Combining the KNX and an IEEE 802.15.4 based wireless system to build a Context Aware System

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Abstract:
In the present time there are new trends in the area of information technology. A keyrole plays the so called pervasive computing. As a result of the enormous increase of performance of the processor- and storage technology while simultaneously reducing the weigth, volume and power consumption extremly, the computers become virtually invisible and ubiquitous.
The area of prevasive computing requires a rethinking in information technology. This in particular deals with the ubiquitous information. The point is to provide the situation-, time- and location dependent information for everyone, everytime and everywhere.
The emergence of the mobile, wireless and ubiquitous computing has made it necessary to develop a highly-dynamic infrastructure that enables clients to discover and utilize the services of interest, devices proposing those services to advertise them to the network, and a network to automatically detect the services that have become unavailable.
This paper deals with the development of a distributed system composed of computers, sensors, actuators and intelligent agents to adapt services and ressources to the actual situation of one or several users. The base for the contextual services are on the one hand the location and on the other hand environmental criteria like temperature, loudness, illumination, the number and identification of the involved persons etc.
Keywords: KNX, 802.15.4, ZigBee, context adaptive system, context-awareness, ubiquitous computing

1 Introduction

For a long time it is to be observed that the cross-linking of systems in the personal surrounding field increases strongly. At first computers were connected with printers. In the course of the time several computers over high speed Internet connections were interlaced. Now the trend appears, systems such as air conditioning systems, heaters, refrigerators, lighting systems, sensor systems, etc. to also integrate into these networks. This development continues within many ranges. Computer systems penetrate so increasingly our living and supply themselves quasi “everywhere“ and “always“ with services and information. These data form the basis for the so-called context-aware system. That essentially means that

- Information and services are implicitly adapted to the situation of a user. This concerns the processing and representation of the application data as well as the handling of the locally available devices.
- Services are executed quasi automatically or are adapted as a function of the special situation.
- Information could be aggregated for a later processing to derivate behaviors.

The goal of this project, which is outlined further, is to develop a distributed system of networked computers, sensors, actuators and intelligent agents to make situation-, time and place-dependent relevant information available for “everyone“, “at any time“ and “everywhere“.

2 System concept

In the following two typical applications for a Context Aware system are described.
In figure 1 two rooms are illustrated, which are coupled with one another over the Ethernet. In each area a so-called „Room Controller“ is placed. It is configured that a radio network is provided als well as EIB. Over the wireless network a Switch Remote Controller as well as a Motion Sensor are tied up. Over the EIB, switching actuators, a shutter control or a multimedia playback unit as well as a Switch Load Controller are tied up. With the help of this simple

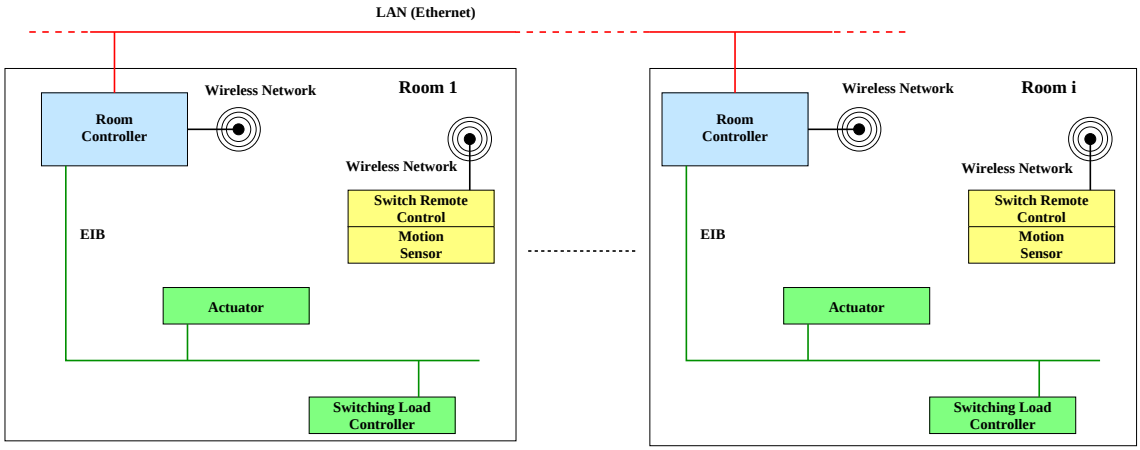

Figure 1: Overview of system concept

configuration now it can be clarified, that devices merge themselves into the everyday life:

