Dependability Analysis of the Controller-Pilot Data Link Communications Application

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The Controller-Pilot Data Link Communications (CPDLC) enables the air traffic message exchange over a digital data link. The replacement of the current voice system could impact the safety of the air transport system. The objective of this research is to access this impact through a human-in-the-loop simulation to push the system to its extreme conditions. This study will benefit future capacity analysis of the CPDLC protocol.

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Abstract

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1. Introduction

With the growth of the air traffic, an improvement of the current system was required. The International Civil Aviation Organization (ICAO) proposed a new conception of technologies and procedures to update the world air traffic control system and address the next long term air transport needs. This new conception is called CNS/ATM and was defined in [1]. The CNS/ATM stands for Communication, Navigation and Surveillance for Air Traffic Management.

In terms of communication, the main improvement is the replacement of the voice communication over analog radio channels with text messages over a digital data link. The Controller-Pilot Data Link Communications (CPDLC) is the new paradigm of air traffic message exchange. There are many issues on using text instead of voice, and also, on using a data link instead of analog radio. Therefore, the dependability of these new communication systems should be carefully studied.

2. The Air Traffic Control System

The main goal of the air traffic control system is the management of the aircraft traffic in the controlled airspace in order to keep a safe and expedite flow. It is composed by the airspace itself and by several systems and agents to due this duty.

The Airspace is divided in controlled and uncontrolled areas. In the uncontrolled areas, the pilot is directly responsible for the flight. However, in the controlled areas, there is an authority responsible by the flights. Each partition of the airspace, called sector, is controlled by an air traffic control authority (ATC).

The ATC operator, also called controller or ATCo, is the person inside the ATC authority responsible for the flight control. The ATC receives information to create a situational map of the traffic in its jurisdiction. Therefore, the controller receives data from the surveillance and communication systems. This data includes the aircrafts state, weather information, flight plans, etc. Then, the controller direct the traffic sending orders through the communication system, closing the control loop of the air traffic control system [2].

Because of its centralized control, the air traffic control system relies on the communications, so the CPDLC will affects the overall safety of the system.

3. The CPDLC Application

The Controller-Pilot Data Link Communications (CPDLC) is an application of the Aeronautical Telecommunications Network (ATN) and one of the CNS/ATM technologies. According to [3], this application allows data link communication between controllers and pilots.

The CPDLC specification establishes a set of text messages and a connection protocol. The message set is based on the actual voice message protocol, with the required adaptations for use in the text form. The connection protocol ensures that in a certain time, only one ATC is responsible for an aircraft, to avoid authority conflicts.

In theory, the system could be run on top of any network protocols used in the ATN. Moreover, the CPDLC application has to meet performance
requirements depending on which phase of the flight it will be used.

In the short term, this application will replace the actual voice communication over analog channels. One of the advantages is the better understanding of a text message comparing to a voice message, especially when it has poor audio quality. In addition, because of the defined message set, it could be translated to any language automatically, or even be printed and read again without the need of retransmission. The communication could be sent only to desired destinations, instead of the actual broadcast. The binary messages are faster to transmit than the voice communication could be send only to desired again without the need of retransmission. The communications. For this reason, its pros and cons are changes the current paradigm of air traffic aircraft position and system conditions.

Therefore, the CPDLC is a new technology that changes the current paradigm of air traffic communications. For this reason, its pros and cons are the focus of this research.

4. Research Goals and Approach

The ongoing research aims to study the dependability of the CPDLC application. However, this study is focused on the evaluation of the availability, reliability and safety aspects of dependability.

The CPDLC is already being applied in many airspaces. In the Brazilian Atlantic Ocean airspace, the application is being used in replacement of the old high-frequency (HF) radio systems in the transoceanic flights. The system is operating since November 2008, according to [4]. In Europe, the Maastricht Airspace is also using the CPDLC. The current implementations are being used for the en route flight phase, where the aircrafts are stabilized, flying on a straight line, and on a low density airspace. However, the future needs of the air transport will demand the use of CPDLC in all flight phases and high density areas.

Many works, for example the LINK2000+ Project from Eurocontrol [5], did real-time simulations to validate the first CPDLC implementations. These studies have proven that real-time simulation with real pilots and controllers are a valuable tool in validating data link applications.

Moreover airspace distributed simulation networks are being successfully used to evaluate new air traffic procedures [6]. These networks were constructed primary for entertainment purposes. With the growth in the flight simulation community, these networks appeared as a way to simulate the air traffic controller. The ATCo has an application that mimics the radar console and the pilots use any commercial flight simulator with an additional plug-in. With this environment, the users can promote flights following the real world procedures.

Based on the referred studies, a simulation platform was proposed to enable the CPDLC evaluation in real time with human-in-the-loop integration. The Figure 1 shows the proposed architecture for the platform. The experiment management kernel is responsible to configure and collect the environment data, interfacing with all other modules. The Ai, and ATCo represents the agents of the air traffic system, respectively the aircrafts and the controllers.

The aircraft module represents the local environment of the flight and the airplane, having the navigation model, the weather and physics simulation. Also, it has a COTS flight simulator to enables the interaction of human pilots. The controller module permits that a person act as an ATCo, having access to a radar console and communication tools.

Figure 1. Simulation Platform

The air space server provides a common space to agents share their states, so creating a global representation of the air traffic system. The communication server enables the message exchange between pilots and controllers. This server will simulate the protocols used in the CPDLC application. With the network being simulated on the communication server, many kinds of experiments could be conducted. The delay, the jitter and the rate of messages lost can be adjusted to simulate extreme conditions of the air traffic system. Also, the realistic
ATCo console and the pilot’s flight simulation will reflect the real operations and the real needs of the CPDLC.

The experiments will be run simulating a terminal airspace, which is a sector with a huge number of near aircrafts. In these terminal areas, the flights are taking off and landing, so the controllers have to transmit many orders to synchronize the flow.

Hence, the simulation platform will be implemented and will be used to evaluate the availability, reliability and safety of the CPDLC application. The experiments will vary the communication parameters of the application with human pilots and controllers, in a real-time simulation, interacting with the system.

5. Preliminary Results

For the simulation of the CPDLC interfaces, an open source mock-up was evaluated [7]. This mock-up implements the transport of the CPDLC messages and the man-machine interface as well. Since it has both the controller and the pilot interfaces, a complete message set and an open source license, it was chosen to be used in the simulation platform.

However, some modifications were necessary to use this software as required by the experiments. A record function was created to build a message log with accurate times of the transmissions and receptions on all software modules.

The message delivery method used in the application was changed from client pooling to server push, reflecting the behavior of the CPDLC system. Also, a varying delay parameter was introduced to enable the evaluation of the different cases loads in the CPDLC application.

This software, with the modifications, was successfully used to simulate a pair of aircraft and controller to conduct a complete flight, from the take-off to the landing.

6. Conclusion and Future Directions

The CPDLC application, which is part of the CNS/ATM concept, is a key technology to address the future air traffic needs. The safety of the air transport system is a society concern, so this research work aims to study the dependability of this communication system.

To do this, a simulation platform was proposed and will be used to evaluate the CPDLC user’s behavior. This platform is under implementation, and some results were achieved with a modification of a CPDLC open source software.

The future steps of this research are: the full development of the simulation platform; the execution of several human-in-the-loop real time experiments with the CPDLC application; the posterior analysis of the experiment results and the assessment of the impact of the availability, reliability and safety of the CPDLC in the air traffic system safety.

This study could be used in future fast-time simulations, to determine a safety capacity of the real air traffic sectors, when they will be using these new CNS/ATM technologies.

7. References


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