Wireless Transducer Systems Architectures – A User's Perspective

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ABSTRACT

This paper provides essential requirements and describes some possible architectures of so-called Wireless Transducers Systems from the user's perspective and discusses the application advantages of each architecture, in the airplane-testing environment. The intent of this paper is to stimulate discussion in the transducer user and supplier communities and standards committees, leading to increased product suitability and lower cost for commercial off the shelf wireless transducer products.

KEY WORDS

Flight Test Instrumentation, Wireless, Efficiency, Reliability, Suitability

INTRODUCTION

Wireless transducer systems hold the potential for reducing cost, flow time, engineering design and manufacturing effort, while increasing flexibility to accommodate emerging instrumentation requirements during flight testing. In order to achieve these benefits, it is necessary to consider when, how, where and why wireless transducers offer advantages over conventional wired systems and to configure these systems so that advantages are optimized and disadvantages are minimized. In addition, it seems highly desirable that these systems fit seamlessly into the architecture of the data systems of the future.

COMMERCIAL AIRPLANE FLIGHT TEST APPLICATIONS FOR WIRELESS TRANSDUCER SYSTEMS

To fulfill their promise, wireless transducer systems must meet some essential requirements. These include:

- Accommodate diverse sensor capability
- Highly reliable
- Rugged design

- Electromagnetic compatibility with aircraft systems
- A method of testing the performance of the RF link
- Ability to cause a group of wireless sensors to sample simultaneously
- Definable and repeatable latency
- No cross talk between sensors
- Data/sensor dropouts readily apparent
- Electrical power status on demand
- A traceable link between the sensor and the recorded data
    - Sensor unique identification
    - Base group unique identification
- Deterministic timing
- Fault tolerant RF link
- Transmission range of 100 meters or more
- Long (> 30 days) battery life (if used)
- High sample rate (up to 6400 sps)
- Diminutive size

It may be some time before all of these requirements can be accommodated. The needs for transmission range and battery life, for example, seem to offer some insurmountable obstacles. A combination of innovative approaches will be required to generate a solution. These are likely to include a combination of battery improvements, energy scavenging, data transmission only on change, sleep mode operation, high gain receivers/antennas and wireless mesh architecture; although wireless meshes could result in increased power consumption for relaying data to its ultimate destination.

In flight testing of Boeing commercial airplanes, there are several specific application scenarios where wireless transducer systems offer the potential of breakthrough improvements in flight test instrumentation flow times and costs.

The first BCA flight test wireless application scenario is for measurements made external to the airplane cabin or pressure vessel. These include measurements on wings, control surfaces, and engines as well as environmental parametric measurements. Measurement types include local accelerations, surface positions, temperatures, pressures, fuel flows, strains and vibrations. The potential advantages of wireless systems for these applications are elimination of long run wire routing, structural penetrations and the need for lightning protection. For this application, a wireless architecture that seems to provide the optimum configuration, while minimizing the need for separate power supplies and/or batteries is one which is designed to scavenge power from local sources (e.g. engine generators) and provide it to transducers via a common power bus. The system should also be designed to collect the data from the various transducers in the local area and transmit it via a wireless link to a receiving antenna and host computer inside the airplane cabin. Figure 1 illustrates an example of this architecture, employing IEEE p1451.3 smart sensors and IEEE 802.11x[1] wireless link. In this illustration, a TBIM is a

[1] The appropriate wireless specification will be determined by a number of factors, including bandwidth, system interoperability and transmission range.

Transducer Bus Interface Module and a GPTBIM is a General Purpose TBIM. An NCAP is a Network Capable Application Processor.

