PCM TO ETHERNET: A HYBRID SYSTEM USED TO CERTIFY THE NEXT GENERATION OF DATA TRANSFER TECHNOLOGY

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ABSTRACT

The last few years has witnessed the adoption of Ethernet technology in an increasing number of FTI applications[1]. This is a result of both the growing acceptance within the community of the application of the technology, the availability of suitable hardware and the desire for increased parameters/higher data rates that PCM is unable to accommodate. However, migrating from an existing PCM based networked system to Ethernet is not typically just a case of exchanging the necessary hardware. There can be a range of other issues that require addressing such as ensuring determinism and realizing previous investment in hardware – this paper highlights and discusses several of these.

This paper presents a case study of an FTI application on the Embraer Legacy 500 where a hybrid PCM and Ethernet configuration was implemented. One reason for this configuration was that it was necessary to prove to the Brazilian Aeronautical Agency that the data acquired using an Ethernet system was as reliable as that acquired using PCM. An additional reason was that such a system was seen as a safe stepping stone to a full Ethernet system for programs in the near future which are planning to fully migrate to an Ethernet architecture.

INTRODUCTION

There is now recognition that Ethernet based data acquisition systems offer key advantages in FTI applications such as: increased bandwidth; flexible and scalable topologies; standard management and configuration tools; and reduced costs. This is a result of both the growing evidence from successful programs which have applied the technology[2], the availability of suitable hardware, initiatives that endeavor to define open standards for the interoperation of networked enabled systems and the desire for increased parameters/higher data rates that PCM is unable to accommodate. This paper briefly discusses some barriers to Ethernet adoption and then presents a case study where some of these, and other issues, were encountered. The motivations for using Ethernet and the approach taken are explored and the implementation is then discussed.

ADOPTION BARRIERS

There are barriers to Ethernet adoption that exist today that are not linked to technology availability. One barrier is the prior investment in test hardware that uses older technologies such as PCM, CAIS or proprietary interconnects. While hardware can physically be replaced, there is often a need to continue to extract value from the existing infrastructure both now and into the future – the investment can be very difficult to justify. However, there are systems that do not require significant reinvestment. Modular COTS data acquisition systems (DAS) are now prevalent and changing physical interface can be as simple as changing one module, allowing an end user to restrict reinvestment to one module per chassis, one or more Ethernet switches and the necessary modules to output to another format (e.g. PCM for telemetry or for recording if an IP recorder is not also selected). This is of little use to those whose existing infrastructure requires entire new lines of product to make such changes. Either way, an alternative is to transition in smaller steps to create a hybrid system. This has the advantages of utilizing existing hardware while introducing new elements into the system. The investment requirements can be less, in particular if the existing system supports a full transition in the longer term.

Deterministic data is a vital requirement of an FTI system and PCM is a well-known deterministic means of transmitting data that allows flight test engineers to calculate associated transmission delays and data throughput very accurately[1]. Although Ethernet transmission is inherently non-deterministic, the techniques to mitigate non-deterministic behavior in an Ethernet system are now well understood and simple to implement[3] – though that does not mean this deterministic behavior will necessarily be accepted in a new system without proof. The last issue discussed in this paper is the change that any technology causes in terms of timescales to learn about the technology, become familiar with new tools and data formats. The prevalence of Ethernet makes this transition relatively painless since the world community for Ethernet numbers in the hundreds of millions and there is no shortage of documentation, open and mature standards and software.

CASE STUDY

This case study presents the background, system design and testing of a hybrid Ethernet-PCM system for the Embraer Legacy-500 airframe. Historically, the typical PCM based data acquisition system used by Embraer was of the form of Figure 1. In such a system there is one PCM stream and all the data from this section is sent by telemetry and is acquired exclusively for certification purposes. While this form of system accomplishes the required tasks, there were features of an Ethernet system which Embraer wished to exploit, for example, higher data rates.

