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i-IronIC RTD 2010

Long-Distance Wireless Links for Sensor Applications

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Abstract – Wireless communication simplifies data transfer in sensor networks and allows for building mobile sensor nodes. Due to their world-wide availability and reliability, cellular networks are highly suitable for realizing the data-link. Although the sensor's data-rate is low for most applications, using today's high data-rate standards such as 3G and 4G is advantageous in terms of power consumption. We present general considerations on the power consumption of a wireless sensor node and a prototype of a biomedical sensor node using a 3G modem.

Modern multi-mode transceivers and base-band modems are complex systems-on-chip (SoC) which cover multiple standards in different frequency bands. All over the world, more than 40 different service bands are assigned to cellular phone networks and are expected to be serviceable with a state-of-the-art mobile communication device. When operated in a power efficient way, such devices are suited for sensor networks as well, because they can bridge a wide distance and be adapted to variable data transfer demands.

Power Consumption

Most wireless sensor systems are powered by batteries or solar cells. Therefore, power efficiency is a major design aspect. While low-power solutions, consuming only tens to hundreds of milliwatts, are available for sensors and control circuits, the better part of the energy-budget is burned up for the wireless link, which when active consumes several watts.

In many applications, real-time data reception is not a necessity. Thus, energy savings can be achieved by reducing the duty-cycle (DC) of the transceiver (Fig. 1). To do so, the data-rate of the employed modem must be considerably higher than the one of the sensed signal.

The drawback of DC reduction is an increasing memory size. Since random access memory (RAM) has a considerable static power consumption, the power savings due to the lowering of the transceiver's duty-cycle is compensated or even exceeded by the power consumption of the RAM (Fig. 2). The optimum choice of transmission standard and memory size is strongly related to the sensor's data-rate.

i-IronIC Sensor Node Scenario

To demonstrate the transmission of sensor data over the cellular network as communication link, the development of a wearable sensor node central station which collects data from different implanted sensors and transmits them over the cellular network, has been carried out (Fig. 4). To reduce the power consumption, the data is compressed and stored such that a low DC can be achieved.

An early prototype (Fig. 5) was built with a commercial 3G modem. A biomedical sensor front-end application-specific integrated circuit (ASIC) which was recently developed at ETH in another project is used for the data generation. The digital signal processing and control circuit is implemented on a field programmable gate array (FPGA) evaluation board. The prototype forwards the collected data to a specified server. In our setup, the server application runs on a laptop and displays the received data on a graphical user interface (GUI) (Fig. 3).

In future, the evaluation board will be replaced by a power-efficient own design, which reduces the central sensor node significantly in size and allows it to be powered with a lightweight lithium-ion battery, resulting in a wearable system.

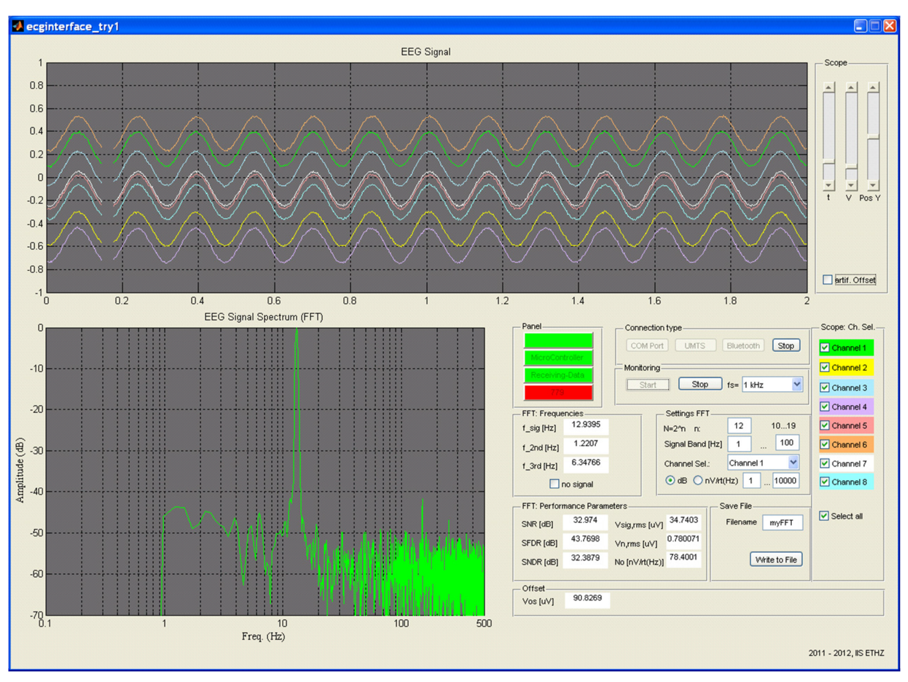

Fig. 3: GUI plotting the signals received over the 3G link on a laptop acting as server.

