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A novel transceiver structure including power and audio amplifiers for Internet of Things applications☆

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ABSTRACT

Both of the Circuit and System design aspects of the Internet of Things (IoT) are emerging with computation and communication issues. In communication, it utilizes transceivers like wireless sensor network (WSN). In spite of the conventional WSN, a key component of IoT is its direct engagement with humans (animals). Therefore, communication is required in audio–visual ranges. This means an IoT device (IoTD) will be ported with audio amplifiers. This paper presents a novel IoT transceiver with a reconfigurable PA-CDA with time-domain and task-oriented multiplexing. The run-time reconfiguration of an area-power-efficient common part is utilized. The topology and scheduling issues of the Bluetooth Low Energy (BLE) standard are well-suited to the proposed architecture. Time, energy, and protocol concerns are studied and appropriate models presented. The PA and CDA operate in the 2.4 GHz and audio-range frequencies, respectively. The battery life and power consumption are improved by about 40% and 20%, respectively.

1. Introduction

Nowadays, cyber-physical systems and cybernetic applications have developed enormously. Cybernetics is defined as “the science of communication and control in the animal or HUMAN and MACHINE” [1]. On the other hand, cyber-physical systems, with their wide range of definitions and applications, such as smart grid, process control systems, and distributed robotics, are growing and expanding rapidly.

In this field, some systems, such as biological, physical, mechanical, and social ones, are studied in order to analyze a closed signaling loop. In this way, changes in the system mode can change its environment and these variations are reflected in the system. In other words, the cybernetic system can be modeled as a feedback system. In this model, persons or animals play the feedback block role. In order to get an idea of this definition and new concepts (applications), all the communication concepts are shown in Table 1.

As depicted in Table 1, four types of communications are defined. All of them are considered to be cyber-physical system compliant (CSC). The implantation layer of MAN–MAN communication is recognized as the mobile network (MN) and the MACHINE–MACHINE connecting layer is known as WSN. However, the MAN–MACHINE and MACHINE–MAN implantation layers have not been defined yet. MAN, in Table 1, is defined as a man or an animal that interacts with a network and MACHINE as a network, protocol, or machine.

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Table 1
Cybernetic aspect of cyber physical system.

Control (computation) & communication	MAN 	MACHINE 
MAN 	CSC/MN[1]	CSC/NA[2]
MACHINE 	CSC/NA[2]	CSC/WSN

Legends: 1: Mobile Network 2: Not available

Table 2
Comparison of CMOS CDA-PA.

Ref	Year	Tech [nm]	CDA based structure	PA based structure	Normalized Area	Frequency range
[20]	2012	180	✓	✗	1	Audio (<20 KHz)
[21]	2015	180	✓	✗	1	Audio (<20 KHz)
[22]	2010	180	✗	✓	1	RF (2.4 GHz)
[23]	2010	130	✗	✓	1	RF (1.8 GHz)
Proposed CDA-PA(at high level)		180	✓	✓	0.7	Audio (<20KHz)+RF (2.4 GHz)
Proposed CDA-PA(at low level)		180	✓	✓	0.7	Audio (<20KHz)+RF (2.4 GHz)

The IoT, with its diverse area of applications, is growing rapidly. It is predicted that 25–30 billion related devices will be in the market within 2020 [2]. The IoT is a network of objects that interacts with each other through a local or global network facility. This network is, optimistically, a progressive higher mode of the WSN. The WSN application contains nodes that are connected to each other under a certain protocol. Inherently, each WSN node works with its counterpart or sink nodes and does not interact with people or animals (i.e. machine-to-machine connectivity). The need for some applications to fill this gap has led to the invention and extension of IoT gadgets in recent years.

According to the literature, several transceivers were studied and investigated. In [3], a low-power transceiver is presented, which utilizes a novel MAC scheme to achieve a better duty cycle in the transmitter and receiver. A cloud-based model is presented in [4]. In this work, a framework is used by a scalable cloud. A fully integrated CMOS transceiver is used in the GFSK modulator in [4].

In [5], a transceiver with digital modulation for IoT applications is proposed. A regeneration receiver is introduced in this reference. In [6], an asymmetric transceiver intended for use in a capsule is introduced. Here, different blocks of transceivers and receivers are designed and various techniques used to decrease the power consumption of the transceivers. In [7], a method for fault detection is presented. In this manner, the best route for signal delivery is created to decrease the energy consumption of the transceiver.

On the other hand, a lot of research has been done on micro-sensor networks in the fields of circuits and systems. At the system level, several studies have focused on routing and flow-control algorithms that enhance the quality of service (QoS) [8]. According to the literature, the idea behind transceiver design is to utilize the network layer. In these types of transceivers, humans or animals are not incorporated in the communication, although, in a lot of IoT applications, MAN is an important part of the communication. Therefore, it seems inevitable to have a new version of the transceiver structure design. The conventional transceivers are designed for MACHINE-to-MACHINE communication. However, different IoT applications are needed to utilize audio amplifiers in a divergent spectrum to cover MAN-to-MACHINE communication. Such audio amplifiers are utilized after A/D as distinct elements. Meanwhile, in many IoT applications, the audio amplifier is an inseparable part of the transceiver structure. So, the transceiver structure should be redesigned to fix this defect. Any technique that passes the standard verification, decreases power consumption, and improves the performance of IoTDs is desired. The main characteristics of a transceiver in IoT applications are an appropriate data rate and playable audio signals. In addition, it must be mentioned that we do not need a high-quality audio signal.

Transceiver system improvements are needed to decrease power and area requirements. A lot of critical blocks are used in this system, including Radio-Frequency Identification RFID elements, amplifiers, smart sensors, smartphones, etc. Multiple protocols and standards are used in IoT applications; therefore, the operating frequencies should be flexible. Various protocols and standards demand attention in the IoT; so, it is important to design new structures that satisfy all demands and features. The most important characteristics of the IoT system are designated in two different frequencies: audio and radio. On the other hand, PAs and audio amplifiers should have high efficiency to ensure a long battery life in both modes. Therefore, a reconfigurable power amplifier (CDA and PA) that can be optimized for different frequencies is required.

In this paper, we work on some devices that are connected with each other and, at the same time, these devices may relate to their counterparts or to a person or animal. We should note that each communication has different standards. The