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CORIN/DORIN: A WDM-ENABLED PLATFORM FOR AERO-ENGINE CONTROL SYSTEMS

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Introduction

The Full Authority Digital Electronic Control (FADEC) centralized architecture has become the norm in aero-engine control systems. With a centralized system, changes are costly and complex [1]. The goal of this work is to develop the architectural design concept for a distributed supporting network called Coarse WDM Optical Ring Network (CORIN) appropriate for aero-engine performance monitoring. A CORIN features high bandwidth, reliability, modularity, scalability, flexibility, and inherently supports deployment of a Distributed Control System (DCS). This can be upgraded to a Dense WDM Optical Ring Network (DORIN) in the next development phase.

Architecture Overview and Design

In the proposed architecture, three layers with clear functional partition are incorporated. The TransMission Layer (TML), the Optical Network Layer (ONL) and the TransPortation Layer (TPL). Similar to the OSI layered internet architecture, these three layers are functionally independent, leaving standard interfaces for other layers to communicate. Function expansion can be realized only in a particular layer, hence introducing modularity for future upgrading and maintenance.

The TML defines all the optical and physical device specifications. It provides the functional and procedural means to transfer data between network entities and to detect and possibly correct errors that may occur in the physical layer. Signals can be encoded for particular channels (wavelengths) and decoded at the receiver side.

The ONL responds to TPL service requests and issues service requests to the TML. A light path requested by certain services will be set up between the source node and the destination node. The signal will optically bypass the intermediate nodes. Link-level protection schemes are implemented in ONL.

In the TPL, raw data, either collected from sensors or commands from processing units, are formed into specific format. The data are segmented, packaged, classified, and stamped with local and destination information for ONL to deliver.

To carry the logically designed layers, a four-fiber Optical Channel Dedicated Path Ring (OChDPRING) structure with unidirectional fibers is used. An illustrative architecture, comprising four functional Ring Nodes (RNs), is shown in Figure 1. A Ring Node (RN) supports signal degradation detection and intelligent automatic primary/backup link switching. The architecture of a RN is shown in Figure 2.

Multiple sensor boards are connected to a RN in a tree structure, and share the data channel by a Time Division Multiplexing manner. RN node communicates with its peers by Time Triggered Protocol [2] to guarantee real-time and determinism. A majority of decisions can be made by a local processor if no global information is required. For those decisions which cannot be made locally, requests are sent to remote nodes by inter-node communications. This distributed processing manner enables modularity design and functional partition, thus achieving less complexity and shorter developing cycle. A CORIN is expected to seamlessly integrate fiber sensors other than their electronic counterparts, hence can maximally exploit the benefits promised by fiber optics.

A CORIN employs a primary/standby strategy to guarantee hardware availability, and deploys proactive redundant fiber links in consideration of link failures. An intelligent switching scheme is

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implemented in each RN, with the ability to switch between the working and down links. The fibers are placed link-disjoint to minimize the possibility of simultaneous failures within the same area.

Performance Evaluation

The performance of a CORIN was investigated by computer simulation. Figure 3 shows the relationship between connection blocking probability and connection holding time. As the connection holding time increases, the connection blocking probability increases correspondingly because of the increasing probability that a connection overlaps with others in time domain. For critical applications, it is important to identify the zero-blocking point to guarantee non-blocking provisioning. This can be achieved in accordance with precise and detailed traffic estimation. Figure 4 examines the reliability of a CORIN under multiple failures. It shows that it can withstand up to 5 simultaneous failures with no connections dropped. The backup resources guarantee a high ratio of successfully reprovisioned connections to the total affected ones.

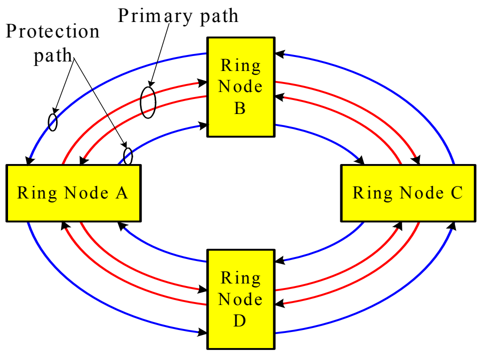

Figure 1. Four-Node CORIN

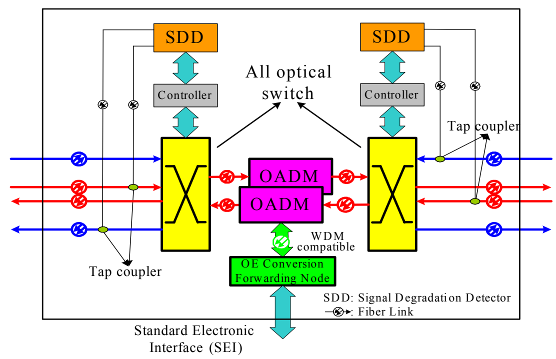

Figure 2. Architecture of a Ring Node

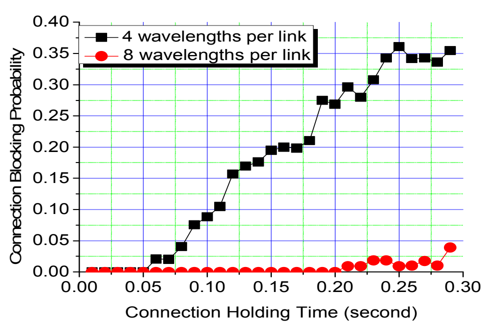

Figure 3. Connection Blocking Probability vs. Connection Holding Time

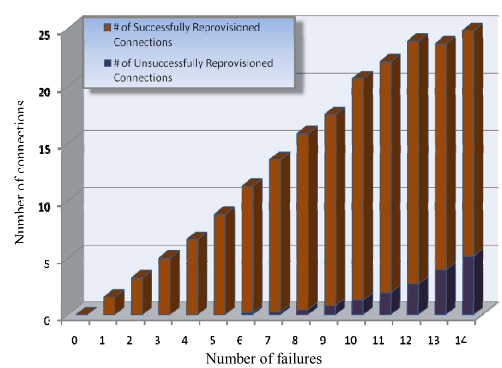

Figure 4. Reliablity under multiple failures

Conclusion

A paradigm for WDM-enabled networking for supporting aero-engine control systems has been proposed. A layered architecture has been defined. The traffic blocking probability was studied and advantage in terms of reliability was demonstrated by simulation. This paradigm provides an opportunity to develop a platform for implementing Distributed Control Systems. Further effort to upgrade the paradigm from CORIN to DORIN using DWDM will continue.

References

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