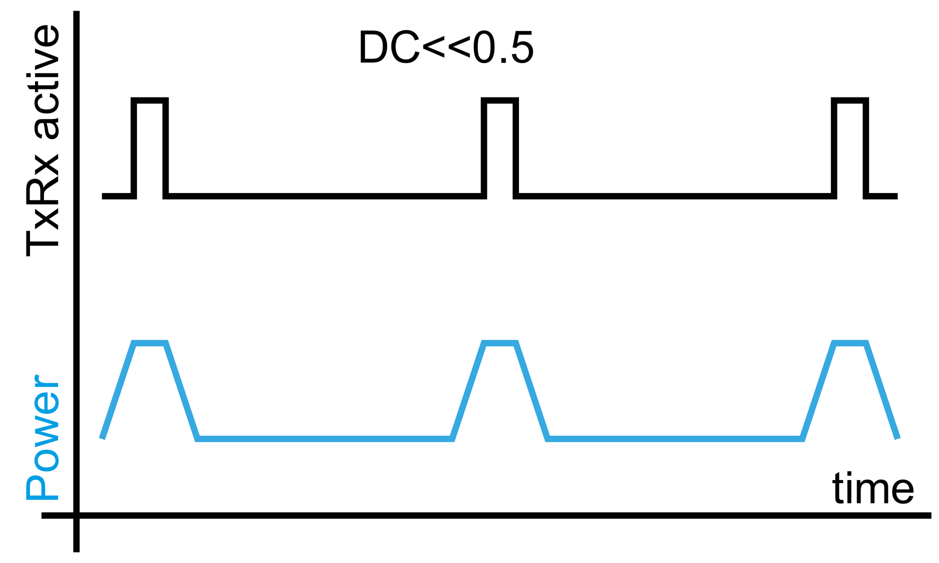

Fig. 1: Since a high data-rate transmitter allows to transmit more data in the same time, the duty-cycle (DC) of the system, i.e., the time fraction during which the transceiver (TxRx) is active, can be reduced. Since the transmit power is of the same order of magnitude for 2G, 3G and 4G systems, employing a considerable faster 3G or 4G modem for applications which — in terms of data rate — could also be realized with 2G allows a significant reduction of the overall system's power consumption.