- The motion sensor determines whether a person is present in the area and even identifies if necessary this over other procedures. With these database supported information, scenarios can be called up. E. g. the light can be switched automatically as a function of the identified person, brightness or time of day. Further dependence are conceivable. Additionally it is possible to play the favourite music of the person, while in another area the light is switched off and no music is to be heard.
  It is now possible that the music follows the person through the house dependent from her position.

- In another example it could be possible to show all services available within a room on the display of a PDA. For example the PDA, located in Room 1, indicates the number of lamps and further devices that are available and how to control this services, e.g. which lamps are to be switched or dimmed or how to serve the multimedia playback unit.

The number and variety of sensors depend strongly on the complexity of the context-aware system. In the case, if many sensors are to be integrated, the binding takes place by special wireless technologies. Within this range special radio nets have themselves established, the so-called Sensor nets

3 Sensor Networks

Wireless sensor networks penetrate our life due to the reducing dimensions and the increasing perfomance. They are utilized in many applications in the private surrounding field, in medical range, in the goods economy etc. The application of the so-called Personal Area Networks (PAN) is associated with some conflicts. Because of the constrainsts of the wide spread application areas a compromise between organization, security power consumption and bandwidth must be found. The IEEE 802.15.4 represents a capable solution to penetrate the market.

3.1 IEEE 802.15.4

The IEEE 802.15.4 protocol stack defines a communication standard for radio networks. The development initially started by Philips Electronics in the year 1998. The standardisation was completed in 2004. Transceiver-Chips of different companies are avaiable. The use of IEEE 802.15.4 aims mainly at the market of the sensors. This standard isn't suitable for transmitting large or even multimedia contents. The IEEE 802.15.4 has following features:

- up to 2^{16} different devices per channel
- up to 27 channels in the 3 frequency ranges (2.4 GHz(worldwide), 868-870 MHz (Europe/Asia) and 902/928 MHz(America/pazific area)), max data transfer rate of 250 kbps
- low requirements due to the connected devices (8 Bit Micro controller unit, protocol stack only up to 37 KByte)
- possibility to handle time-critical data in beacon-enabled networks
- low latency
- low cost devices: available from 3 Euro/piece
- low power loss: max. current lower than 20mA 1.8V

The IEEE802.15.4 is a very simple and efficient protocol. It has only 26 primitives (for example: Bluetooth embraces 126 primitives).
This protocol describes two layers: The MAC Layer and the Physical Layer (see figure 2). The Physical Layer layer contains the sending and receipt components, briefly the actual physical binding. Other features concern the activation and deactivation of the transmitter/receiver and the selection, scanning and examination of the physical channels. The MAC Layer is responsible for the beacon control, channel access, frame examination etc..
The IEEE 802.15.4 standard differentiates between two device classes, which differ mostly in the communication capabilities: the so-called Full Function Devices (FFD) and Reduced Function Devices (RFD). FFDs are able to communicate both with other FFDs and with RFDs, while RFDs exchange information with FFDs only.
As fundamental topologies star and Peer-to-peer networks are available (see figure 3).
A special role becomes a PAN coordinator: In each network type (star or Peer ton more peer) always one FFD assumes central control functions. This node is responsible for the synchronisation by dispatching beacons. Furthermore the PAN coordinator can take the role of a router.

