Poster: Towards an Ultra-wide Band Sensor Network for Aircraft Applications

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Abstract

We present a wireless sensor network, deployed and tested for real aircraft applications. By employing IEEE 802.15.4-2011 UWB compliant transceivers, with a time slotted channel access protocol, characteristics of indoor propagation are studied. A test setup in an aircraft's empty passenger cabin is presented and wireless channel features are analysed. Specifically, coherence time and shadowing are determined, which constitute the fundamental step for retrieving a generalized channel model.

1 Introduction

In today's society people take the opportunity to work, live and travel at various places all over the world. This imposes new demands for public transportation systems. In aviation industry, modern aircraft need to be reliable and secure but yet economically efficient. Thousands of sensors and actuators for cabin monitoring and control applications cause maintenance, installation costs and add weight to a plane [1]. To reduce these costs, sensor nodes ideally operate autonomously, independent on location or power supply. Wired connections are therefore often impracticable and should be avoided where possible. The Reliable Wireless Sensor Network for Aircraft Applications (REWISE) project aims to deliver such a solution, dispensing for external power supply and utilizing a wireless communication to substitute wired data cables. It further enables dynamical adaptation to changes of the existing sensor/actuator system and eases reconfigurations and redesign of the passenger cabin without time consuming cable rearrangements.

Deploying a Wireless Sensor Network within the passenger's cabin entails several challenges. Examples are providing enough capacity to serve thousands of nodes, meeting stringent reliability constraints and coping with interference or jamming. REWISE therefore utilizes Time Division Multiple Access (TDMA), in combination with a node discovery scheme, to dynamically schedule the number and duration of time slots. As each node obtains an unique time slot, collision-free channel access is guaranteed. Various control time slots can be reserved to broadcast acknowledgements, channel reconfiguration data and time slot reassignments. These reserved slots also provide robustness to the design as they can be used by nodes to resynchronize to access points when corrections in slot alignments are required. The employed MAC protocol also enables duty cycling, which prolongs a node's lifetime and hence, prevents quick depletion of its battery.

To achieve resilience against narrow-band interference, IEEE 802.15.4-2011 ultra wideband (UWB) compliant wireless transceivers, exploiting a bandwidth of 500 MHz, are used. These transceivers operate within a tunable frequency range, spanning 6 RF bands from 3.5 GHz to 6.5 GHz [2].

2 System Overview

Figure 1 illustrates the system setup, comprising main components and their interaction.

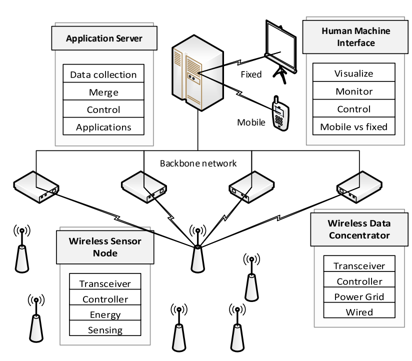

Figure 1: System components overview and their interaction.

Wireless Sensor Nodes (WSN) are deployed at various positions, serving to monitor and interact with the environment. Applications include structural health monitoring, flight control tasks and enhancing passenger's comfort. Sensed data is constantly disseminated by WSNs and gathered at Wireless Data Concentrators (WDC). Connected to the power grid and deployed at specific locations, WDCs form cells that interact and control surrounding WSNs. Data concentrators are in charge of node discovery, scheduling of

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slots and data aggregation. The received data is forwarded to a centralized Application Server (AS) which merges information and provides a visual representation at a Human Machine Interface (HMI) in the flight attendant's compartment or a mobile unit to quickly access flight related information.

3 Sensors Deployment and Test Setup

To test the channel features, 17 sensor nodes are deployed in an empty passenger cabin which is further referred to as mock-up. They are deployed at practical positions for real flight applications. Specifically, four seat rows are equipped with three WSNs each at the top, middle and floor console of a passenger cabin. Five more sensor nodes, operating in WDC mode are deployed at corners and the middle ceiling of the cabin. A deployment schematic of the WSN within the mock-up is shown in Figures 2 (a) and (b).