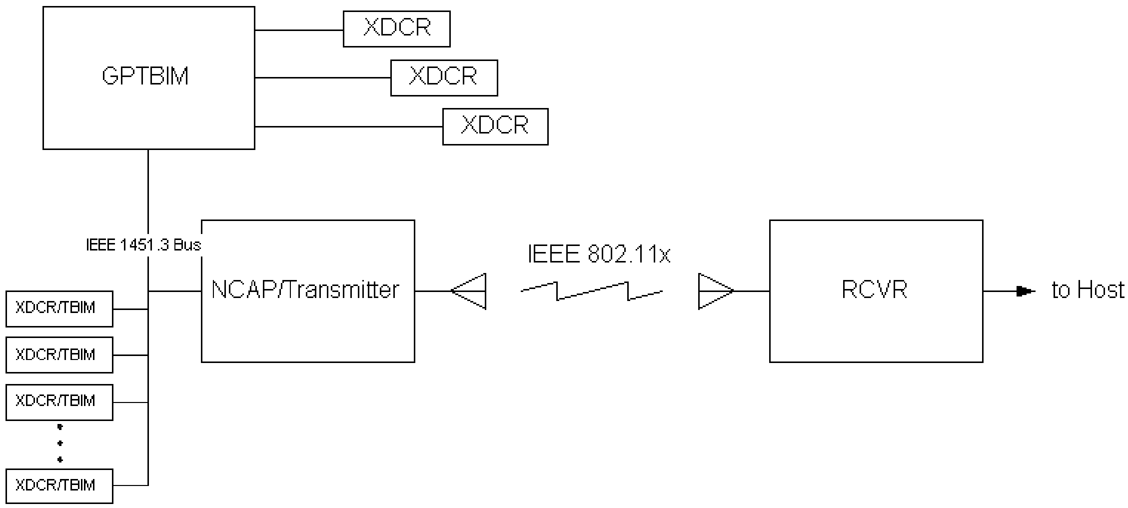

Figure 1 IEEE 1451.3 Smart Transducer Bus to IEEE 802.11x (Wireless) NCAP

A second BCA flight test wireless application scenario is measurements on moving parts. These measurements include landing gear wheel measurements (e.g. tire bead seat and fuse plug temperatures) and control surface measurements (e.g. position, vibration). The architecture, which best suits this application, is a stand-alone wireless sensor, sensor group, or wireless mesh. Stand-alone sensors offer the advantage of minimum power requirements, whereas a wireless mesh offers the potential of improved data transmission reliability. Any self-contained wireless sensor, which incorporates a battery as its primary power source, will need to be capable of surviving and possibly operating at very low temperatures and operating for a reasonable period of time (at least 30 days). Figures 2 and 3 illustrate two possible architectures for this application. At the current time, the IEEE p1451.5 is just beginning its development and could select a physical layer which differs significantly from the two illustrated below. These concepts are offered for consideration and to encourage discussion of the pros and cons within the user and supplier communities.