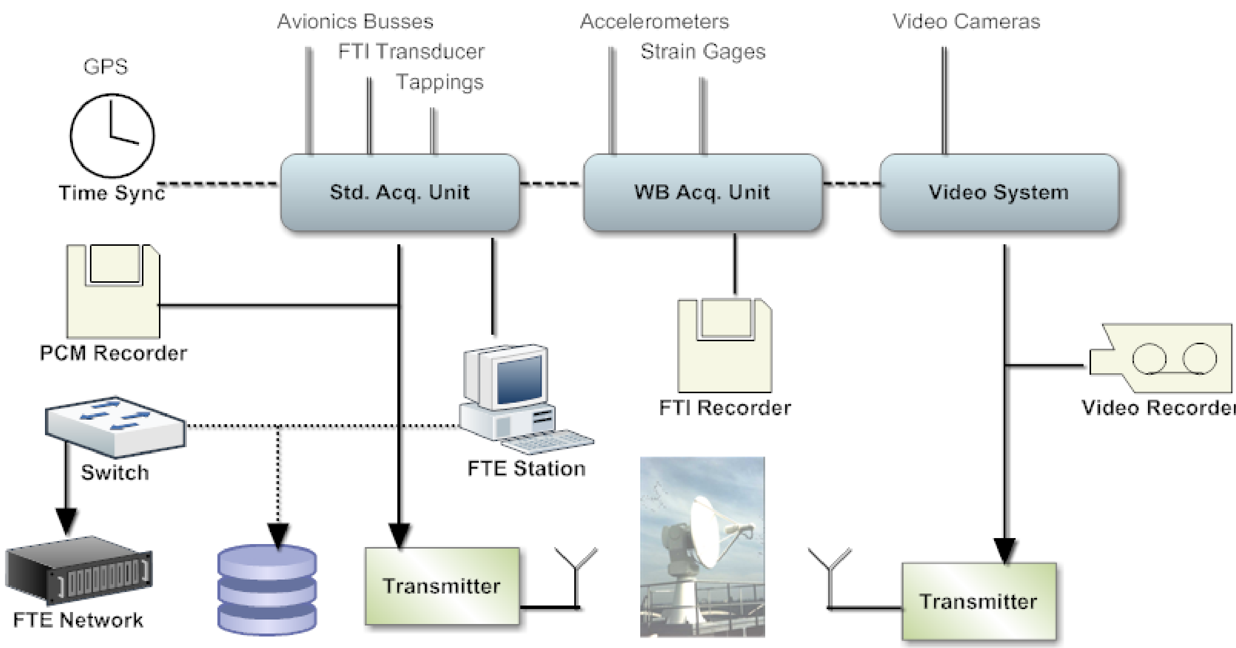

Figure 1: Typical PCM data acquisition system

For flight certification, typically only the parameters required from avionics bus would be recorded. However, with the availability of denser and more compact storage, this is no longer necessarily a limitation and there is relatively little extra effort required to implement a system that could provide the avionic/ aeronautical departments with more extensive data. This was very desirable as this would help everyone when troubleshooting problems and provide data for simulations, which would then translate to shorter required time in the air for the aircraft. Figure 2 shows how the number of flight test parameters used/ planned for use in Embraer's development programs has increased significantly over the past couple of decades, in particular in recent years. This increased need for bandwidth cannot be easily accommodated by PCM. This desire to collect more data both for flight test and for multiple departments was a strong motivating factor in selecting Ethernet as the future transport protocol.

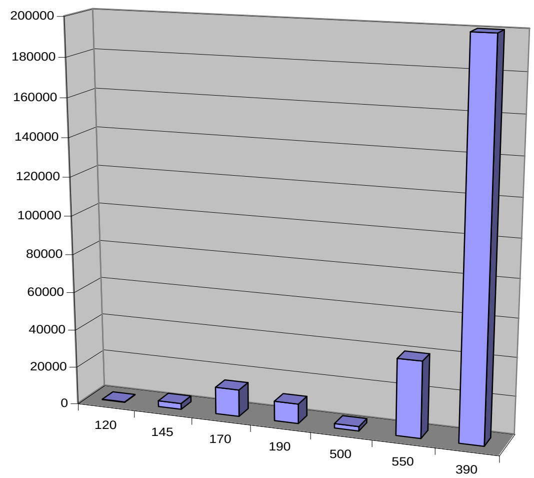

Figure 2: The rise in the number of flight test parameters per development program

RAPID INSTALLATION

The Ethernet systems ability to accommodate faster data rates would also enable the removal of separate dedicated systems –avionic bus recorders, engine monitoring units and so forth. The resulting system would be more compact and less complicated making it easier to setup, install and remove. Embraer typically uses systems mounted in mobile racks (e.g. Figure 3) because of the limited time the FTI team have to install equipment and to better accommodate the scenarios where the equipment may need to be removed and then reinstalled after some aircraft modifications have been made. Their FTI DAS philosophy is to have modularity and reusability in their equipment. For example, to instrument a different aircraft with different data requirements, they could just modify the equipment in the rack and transfer to another craft. This reusability is a key DAS requirement.

