Modeling Aeronautic Networks for Internet Scenarios

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***Abstract*—Aeronautic networks have stringent requirements in terms of safety and reliability, and often imply excessive use of redundancy. The approach of introducing Internet technology is challenging with regard to the required certification processes. In this paper, we briefly present the platform DIMTOOL that allows to determine performance bounds in aeronautic communication networks using standard approaches such as simulation and network calculus analysis. Our tool is designed to simplify the evaluation and deployment of communication networks that support Internet technology without impeding existing safety and security levels.**

I. Introduction

In aeronautic networks, Internet applications are of particular interest in the field of In-Flight-Entertainment (IFE), e. g., Internet access, playing interactive games or watching movies. Currently, providing these services means additional communication infrastructure as it requires co-existence of several networks with highly varying safety and criticality requirements. Since additional weight is expected by those wired networks, novel approaches have to be developed that target at bringing several safety domains on the same network. One solution would be to give all traffic flows the highest safety level, but this approach is usually too cost intensive and usually implies the existence of links with low load.

Figure 1 shows some of the challenges for aeronautic networks that avionic has to address in the next decades, e. g., providing Internet access to passengers on their own mobile devices, or receiving podcasts from the ground. The following aircraft domains are distinguished [1]: (a) Aircraft Control Domain (ACD), (b) Airline Information Services Domain (AISD), (c) Passenger Information and Entertainment Service Domain (PIESD), and (d) Passenger-Owned Devices Domain (PODD).

The domain ACD covers critical tasks such as smoke detection in the lavatory as well as cabin crew intercommunication. Internet applications are primarily envisaged in the domains PIESD and PODD. Passenger devices and crew devices will be in those domains, e. g., tablet PCs, laptops or mobile phones.

Today, aeronautic and automotive industry consider the benefit of using switched Ethernet for in-vehicle networks, such that real-time capabilities have to be checked against the given requirements or even proven in the certification phase. The certification and requirements checks usually fall

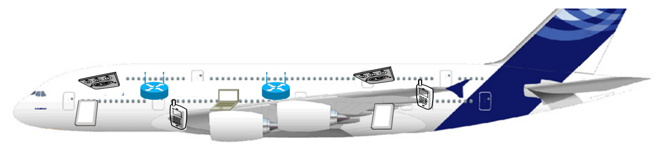

Fig. 1. Future Internet Scenarios in Modern Airplanes

into the categories network analysis, network simulation and measurements in demonstrators, such that tools are necessary to support engineers. The presented platform gives a consistent interface to those approaches by encapsulating the desired back-ends. The aspects of the performance bounds are classified into minimum, maximum, median and average value. The delays consists of up to four different delay types, namely propagation delay, processing delay, transmission delay and queuing delay. Furthermore, we provide traffic models that are either based on the token bucket models known from deterministic Network Calculus (NC), and stochastical models known from network simulation and stochastic NC. The latest version of our platform provides performance calculation by Monte Carlo Simulation (SIM), Worse Case Simulation (WCS), Network Calculus (NC), and Model Checking (MC) given by the Mixed Integer Program (MIP) approach presented in [2].

This paper is structured as follows: Section II shows related solutions with respect to performance evaluation. Section III provides an overview of the presented platform in terms of architectural design decisions and provided back-ends. Section IV gives an insight on real-time networks as they occur in the field of aeronautics. Section V summarizes the main aspects and gives an outlook on future work.

II. Related Work

Performance evaluation in communication networks can be classified by the employed theory and their building blocks. We introduce the following classification which implicitly states the theoretical background as given in the introduction (SIM, NC, MC, WCS). For this, several implementations and tools were created by academia and industry that support engineers and scientists to obtain results in parameter studies. The network simulators SSF [3], OMNeT++ [4], and OPNET [5] are examples for available products in SIM. These solutions

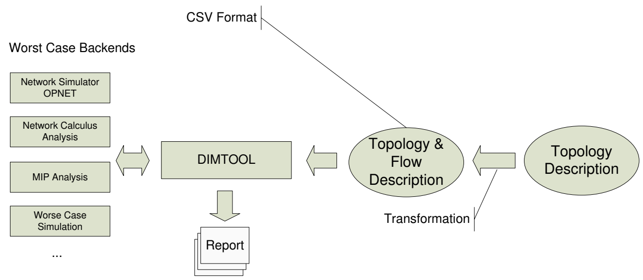

Fig. 2. Toolbox DIMTOOL

are established approaches to determine performance bounds in industrial communication networks, and provide extensive libraries. In the field of NC, popular solutions are DISCO [6], COINC [7], and RTC [8], but basically, this approach has still to struggle with the achieved tightness of the determined bounds [9]. The use of MC in large networks plays a minor role due to the state explosion problem known from MC, yet being a viable approach for simpler networks. The model checker Uppaal [10] is an example that has been used for industrial Ethernet [11]. The algorithm proposed in [12] also falls into this category. The WCS is an extension to the Monte Carlo network simulation as introduced in [2]. The idea is that worst case points are identified prior to the actual simulation and after that, a parametrized study is executed. In contrast to the tools discussed in this section, the presented platform provides several performance estimators in a single toolbox to determine transparent and comparable performance bounds.

III. ARCHITECTURE

The structural architecture of the presented solution is given in Figure 2. To offer convenient handling, we provide import routines for the network editor *Network Notepad* [13] and OPNET's [5] topology editor. Both tools allow modeling communication networks emerging from industrial environments as the aircraft cabin network or in-car networks. The generated *Topology Description* is converted in a comma-separated-value-based *Topology and Flow Description* which explicitly states traffic flows based on stochastic or deterministic traffic patterns. The *Topology and Flow Description* is passed to the DIMTOOL that creates reports from performance calculator back-ends, which are required by certification processes.

IV. REAL-TIME NETWORKS IN AERONAUTICS

Industrial communication networks frequently require guarantees in terms of response times or availability. Examples for those networks can be found in automation industry as well as in automotive and aeronautics domains. The presented platform DIMTOOL has been used to study performance bounds in aeronautic networks. Besides flight control and sensors, the cabin system has very high demands with respect to safety and reliability. The Cabin Management System (CMS) lies at the very core of the cabin system and covers safety relevant applications, such as Passenger Address (PA) (i.e., audio announcements from crew to passengers), Cabin Illumination (CIL) (i.e., cabin illumination with different light scenarios), and Cabin Interphone (i.e., crew interphone, conference circuit). Former CMS implementations used 10BASE2 as physical layer which supports data transmission at 10MBit/s half duplex. Thereby, Time Division Multiple Access (TDMA) techniques were employed to eliminate collisions in the broadcast domain by design. Nowadays, emerging attempts use state-of-the-art improvements in transmission techniques that imply the use of switched queuing networks. For such a switched network, previously applied certification strategies cannot be utilized. Therefore, novel tools become necessary, that give assistance in certification process.

V. CONCLUSION AND FUTURE WORK

In this paper we presented our novel platform DIMTOOL for performance evaluation of aeronautic networks in support of Internet scenarios. State-of-the-art performance evaluation techniques often target at the underlying performance evaluation approach, which are based on different models. The presented toolbox provides these techniques in a single toolbox, such that comparability and transparency of performance bounds is given. Implementing Internet applications on the same physical network helps to save weight and effort in wiring, but requires performance bounds that do not degrade existing real-time bounds required by the certification process. Our toolbox will be used to investigate the aircraft cabin management system that comes with high safety requirements in terms of latency and jitter. Furthermore, we will address additional scenarios in the field of aeronautic networks like the internal cabin server communication.

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