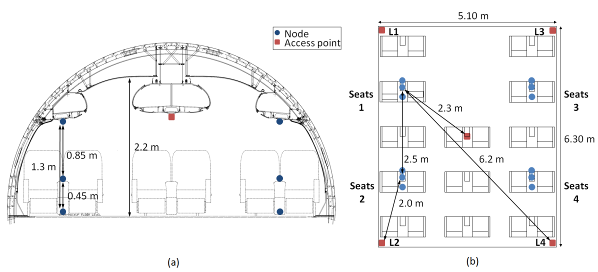

Figure 2: Sensors deployment, a) cross-section and b) top-level view.

Observations of received signal strength indicator (RSSI) values from all wireless links of WSNs to multiple WDCs, enable qualitative characterization of channel features, including line of sight (LOS) as well as non LOS paths.

4 Results and Discussion

Initial tests aim at determining channel characteristics, such as coherence time and shadowing. Therefore, they are performed without applying external interference. The main goal is to observe and learn the distinctive wireless channel features in an passenger cabin environment.

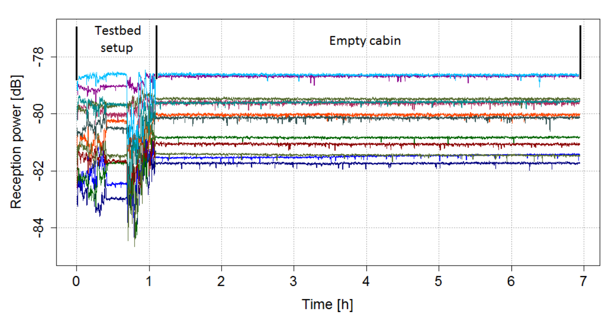

Figure 3: RSSI traces of all WSNs to one WDC, showing multiple reception power levels, caused by dynamic and static shadow fading.

RSSI series of all WSN links to one WDC are shown in Figure 3. Depending on the intermediate distance between WSN and WDC, as well as on the number of obstacles, respectively seat rows, on the wireless link, multiple distinguishable RSSI levels result. Also, some fluctuations in reception power are localized at the beginning of the test, which is due to people setting up the test scenario.

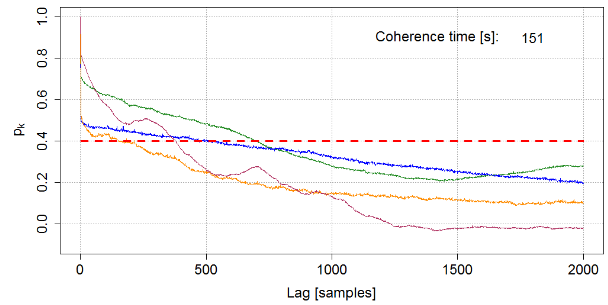

Figure 4: Coherence time analysis for different cabin locations (seats).

By computing the autocorrelation function on different series of measured RSSI values (over the empty cabin part), the channel coherence time can be determined from (1).

$$p_k = \frac{\sum_{t=k+1}^{T}(x_t - \bar{x})(x_{t-k} - \bar{x})}{\sum_{t=1}^{T}(x_t - \bar{x})^2} \quad (1)$$

The RSSI series is denoted as x_t with average value $\bar{x}$, lag k and sample length T. Each series, describing a specific link, exposes how fast the channel becomes uncorrelated. Considering a similarity factor above 0.2 to be significant [3], we set an autocorrelation threshold of $p_k = 0.4$. This corresponds to a minimum time of 151 s, which is referred to as channel coherence time and depicted in Figure 4. As the test is performed on an empty cabin, this value serve as a best case scenario for the system design, indicating the large-scale fading behaviour on the channel.

Regarding the testbed setup part of Figure 3, the correspondences of these power fluctuations on different WSN-WDC links indicate significant spatial correlations within the cabin. These spatial correlations, together with the coherence time analysis of Figure 4 give insights on the characteristics of a cabin propagation scenario. This in turn enables the development of a generalized wireless channel model, suitable for various aircraft passenger cabins. Data gathered by all WDCs for multiple node positions in an occupied cabin (ongoing work) will further improve and refine the model to be applicable for any cabin scenario. Such an empirical model is expected to facilitate a realistic performance evaluation of different resource allocation schemes, based on real test data.

5 Acknowledgements

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