Demo Abstract: ZigBee-Based Platform for Energy Efficient Buildings

Cengiz Gezer[1] Chiara Buratti[1] Armando Visconti[2] Riccardo Ukmar[2] and Roberto Verdone[1]

[1] WiLab - DEIS at University of Bologna
V.le Risorgimento, 2, I-40136 Bologna, Italy
{cengiz.gezer,c.buratti,roberto.verdone}@unibo.it
[2] ST Microelectronics, Design and Industrial Center Castelletto
Via Tolomeo, 1, I-20010 Milano, Italy
{armando.visconti,riccardo.ukmar}@st.com

Abstract. In recent years, studies on the energy efficiency in buildings have widely attracted the attention of researchers. In order to reach the optimal management of energy consumption, deployment of sensor devices, that can measure the power consumed by appliances, is crucial. The project eDIANA, funded by the EC through the ARTEMIS framework, focuses on this target. According to the eDIANA application scenario, sensors are distributed over *cells*, that are apartments or working units, and send data to a concentrator, denoted as Cell Device Concentrator (CDC). In this demonstration we have considered a wireless sensor network, composed of IEEE 802.15.4/ZigBee devices transmitting data to the ZigBee coordinator, located inside the CDC. SPEAr600 and Freescale boards are connected to constitute a prototype CDC. Multi-hop ZigBee networks have been formed and latency measurements conducted in different number of hops. The realized prototype provides a basis for the development of the eDIANA platform.

1 The eDIANA Project

The eDIANA (Embedded Systems for Energy Efficient Buildings) project [1], funded by the European Commission within FP7 through ARTEMIS, addresses the need of energy efficiency in buildings through innovative solutions based on networked embedded systems. The main goal of eDIANA is to achieve efficiency in the use of energy resources. The main elements of the eDIANA scenario are the cell, that could be a single house, an apartment or working unit, and the macro-cell, that is a group of cells. Each macro-cell identifies the contract with the energy service provider. Both the cell and the macro-cell are managed by a Cell Device Concentrator (CDC) and a Macro-Cell Concentrator (MCC), respectively. Wireless sensors are distributed in the cell, to measure the energy consumed by appliances, or detect events (e.g., the arrive of a person in a room). The CDC collects the data received from sensors and sends them to the MCC. The latter implements the control strategy to optimally manage energy consumption and take decision on how and when to supply energy to cell.

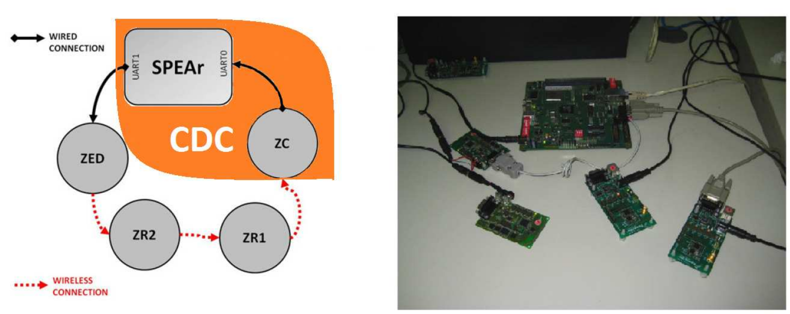
2 The Demonstrator: SPEAr^{TM} and the Multi-Hop ZigBee Network

In this demo application, a cell is considered and a ZigBee network is assumed to be used for monitoring. A prototype CDC device is developed by using the ST SPEAr600 and Freescale 13192-EVB evaluation boards.

The SPEAr600 is a highly integrated eMPU with flexible memory support, powerful connectivity features, programmable LCD interface and high-performance dual 32-bit ARM926EJ-S CPU cores. The SPEAr600 is a versatile device which supports a wide range of embedded applications and for programming in Linux, board support packets are available based on STLinux distribution.

IEEE 802.15.4/ZigBee compliant devices produced by the Freescale have been used to form the multi-hop network. IEEE 802.15.4 is a short-range communication standard suitable for wireless sensor networks. The 802.15.4 standard only defines the protocols for the physical and MAC layers, whereas the upper layers are defined by the ZigBee Alliance [2]. ZigBee Specifications allow mesh and tree-based topologies and defines three device; ZigBee Coordinator (ZC) which is the owner of the network, ZigBee Routers (ZRs) which can relay messages and ZigBee End Devices (ZEDs) which behave as leaves in the topology without routing capabilities. As ZED, Freescale 13192-SARD board and as ZC and ZRs, 13192-EVB boards have been used. These two boards contain MC13192 transceiver which operate in 2.4 GHz ISM band. During the experiments default transmit power of 0 dBm and ZigBee 2007 stack developed by Freescale is used.

In our demonstration the ZC located as a part of the CDC since in eDiana scenario all the information coming from ZEDs and ZRs should be gathered in CDC. This has been done by connecting the 13192-EVB board, which functions as ZC, to SPEAr600 board through the UART (Universal Asynchronous Receiver-Transmitter) interface. These two boards together are constituted the CDC. After, by including different number of ZRs to the network in between ZED and CCD, different number of hop routes are created.



(a) (b)

Fig. 1: Three Hops; (a) Connection Diagram (b) Hardware Setup

3 Latency Measurements in ZigBee

Data coming form specific sensors requires to be received by the CDC with small delays, since the CDC has to take immediate actions. Therefore, the evaluation of performance in terms of latency, is essential. In order to measure latency we have also connected the ZED to the SPEAr600 through another UART interface and we generated the data to be transmitted from ZED with the command coming from SPEAr600. Therefore, in the demo SPEAr600 sends a command through UART1 to the ZED, and the ZED starts transmission of the packet to the next hop (see Figure 1). Passing after the ZRs the packet is received by the ZC and sent to SPEAr600 through UART0. The code that runs on the SPEAr600 keeps the time between the instance when the command is written to the UART1 and the instance when the packet from UART0 is received.

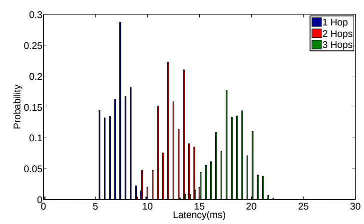


Fig. 2: Latency Measerements

In Figure 2 the discrete probability distribution of the packet latencies are shown. In the one-hop case the distribution of latencies is almost uniform since the ZED uses CSMA/CA and randomly chooses the backoff duration within a given window (generally denoted as contention window). On the other hand, in two- and three-hop cases the lobes of distributions get wider because of the increasing number of hops. During the experiments size of the physical layer protocol data unit (PPDU) was 35 bytes. We have not used reliable transport in ZigBee Application Layer (APL).In the demonstration different sized packets will be forwarded in the ZigBee network and latencies in different network traffic conditions will be visualized on a PC connected to SPEAr600.

4 Acknowledgment

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References

1. eDIANA, Artemis Project, http://www.artemis-ediana.eu/
2. The ZigBee Alliance web site: http://www.zigbee.org/en/index.asp