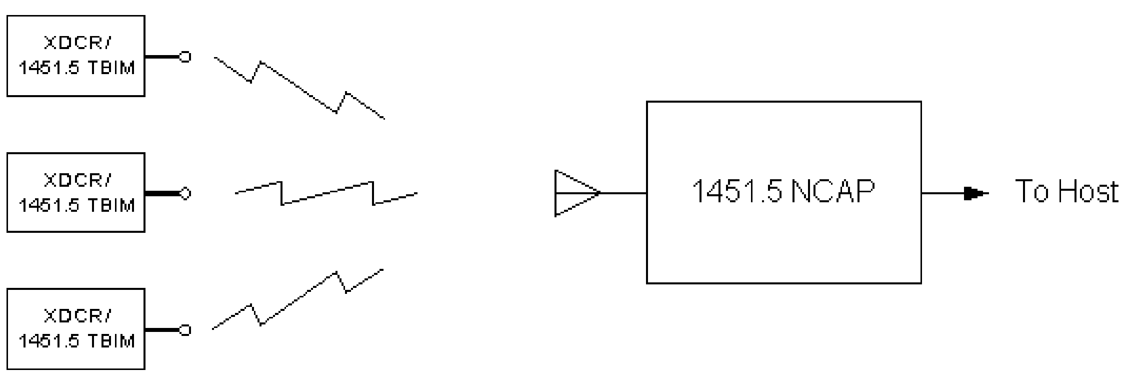

Figure 2 IEEE 1451.5 Wireless Transducer System

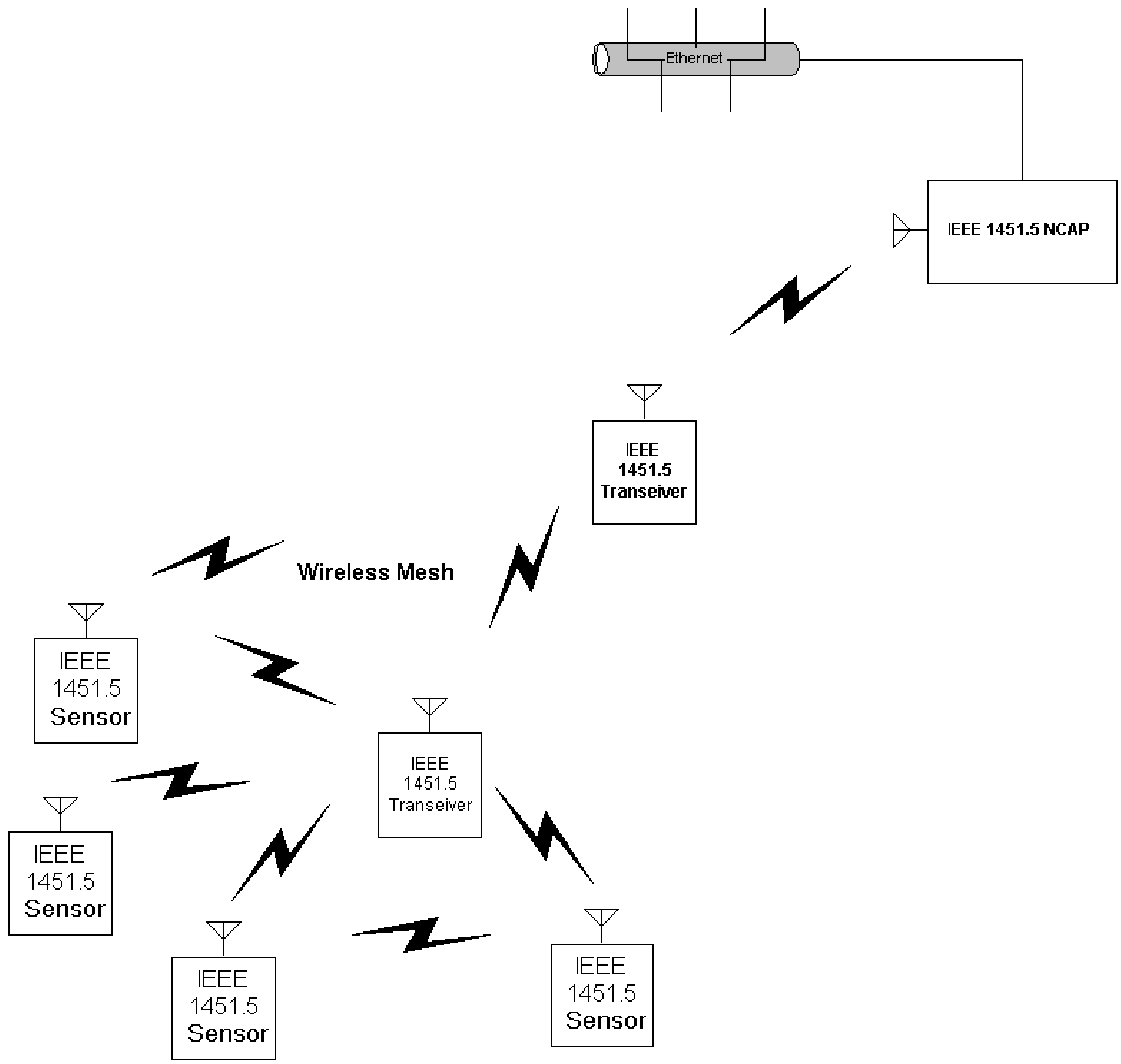

Figure 3 IEEE 1451.5 Wireless Mesh Transducer System

A third BCA flight test wireless application includes last minute add-on measurements, for which no additional wiring can be added. Often during test, phenomena differ from prediction and require further investigation and the addition of instrumentation. Adding wires may be impractical, or even impossible. In these cases, the ability to add wireless stand-alone, or wireless mesh sensors would be highly desirable. In cases where there is a smart sensor bus nearby, a possible solution would be to add a transceiver to the smart sensor bus, then add as many wireless sensors as needed (within the smart sensor buss' and wireless link's capabilities). This architecture is illustrated in figure 4.