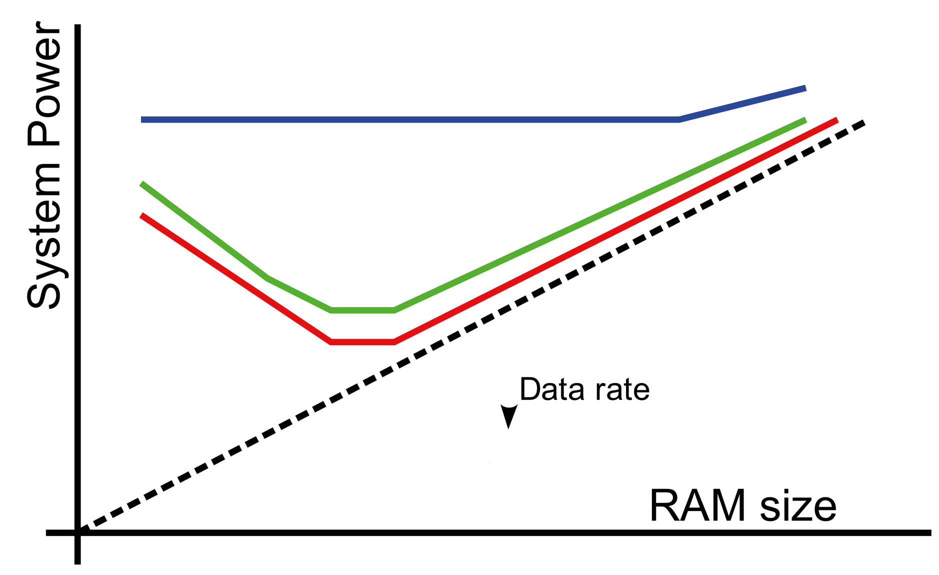

Fig. 2: Reducing the transmission duty-cycle requires data storage which causes additional power consumption. For RAM, the power consumption is proportional to its size, i.e., the storage capacity. The figure shows the trade-off between minimizing the average power of the radio by enlarging the system's memory and the increasing energy consumption of the memory itself. The blue curve represents a sensor node operating with a low data-rate transmitter: Its radio is always on, therefore it does not benefit from increasing RAM size. The red and green curves represent a system with the same sensor but using a high data-rate modem. They can reduce the power to a certain optimum value which is generally not defined by the transmission speed but more so by the memory's power consumption.

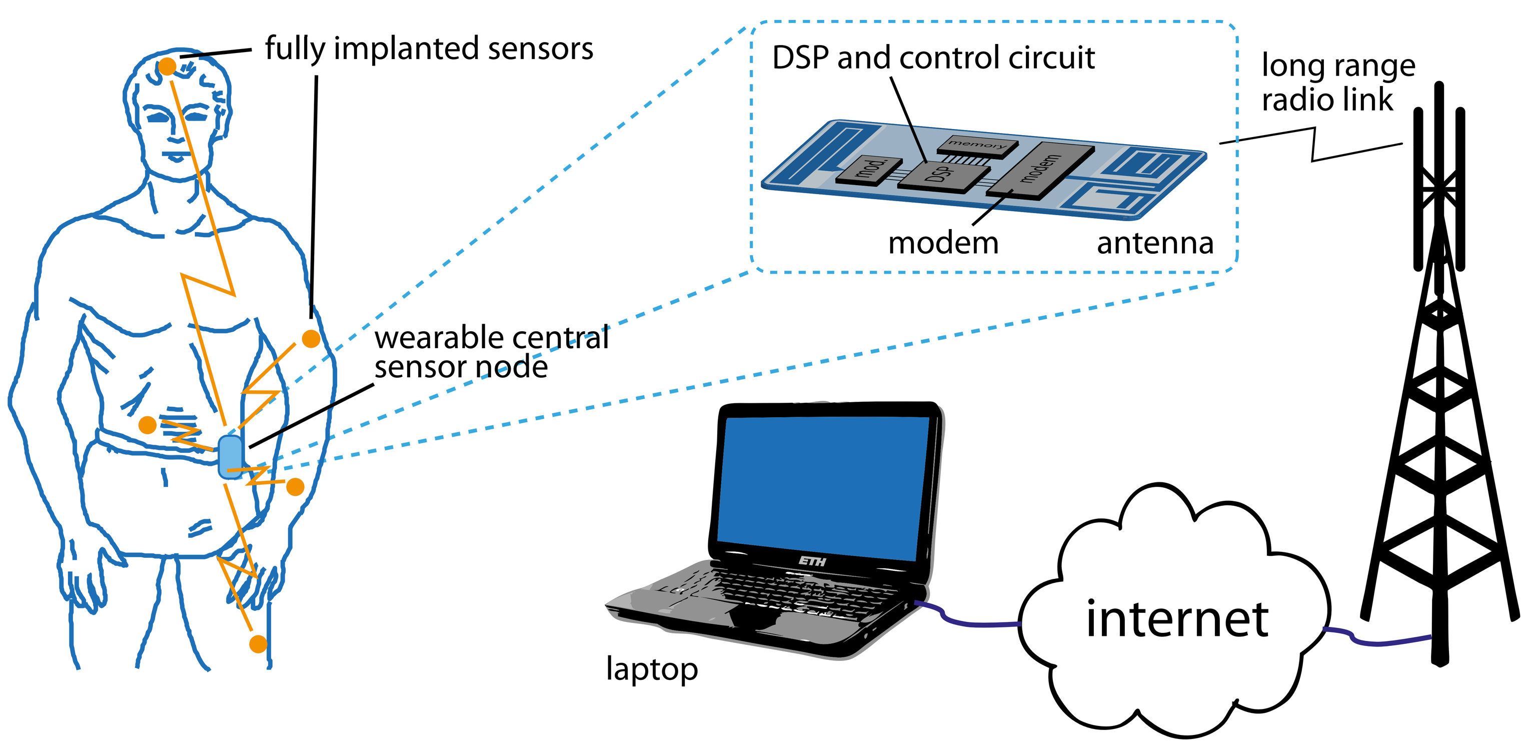

Fig. 4: i-IronIC system concept: a wearable central sensor node collects data from different sensors over a body area network. The sensed data is then processed and temporarily stored in a memory prior to being forwarded over a long-distance radio link to a central monitoring station.