Figure 3: The FTI equipment is assembled in racks for rapid installation

MOVING TO ETHERNET

Embraer chose not to move directly to an Ethernet system for two principle reasons. The first was that in order to meet the certification requirements of the National Civil Aviation Agency of Brazil (ANAC), they had to prove that the data from the Ethernet system was the same as that which would be found in a PCM system. As with any technology/ equipment change, it was important to prove the reliability and safety of the new elements. The second reason was the low risk long term approach the agency wanted to take whereby they would transition over 7 years to the new technology without impacting any aircraft's development timelines as illustrated in Figure 4.

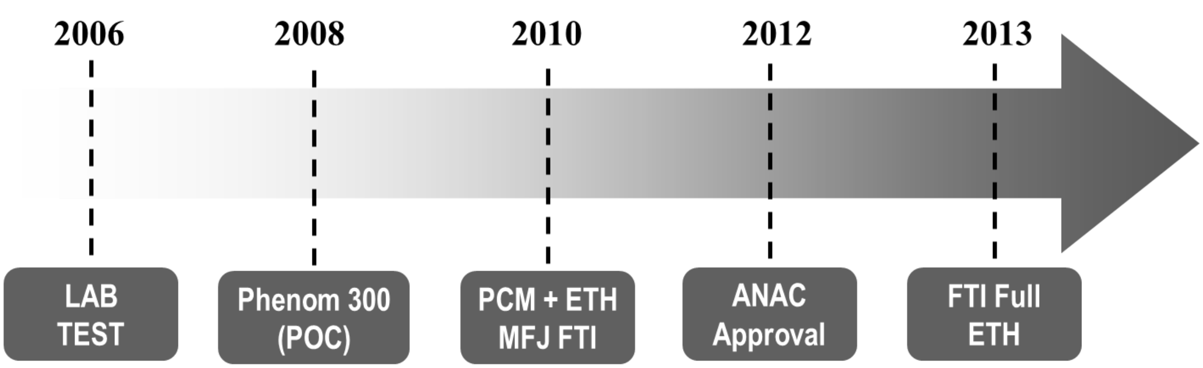

Figure 4 : The timeline for transitioning fully from PCM to Ethernet

SYSTEM

The system Embraer installed consisted of three sub-systems as shown in Figure 5 – a ‘big and slow’, a ‘high-speed’ and an ‘optional’ third system. All PCM data was also sent to an Ethernet packet called PCM replica for certification purposes. In essence, this packet was an exact copy of the PCM minor frame wrapped in an Ethernet frame - because the DAU was modular and could handle multiple data-sinks simultaneously, implementing this only required adding one module into the chassis and using the PCM master to record an exact PCM replica. This enables direct comparison of the data to ensure the same data is recorded whether sent in a PCM major frame or in an Ethernet frame. Custom software was developed to examine and compare the data.

The ‘big and slow’ system consists of 18 chassis with a maximum data rate of each parameter of 512 sps. All parsed data (PCM) is sent by telemetry. There are a number of ARINC 429 and Time triggered Protocol (TTP) buses whose data was acquired in ‘packetizer mode’. ‘Packetizer mode’ means all messages/ transactions on a bus are captured and time tagged. They are then encapsulated in the payload of a packet. Asynchronous buses use aperiodic transmission to effectively use bandwidth. This reduces the amount of bandwidth required and the storage space needed in the system as stale data is not constantly being pushed through the system.

