Wireless Sensor Network based on OCDMA for closed environments

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***Abstract*—An infrared optical wireless system is presented, consisting on autonomous remote nodes communicating with a central node. The network is designed for telecommand/telemetry purposes, comprising a large number of nodes at a low data rate . Simultaneous access is granted by using CDMA techniques, and an appropriate selection of the code family can also keep power consumption to a minimum.**

***Index Terms*—Code Division Multiple-Access (CDMA), Optical CDMA (OCDMA), Direct-Sequence Spread-Spectrum (DS/SS), wireless communications, wireless sensor networks (WSN), Random Optical Codes (ROCs), telecommand, telemetry.**

I. Introduction

In the late years, optical wireless has been considered as an alternative to wired and radiofrequency communications. In environments with special restrictions on electromagentic interference (EMI), such as aircrafts or hospitals, this technique provides mobility without affecting other systems' performance. Previous studies [1], [2] have compared the performance of radiofrequency and infrared optical communications, and channel estimations [3] demonstrate that the effect of the channel can be neglected in small environments if chip rates are lower than some hundreds of MHz.

Infrared (IR) systems are commonly used for point-to-point, line-of-sight links. But using Spread-Spectrum techniques, such as OCDMA, independent and simultaneous channel access can be granted for several network nodes [4]. Different code families have beeen proposed [5], [6], [7], each with particular properties that affect system's parameters like the bit-error rate (BER) or the maximum data rate achievable.

In this work a telecommand/telemetry (TC/TM) network consisting on 25 autonomous nodes is described. All nodes are capable of communicating with a central node through a full-duplex asynchronous optical wireless channel.

II. System Overview

The objective of this development is to communicate several nodes in a small and closed volume, assuming traveling distances up to 2-3 meters. The line-of-sight (LoS) is not gauaranteed and working in diffusion is required, as the position of the nodes should be constraint-free. Power needs will also be kept to a minimum, enabling battery operation and long lifetimes. Data rate is 1 kbps, which is well suited for the network purposes.

The large number of nodes in the system (25 units were tested simultaneously) makes OCDMA a good choice to simplify the system design and operation. This technique controls multiple user interference (MUI), making medium access control protocols not necessary to ensure the desired behavior. Furthermore, the system is given a great flexibility to accommodate new nodes without affecting network characteristics such as the bandwidth available. For the intended application, spread-spectrum techniques offer an additional security as all data goes through an encription when transmitted.

Terminal nodes have been implemented using a modular structure to allow an easy reconfiguration to test different target applications. A logic module consisting on a low-power CPLD controls the communication process, data acquisition and the node operation. This module is easily replaceable to allow upgrades if new functionalities are required and a different logic device is to be used. A separate communication module performs the signal conversion from optical to electrical and viceversa, ensuring sent and received signal's integrity. The data acquisition module is beyond this demonstrator's objectives, and all nodes are prepared to simulate both sensor and actuator features by using an user-selectable switch and a RGB LED.

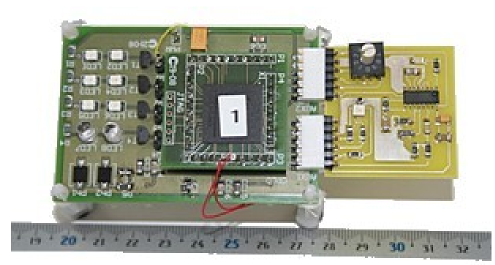

Fig. 1. Node implementation

Central node stores and analyzes all gathered data and controls the communications, requiring bigger processing capabilities than the individual nodes designed. It is based on a commercial control and acquisition system and integrates a microprocessor running a real-time OS with an FPGA backplane to interface with external signals. To simplify the node's operation, channel synchronization is implemented on the central node which stores a delay reference for each terminal node. This delay is updated upon data reception and will be used for transmission to ensure the node can properly recover the data.

Random Optical Codes are used for data coding. As presented in [7], this family has better performance than prime codes for large number of users. A total of 50 codewords are needed to allow full-duplex simultaneous access, 25 for the uplinks and 25 for the downlinks. To obtain a target error probability of 10^{-7}, codes of length $L = 900$ and weight $w = 20$ are required [8]. This means each bit will be divided into 900 slots (named *chips*) and 20 of them will be "marked". Given that the data rate is 1 kbps, the system will be operating at 900 kHz which is well below the limit imposed by the channel response [3] and multipath dispersion effect on the communications can be neglected.

III. Demonstrator

The whole system can be randomly deployed on a table as shown in Fig.2. Central node's emitter and receiver are placed at a variable distance over the table to ensure visibility from all the nodes (which is not necessary in closed environments). Nodes are powered by 2 standard AA batteries (3 V), except for the central node which uses its own power supply unit.

Fig. 2. System overview

Central node provides a system monitor application which allows the operator to inspect the network status and set the data to be sent to each node. All 25 nodes are presented with the actual values coming from the user-selectable switch, and different colors can be selected on the monitor application that will be sent to the node and shown on the attached RGB LED. This way a simple visual inspection is possible over the whole system operation.

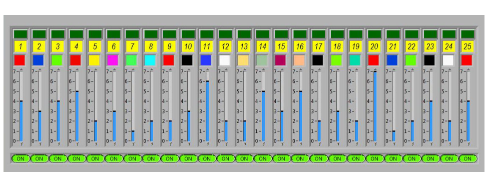

Fig. 3. System monitor application

IV. Conclusions

A test system has been designed and implemented to validate the behavior of OCDMA techniques in closed environments. A broad area is covered and nodes can be deployed in random positions thanks to the diffusive design. Random Optical Codes (ROC) have been tested for environments with a large number of simultaneous users, validating the results from previous simulations and assessing its good properties for these applications. Also, the possibility of dinamically assigning codewords depending on the workload shall be studied to maximize the throughput and optimize the bandwith utilization.

Acknowledgments

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