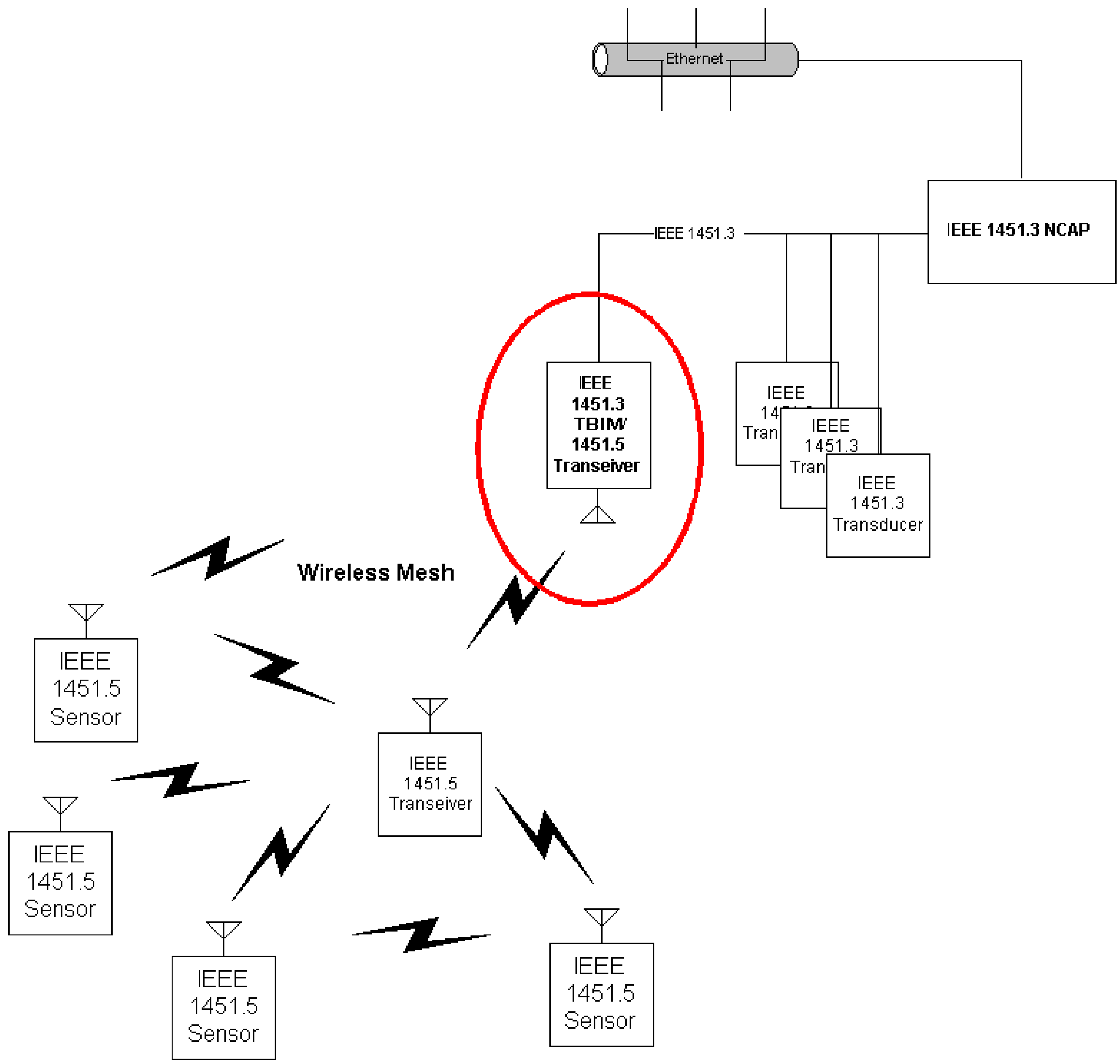

Figure 4 IEEE 1451.5 Wireless/IEEE 1451.3 Hybrid Transducer System

In the past, we in BCA Flight Test have avoided wireless technology. It was simply unsuitable for most of our needs. Major challenges remain for the industry to realize viable wireless transducer systems for use in a flight test environment.

- Power
- Reliability
- Error rate
- Environment
- Cost
- Size
- System compatibility and interoperability
- Producability

In addition, the advent of “packetized” data transmission over networks has exacerbated the problem of meeting the time determinism requirements. These are challenges that we hope the test and measurement community can overcome within the next few years. In an era of limited funding for technology development, Boeing has decided to contribute significantly to this effort, because we realize its potential for high payoff.

For wireless to fulfill its promise in our industry, it must meet all of the requirements, be low cost, flexible and reliable. In addition, the architectures must adapt to the needs presented by the application scenarios. I am aware that other industries may pull the architectures in different directions, but I am confident that suppliers can and will step forward to meet the needs of the aerospace community as articulated in this paper.