3.2 ZigBee

The ZigBee network Layer is attached to the IEEE 802.15.4 protocol stack. ZigBee includes the topologymanagment, MAC managment, routing, discovery protocol and security managment. Additionally the ZigBee protocol contains the application interfaces for the device profile which

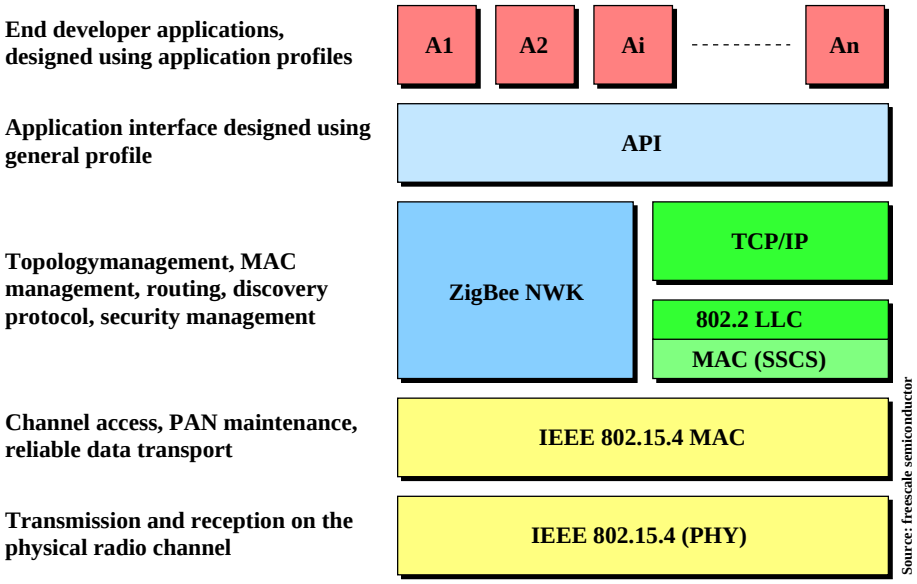

Figure 2: Overview of the protocol stacks

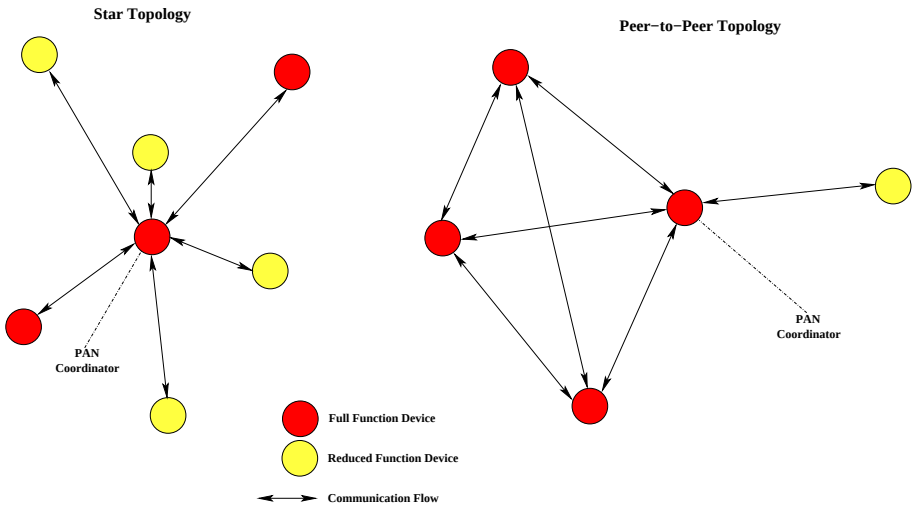

Figure 3: Stern-and Peer-to-peer Topologie at the IEEE 802.15.4

provides the description and interaction for ZigBee devices. The profiles are divided into areas of application e. g. home automatiotion (lighting, heating, ventilation, climate, ...) and consumer electronics. By this grouping and definition it is possible that different devices of different manufacturers can work together and exchange data and control instructions.
Furthermore ZigBee offers a new feature: the so-called service discovery. It is possible to query devices about their attributes and features and to configurae it over the network.

4 Stucture of the System

4.1 Hardware Structure

For the structure of the complete system the following components were used:

UNC20 The UNC20 is a member of FS Forth-Systeme's family of modular solutions for embedded systems. Typical applications include industrial automation systems, medical instrumentation, retail point-of-sale scanners, data acquisition systems. This controller board is characterised by the following capabilities:

- NetSilicon's NS7520 microcontroller
- up to 16MBytes SDRAM, 32-bit wide, up to 8MBytes Flash memory, 16-bit wide
- PHY for 10/100 Ethernet
- the embedded operating system is μCLinux

Programs are written in C and C++ and compiled with the GCC for the ARM 7 processor family.

