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Modeling and Simulation of Aircraft Data Networks

A Thesis

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Abstract

This thesis presents the evolution of Aircraft Data Networks .It describes various Avionics data network protocols based on the Avionics systems architecture. It discusses the evolution from a simple point-to-point protocol presented in ARINC 429 to a shared data bus protocol presented in ARINC 629. Finally, the new Data network based on AFDX (Avionics Full-duplex Ethernet) is discussed. AFDX is a new standard based on Ethernet technology and able to handle today's requirements.

Comparison between the three different protocols is presented. The comparison shows that AFDX provides better performance and flexibility without losing the compliance with safety, redundancy and reliability of Avionics requirements.

A proposed simulation model for AFDX network components is presented. It is based on OPNET platform. A case study network is introduced. This case study is used to evaluate AFDX performance. End-to-End delay analysis for AFDX network is introduced. Different terms that affect End-to-End delay are discussed.

The AFDX Case study network is implemented using ARINC429 and comparison between the two networks is presented. It shows the differences in performance, topology, reliability, redundancy and flexibility. Comparing AFDX with the other standard, it is the highest speed and throughput .Also; it complies with safety, redundancy and reliability of Avionics requirements

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ADN	Avionics Data Network.
AFDX	Avionics Full Duplex switched Ethernet.
ARINC	Aeronautical Radio Incorporated.
BAG	Band Allocation Gap.
BCTT	Best Case Transmission Time.
CMC	Current Mode Coupler.
CRC	Cyclic Redundancy Checksum
CSMA/CA	Carrier Sense Multiple Access with Collisions Avoidance.
CSMA/CD	Carrier Sense Multiple Access with Collisions Detection.
EMC	Electromagnetic Compatibility.
EMI	Electromagnetic Interface.
ESD	Electrostatic Discharge.
ES	End System.
E-To-E	End to End Delay.
FCS	Frame Check Sequence.
FTA	Fault Tree Analysis.
IC	Integrity Checking.
IFG	Interframe Gap.
IMA	Integrated Module Avionics.
IP	Internet Protocol.
LRU	Line Replicable Unit.
MAC	Media Access Control.
MFT	Minimum Frame Time.
NRZ	Non Return to Zero.
OPNET	Optimized Network Engineering Tools.

PSSA	Preliminary Safety Assessment.
RMA	Redundancy Management Algorithm.
RM	Redundancy Management.
SFD	Start Frame Delimiter.
SG	Synchronization Gap.
SIM	Serial Interface Module.
SN	Sequence Number.
SSA	System Safety Assessment.
TCP	Transmission Control Protocol.
TG	Terminal Gap.
TI	Transmit Interval.
UDP	User Datagram Protocol.
VL	Virtual Link.
WCTT	Worst Case Transmission Time.

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Chapter 1

Introduction

1.1 Introduction to Avionics`

"Avionics" is a word derived from the combination of the aviation and electronics, which could be defined as electronics of aircrafts, satellites and spacecrafts. Collinson mentions that the word avionics "was first used in the USA in the early 1950s and has since gained wide scale usage and acceptance" [1].

The development of Avionics started as early as the 18th century. In 1783, the Montgolfier brothers used a barometer to measure altitude. At the end of the 1920s, development of gyroscopes and radio navigation aids, In the 1940s, "World War 2 drove a number of important advances including navigation aids, airborne radar and electronic warfare equipment" [2].

Aircraft avionics began with a few separate, analog systems such as radar, navigation and communication equipment and cockpit displays, connected by dedicated wiring. The number of avionics increased per aircraft, digital technology appeared and systems began to be more complex. Also with the rise of digital technology, equipment was started to be designed to communicate with each other. This communication needed increased the number wirings in the aircraft which resulted in an increase of power consumption and weight. The use of data bus became a need in aviation. Introducing data bus protocol helped to reduce wirings. It also simplified total design and maintenance.

Avionics architectures were also developed according to the order below

1- ***Independent avionics architecture***: in independent avionics architecture equipment has its own functionality independent of other similar or different equipment.