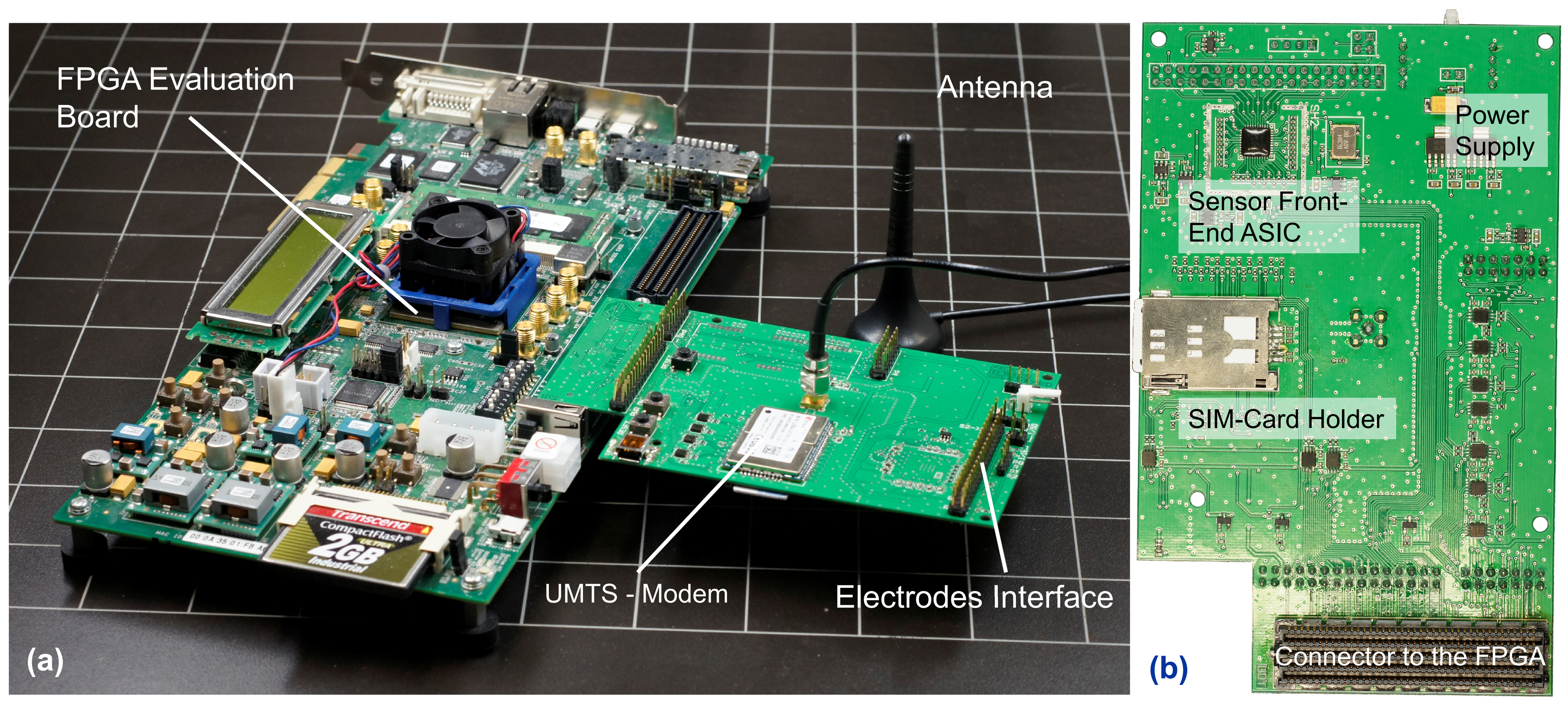

Fig. 5: Early prototype of the demonstrator: An FPGA evaluation board is used for the control circuit, while a commercial UMTS modem and a biomedical sensor front-end ASIC are mounted on a separate printed circuit board (PCB) attached to the evaluation board (a). The bottom side of the PCB carries the SIM-card holder, the sensor front-end ASIC, and some power supply circuitry (b).