DIG536 The DIG536 is a demostration board from Freescale. This board essentially consists of the MCU MCHCS08 and the tranceiver module MC13192 (Figure 4). Both units are coupled over one serial connection (SPI). The network protocol and the applications are processed by the MCU. For the implementation of the programs the Codewarrior development tool of Metrowerks is used.

KNX/EIB components The KNX/EIB components are linked with a BCU1 connected to the second serial port of the UNC20 Modul

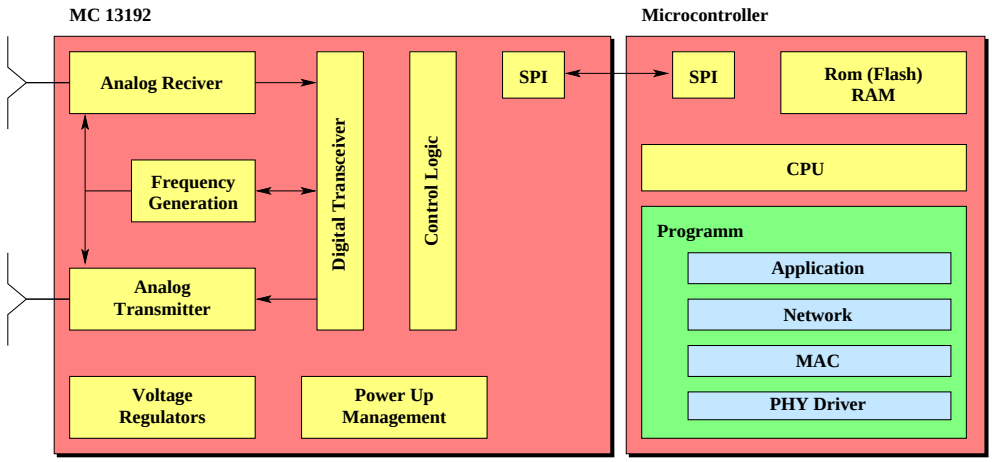

Figure 4: Block Diagramm for the MC 1392 in an application

4.2 Software Structure

The process stucture is split into three layers. The main layer is the Logical Layer. He is completely independent of technology and is responsible for the routing, expiry control and scheduling. The Process Layer realises the gateway processes to adapt the different technologies. At the moment processes for EIB, 802.14.5, TCP/IP are implemented. An adaptation to

other communication standards are slightly possible. The lowest layer is the hardware layer and provides the ports for the different technologies.

4.2.1 The Logic Process

The logic process is responsible for the routing, the expiry control and scheduling. In this case routing encloses the reception and distribution of the eventstasks on the different ports (EIB, etc.). The scheduling is reponsible for executoin of time-steered tasks (unique or repeating). The process works on the database (table Actions!) cyclically and looks for new entries or due scheduling orders. If an entry is found, the process comes along to determine the purpose. In

