Testbed for Wireless Adaptive Signal Processing Systems

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I. Introduction

Nowadays the investigation of wireless sensor networks' (WSN) application is a relevant research topic, because WSN are utilized with success in various fields [1]. In this paper a testbed is introduced, which can be a common base of current investigations on the applicability of wireless sensor networks in closed loop multiple-input multiple-output (MIMO) control systems. The proposed generic application for testing is an active noise control (ANC) [2] system, the feedback part of which comprises a WSN for sensing the noise to be suppressed. Because of the inherent and inevitable problems of radio communication (e.g. packet loss, uncertainty in data transfer time) the deployment of WSN in closed loop applications is not spread yet [3]. The novel feature of this testbed is that it offers a framework for the investigations to eliminate the disadvantageous effects of radio communication.

This arrangement poses strict demands on the main components of the testbed (WSN and ANC algorithms) for ensuring the overall reliability of the system: the sensor network has to provide efficient data transmission towards the signal processing algorithm, which in turn has to be adaptive for the anomalies in data transfer. Because of the wide variety of ANC algorithms and their particular sensitivity against anomalies in the feedback loop, this system is appropriate for test purposes and comparative analysis of results. Major topics that can be studied in this field with the testbed are summarized in this article.

II. The proposed testbed

The block diagram of the testbed can be seen in Fig. 1. The system basically consists of two units. The main parts of signal processing algorithms are implemented on a DSP evaluation board of type ADSP-21364 EZ-KIT LITE [4], which includes an ADSP-21364 (SHARC) processor. The DSP is a 32 bit floating point one with a maximal clock frequency of 333 MHz. The DSP is connected to an AD1835 codec that has two analog input- and eight analog output channels, through which signal can be fed to the loudspeakers. The relatively great number of output channels ensures the possibility of realization of extensive systems. Other loudspeakers can be utilized to generate external sound/noise for test purpose.

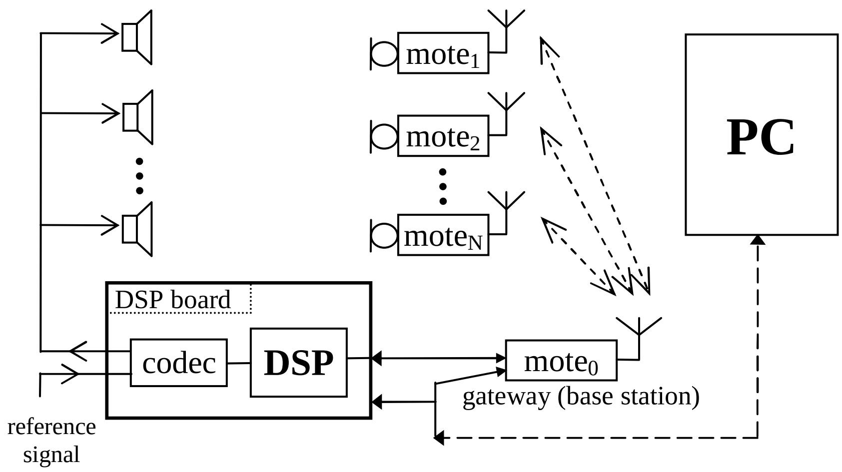

Figure 1: Block diagram of system

The acoustic signal is sensed by the WSN ($\text{mote}_1 \ldots \text{mote}_N$), which is built up of Berkeley micaz motes [5]. These motes are intelligent sensors that consist of an ATmega128 eight bit microcontroller, a CC2420 ZigBee compatible radio transceiver and an MTS310 sensor board. The sensor board includes a microphone, as well, the output signal of which is converted to digital domain by a 10 bit analog to digital converter (ADC) of the microcontroller. A mote ($mote_0$) serves as gateway between the WSN and DSP. The software for motes is developed in TinyOS embedded operating system, but modifications should be carried out in order to decrease the code efficiency.

The PC basically serves as developing and debugging tool for both platforms.

III. Utilization possibilities of testbed

The testbed is suitable for investigating how a WSN can be applied in fast digital signal processing- and closed loop control systems. Topics that can be investigated are listed below:

- Algorithm fitting for specialities of wireless data collections: e.g. handling of data loss and non-equidistant signal transmission are fundamental problems, since traditional algorithms are not prepared for these anomalies.
- Synchronization: crucial task, since the uncertainty in the time instants of the sampling can cause the instability of the whole system. This makes the ANC system appropriate for testing the synchronization algorithms, but the handling of unsynchronized sensors' data on data processing algorithms' side can be investigated, as well.
- Distributed signal processing: the benefit of preprocessing of data is twofold. It can reduce the amount of data to be transmitted, and the extension (e.g. decomposition) of signal processing algorithms on WSN can lead to robust systems, since primary data are processed/transformed (e.g. Fourier transformation) on motes, so primary data loss caused by pocket loss in radio network can be avoided. In connection with this topic, algorithms that work directly on these transformed domain data can be studied.

IV. Results

Recent experiments on the testbed proved its operability, the cooperation of WSN and signal processing algorithm was appropriate. The system contained four motes – operating with the sampling frequency of 1.8 kHz – and four loudspeakers, but the resources make possible further extension of number of the sensors and actuators. As noise source we applied a loudspeaker driven by a signal generator. The noise was measured by an external microphone – placed at the noise sensing sensors – the output signal of which was processed with a digital oscilloscope with FFT function. The noise suppression was nearly the same as in the case we applied wired sensors.

As this example shows the utilization of WSN in closed loop applications can be a feasible goal, and this testbed can serve as a platform for investigations in the field of wireless control. Further investigations will aim at the extension of the system and the reduction of constraints and fault sources emerging due to the wireless data acquisition.

References

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