The high speed system acquired data at a rate of 512 to 8K sps from accelerometers and strain gauges. This system outputted the data in an Ethernet native format i.e. not PCM data wrapped into an Ethernet packet like the ‘big and slow’ system. The third system consisted of four chassis and was used to capture additional bus data. This could be removed and used elsewhere when not required without necessitating the rest of the system to be reprogrammed. The data from these two systems was routed through airborne switches to a recorder which stored the data in the open PCAP format. The entire system was synchronized using the IEEE 1588 PTP protocol for the Ethernet connected DAUs and the proprietary PCM-based xsysnc for the PCM systems. Some detailed data rates found in the system can be seen in Table 1.

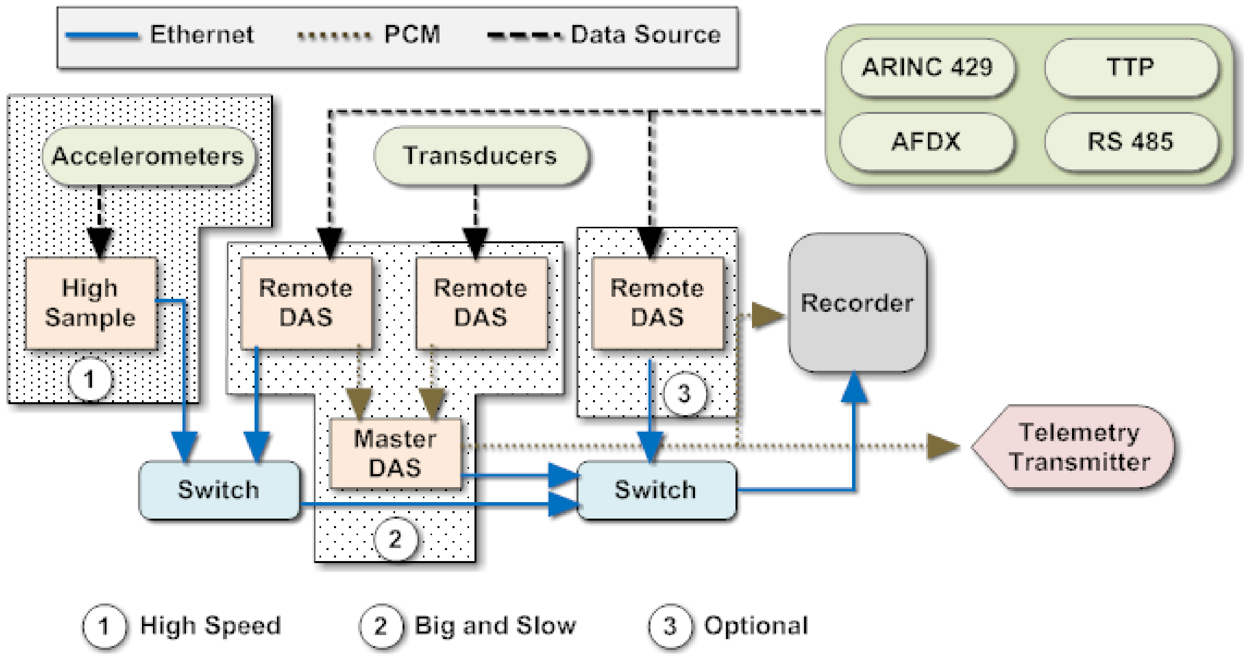

Figure 5: An overview of the system

Item	**Value [**Mbits/sec]
ARINC Bus snarfer traffic contribution (network only)	7.26
TTP Bus snarfer traffic contribution (network only)	12.56
AFDX Bus snarfer traffic contribution (network only)	4.77
PCM unit traffic contribution (network)	7.23
PCM unit traffic contribution (PBM/104)	6.56
high sample rate	15.99
Total Network bit rate	54.37
Recording overhead (%)	**2%**
Total recording bit rate	55.46
Number of hours recording required	**4.5**
Number of seconds recording required	16200 sec
Media size required	117.76 Gbytes

Table 1: A selection of Legacy 500 data rates

All units were programmed using the vendor's DAS Studio 3 software. During this process, DAS Studio 3 tools for building ARINC 429 and importing TTP settings were utilized to aid setup. The availability of modern software tools and an open XML metadata format allowed thousands of parameters to be loaded into the setup with the click of a button. Uniquely, the Embraer FTI team directly acquired data from the TTP bus using a COTS DAU module without the aid of any