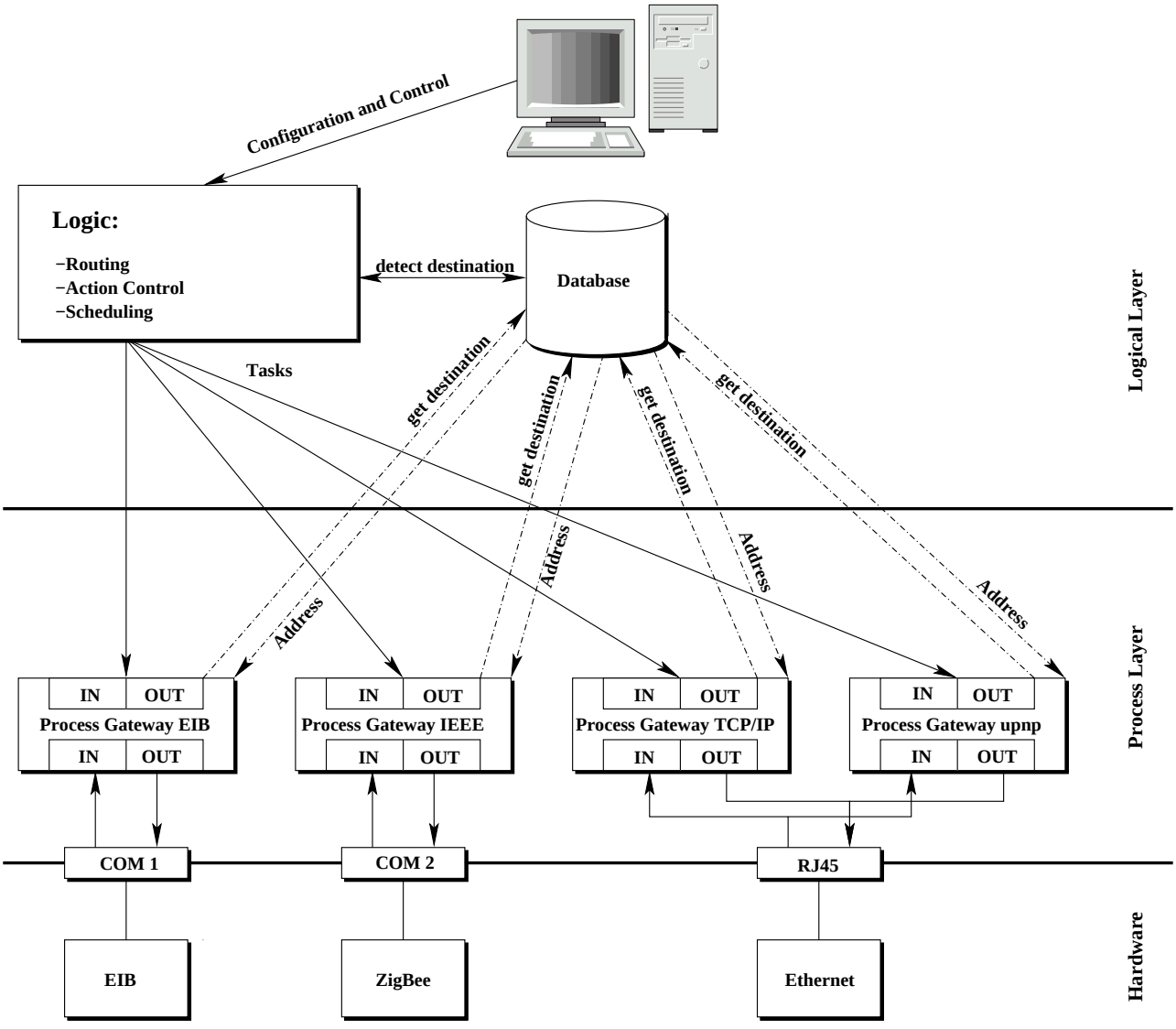

Figure 5: Process structure

the following he searches the routing table(!) for the source address. If no address could be found, the process creats a new entry, which must be bind to the corresponding destination. If the address exist, the destination is selected and a link to the data base entry is transmited to the dedicated gateway process. This process construct a data packet specific for the protocol,

extracting the relevant information out of the data base and dispatch it over the bus.

4.2.2 The Process Gateway-IEEE

This process accepts data packets of the serial interface, extracts the information and insert them into the data base. In the followiing the Logic Process handles these entries. The Gateway-IEEE process receives his tasks from the Logic Process. To be able to construct the data packet, he gets a reference from the Logic Process to the entry in the data base. The complete data unit is sent over the serial interface to the IEEE 802.15.4 hardware for further processing.
The other gateway processes (EIB, TCP/IP) are same from the expiry and, therefore, are described not further.

4.2.3 Structure of the data base

In this project the free database SQLite (open SOURCE) is used. It is developed for embedded systems, supports most usual SQL instructions, has a program size of 30KB. The database can handle up to 2 terrabyte of data.
The structure of our database contains a table for each supported protocol (802.15.4/ZigBee, EIB, TCP/IP). Each table contains the protocol specific information. The tables stores informa-

