Keio University

Thesis Abstract

No.

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Title of Thesis:

Multi-Carrier Backscatter Communication System for Concurrent Wireless and Batteryless Sensing

Summary of Thesis:

This research proposes a new multiple access method which enables concurrent wireless sensor data collection from multiple batteryless LSI sensors. This research is advantageous in the applications where long duration of synchronized sensor stream observation is demanded. The typical industrial application arena of the research is the integrity check of civil structures and machinery.

The batteryless wireless multiple access method is realized by employing the passive RFID mechanism to power up LSI sensors by the radio wave transmitted from a Reader/Writer. The radio reflection from an LSI sensor is either analog or digital modulated with an embedded sensor. To separate responses from multiple LSI sensors at the Reader/Writer, a non-orthogonal subcarrier is assigned to each LSI sensor. Although the non-orthogonal subcarriers can be produced only with a constant rate of antenna switching, they suffer from the mutual harmonics because of the physical nature of the signal shape. Because of these harmonics, the simultaneous usage of multiple subcarriers has not been much explored. Since the effectiveness of harmonic rejection method depends on the signal to interference ratio, optimal subcarrier allocation is essential. Therefore, the challenges of this research are two-fold. One is the harmonic rejection and the other is the optimal subcarrier allocation.

To cancel the harmonics, this research proposes a novel harmonic rejection method using digital signal processing with Hilbert and inverse-Hilbert transformation in the Reader/Writer. The method is implemented in a simulation and a prototype system with software defined radio platform LabVIEW and USRP. The method is evaluated with both simulation and physical experiment. It is revealed that the original signal can be recovered with 98 % cross-correlation accuracy even under 0 dB signal to interference ratio condition.

Since the subcarrier allocation is a combinatorial problem, obtaining the true optimal allocation requires vast amounts of examinations which are impracticable in a system where tens of LSI sensors are used. It is particularly evident when the variable distance and the variable bandwidth required by LSI sensors. This research proposes a subcarrier allocation scheme based on a newly invented performance index, total contamination power, to prioritize indecision cases. The

performance of the proposal is evaluated and compared with existing methods in terms of average communication capacity and system fairness using MATLAB Monte Carlo simulation. It is shown that the proposal can produce a subcarrier allocation which is equivalent to that of brute force method. While the brute force demands $O(n!)$ comparisons, where n represents the number of subcarriers, the proposal only demands $O(n^2)$ computations.

The practicality of the proposal is also evaluated in a vibration experiment where the proposal achieves equivalent performance compared with the wired sensors.

Keywords:
Backscatter Communication, Multiple Access, Sensor RF tag, Harmonic Rejection, Subcarrier Allocation