of a cabin with its all nodes, connection and topology information in 3D.

4.3.1. *Bus Topology*

The bus topology consists of one server, different clients, optical splitter and tunable transmitter. Figure 6 shows a network map ot a bus topology.

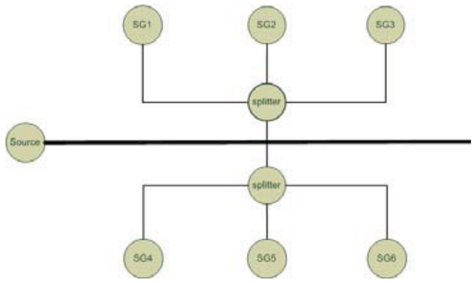

Fig. 6. fig: Bus network map

The information is going from the server to the seat groups and uses WDM. Figure 7 presents the model in MLDesigner. This model applies DWDM and it is simulated by using different laser sources as shown in figure 5.

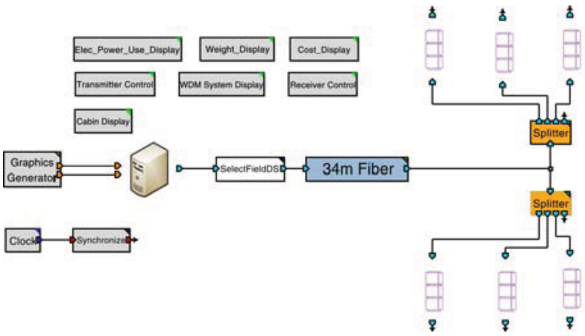

Fig. 7. Bus Topology

4.3.2. *Tree Topology*

The tree toplology is represented by a different number of cables which are going from the source to the sinks shown in figure 8.

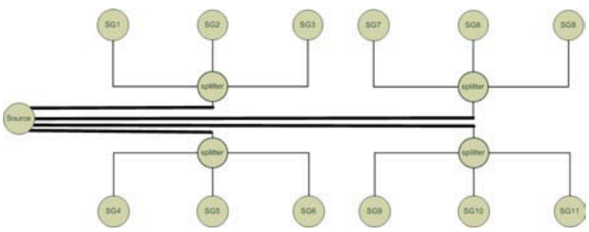

Fig. 8. Tree network map

As a result the data is transmittet via various fibre cables to the seat groups shown in figure 9. Each seat group can belong to a group of several seat groups. This effects the amount of optical components, because there is a different number of cable necessary and even though optical splitter or coupler, mux or demux.

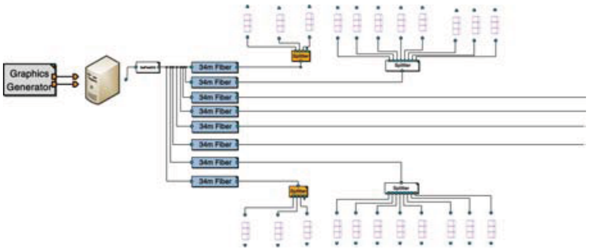

Fig. 9. Tree Topology

4.3.3. *Simulation Results*

The results are represented by system parameters like weight, energy consumption and cost. All these parameters ware computed during the simulation based optical components specification. Figure 10 shows the system cost/parameter of a bus topology. Figure 11 presents the results by using a tree topology. In comparison, it is noticable that only the system costs are different. That is influenced by a higher amount of fibre optic cable used in the tree toplology.

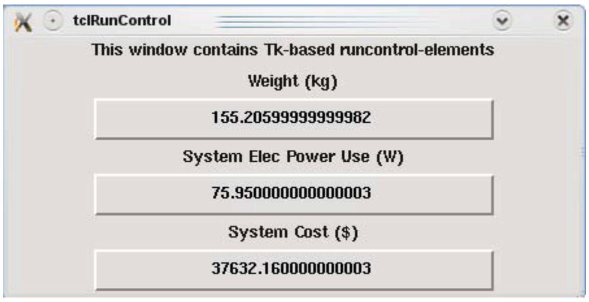

Fig. 10. Result Bus Topology

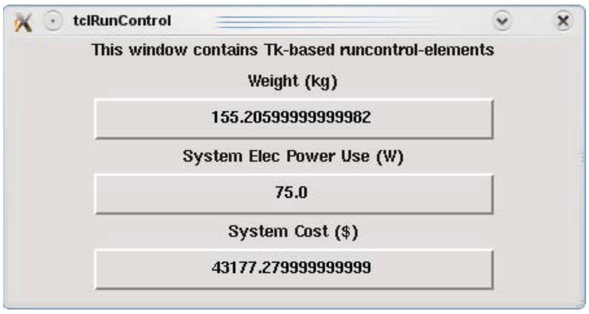

Fig. 11. Result Tree Topology

5. OUTLOOK AND CONCLUSION

5.1. Outlook

The layout of a network architecture is important. Therefore, to represent the model information in a graphical way, like 3D. Hence, another issue is to generate a 3D view of the architecture with its nodes and connections. The outlook of this work will be to develop a planning tool which consists of model part and 3D part. Furthermore, an interface between simulation tools like MLDesigner, Matlab or OPNET has to be developed in order to make simulation results transpaerent and to represent them graphically. The other way is to use the interface to create a network layout, architecture or topology and give these information to the modeling part and start different simulation steps in background. The next step will be to analyse the performance of the network. That means to evaluate and validate the network behaviour in case of a node breaks down and what happens to the information flow. That will also have an affect of redundancy decisions and what kind of redundancy is most suitable for what kind of network architecture.

5.2. Conclusion

The increasing data flow in aircrafts needs higher bandwidth. Therefore, to use photonic networks is a step towards the future of new aicraft architectures. In order to guarantee such an amount of bandwidth new architectures need to be developed. Hence, a new approach is required to push the MBE in the right direction. That means to develop an environment/tool which is possible to simulate behaviour in background and make results visible and easear to clarify a cabin layout by using 3D applications. Accordingly, to get modelling and simulation together with a 3D view of the model itself is a good starting point in the right direction of planning and architecture developing of aircrafts.

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