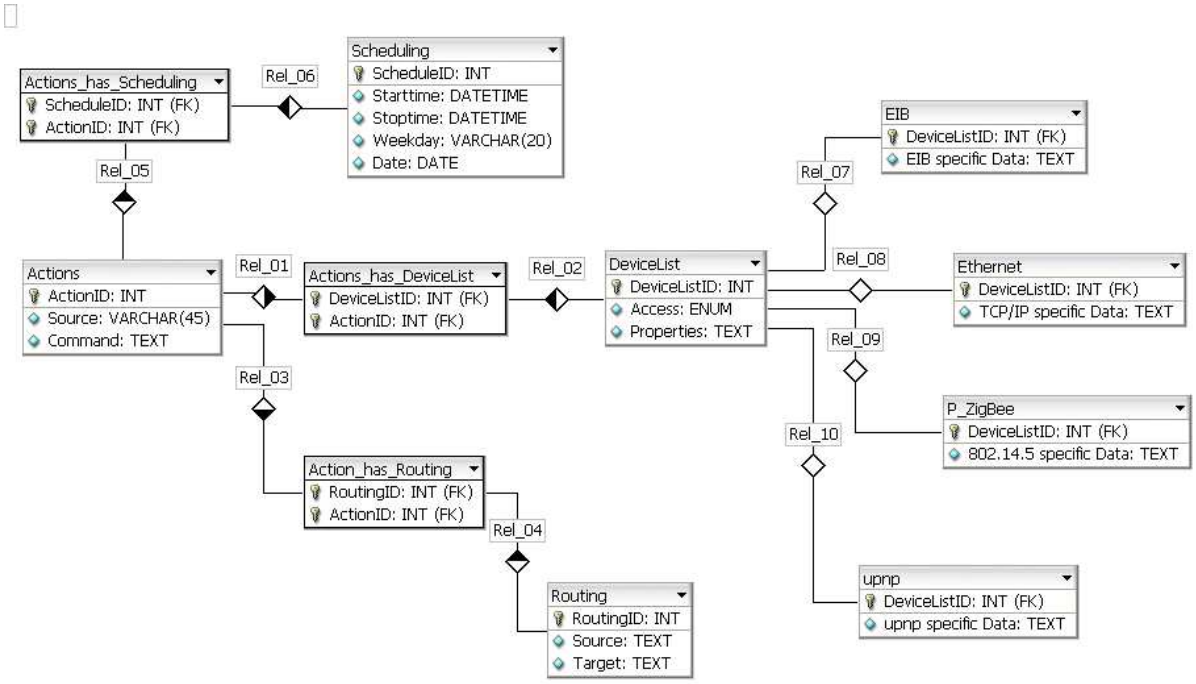

Figure 6: Simpified structure of the database

tion about

- The services
- The incoming events
- The routing

4.3 Case study

The processes, like the Gateway-IEEE, Gateway-EIB ... get their information from the connected devices. Each device sends only the source and some ”specific” data. The processes write this event into the database. The Logic Process gets the new entry from the database and checks the source. Now this process will try to find a destination. This combination will be adjusted by the user or system operator once. If the Logic Process finds a destination in the database it gets the destination information too. These informations are the special parameters for the destination device. For example: The command ”Light on” has another structure for a IEEE 802.15.4 device than a EIB device. With the correct information (or a reference to this) the right process will be activated (Gateway-IEEE for IEEE devices, Gateway-EIB for EIB devices...), gets the data and sends it to the destination device.

5 Conclusion and Future Work

The result of the project is a complex hard- and software library to connect an EIB with an 802.15.4 based radio network as a basis for a distributed context-aware system. The selected design is so flexible and the used hardware components are so powerful that the integration of further communication protocols is problem-free possible.
We are currently implementing different service discovery protocol suites that enables clients to discover and utilize the services of interest and allows devices proposing those services to advertise them to the network.

References

[1] Ian F. Akyildiz et al., *A Survey on Sensor Networks*, IEEE Communications Magazine, pp. 102-114, August 2002

[2] Vasughi Sundramoorthy, Hans Scholten, Pierre Jansen and Pieter Hartel, *Service Discovery At Home*, University of Twente, the Netherlands

[3] Eiman Elnahrawy and Badri Nath, *Context-Aware Sensors*, EWSN 2004, pp. 77-93, 2004, Springer-Verlag

[4] Frank Siegemund, *A Context-Aware Communication Platform for Smart Objects*, PERVASIVE 2004, pp. 69-86, 2004, Springer-Verlag

[5] www.unc20.net

[6] www.ieee.org

[7] www.zigbee.org