Smart-Its on the Internet – Integrating Smart Objects into the Everyday Communication Infrastructure

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INTRODUCTION

The demonstration scenarios described in the following sections show how mobile phones can be used to interact with Smart-Its by using short text messages (SMS messages) and the public GSM infrastructure. They give examples of how Smart-Its can access services provided by the everyday communication infrastructure, e.g. Internet and GSM services, and how smart objects can collaborate with mobile phones and PDAs. Furthermore, it is shown how a simple location service for Smart-Its can be implemented by combining Smart-Its and passive RFID tags. We also show how mobile phones can be used as mobile infrastructure access points for Smart-Its.

As an increasing number of consumer devices are equipped with Bluetooth, the Bluetooth-enabled Smart-Its prototypes, which are used in the following settings, are particularly suitable to access these kinds of devices. The Bluetooth-enabled Smart-Its can access the services of consumer devices invisibly for users as well as use the devices to trigger or notify people.

Smart Product Monitoring

In this demonstration scenario, Smart-Its are attached to sensible products, which are damaged or destroyed when certain physical parameters exceed predefined thresholds. In order to symbolize the fragility of products, an egg carton was used and augmented with a Smart-Its. The Smart-Its monitor physical parameters and derive the state a product is in. To keep the demonstration simple, only three states are considered: OK, damaged, and destroyed. These states are calculated on the basis of available sensory input.

When there is a state transition, the product sends a short text message to a mobile phone via the background infrastructure. The SMS message can be processed automatically – for example by the supply chain management software of the company the product belongs to – or be sent to a worker in the nearby environment to inform him about a problem with the product. The SMS message contains a short description of the problem (for example: "Product x has possibly been damaged.") and a number of commands that can be sent to the product, i.e. to the Smart-Its that is attached to the product. Supported commands include a history and a reset command. Using her mobile phone, the user activates the commands she wants to send to the product and replies to the received SMS message. Thereby, the phone number of the smart object is implicitly given because of the reply. The reply SMS message is received by an access point near the Smart-Its and distributed to the Smart-Its itself, which executes the command activated in the SMS message. Afterwards, consecutive SMS messages can be sent between user and augmented object.

As smart objects often need to interact with persons in their nearby environment, the question arises how they can find persons to interact with and how to determine the number of the mobile phone to which SMS messages are to be sent. Here, the concept of symbolic location rather than physical coordinates seems to become important, because "nearby environment" usually means "the same room" or "the same building". In this slightly modified scenario, people are identified by their mobile phones, which we assume they carry around all the time. When the phone is Bluetooth-enabled, Smart-Its could determine the presence of phones by using the Bluetooth inquiry procedure. However, as radio waves penetrate walls, this procedure is not suitable to find people that share a specific symbolic location such as the same room. Therefore, we favored a hybrid approach that combines Bluetooth and RFID technology. We assume that all smart objects and telephones have RFID tags attached that contain service parameters of the objects they are attached to. Service parameters describe how to access the device. When persons enter a room, their devices are scanned by an RFID tag reader. For the demonstration, a wireless tag reader was built that broadcasts service parameters over Bluetooth into the environment, i.e. to the Smart-Its and an infrastructure access point. The infrastructure access point stores the tag information into a tuple space in the background infrastructure. When a smart object needs to send a notification to all mobile phones in the environment, the phone numbers of all mobile phones in a room are determined by the background infrastructure and an SMS message is sent to these phones.

Remote Interaction with Smart Objects

When a user wants to initiate an interaction with a smart object via SMS, a different approach than in the previous section is necessary because an interaction can be started while the user is far away from the object itself. Each smart object is assigned a phone number and a set of commands the object can process. Technically, this was done by implementing an access point for smart devices that maintains a serial connection to a mobile phone; data received by this phone are processed by the infrastructure access point. The access point transfers received SMS messages and embedded commands to all interested parties.

Only one mobile phone is required for many augmented objects; the phone number of this mobile phone is the phone number of the objects.

Figure 1: Phone book entries (1) and a list of SMS templates for smart objects (2), an edited SMS template with activated command (3), and the response SMS message (4)

However, this phone number and the commands that can be sent to the objects are initially unknown to users. Therefore, a user once must have been in the proximity of an augmented object. When a user comes into the communication range of a smart item, phone book entries for the smart objects are sent to the phone (which must support Bluetooth) using AT commands. Furthermore, an SMS template is written to the phone, which contains the commands the smart object supports. When far away from the object itself, the phone book entry and the template can be used to interact with the object. The SMS template contains a range of commands, which the user can activate with minimal effort. When a smart object has processed the commands embedded in an SMS message, it uses the infrastructure access point to send a response message back to the user's phone. Figure 1 shows an example of this kind of interaction.

Mobile Phones as Mobile Infrastructure Access Points for Smart-Its

In order to implement sophisticated services with the Smart-Its, they often need access to an infrastructure that provides services and powerful resources. However, access points to the infrastructure are often fixed and not available when needed. As an increasing number of mobile phones support Bluetooth, these phones can be used as access points for the Bluetooth enabled Smart-Its. The main advantage is that mobile phones, which are carried around by their users, are always available when an interaction is to take place or access to resources and services is needed. Therefore, in this demo setting Smart-Its are attached to sensible products and send SMS messages over a Bluetooth-enabled mobile phone in range to a background infrastructure. In a supply chain management scenario, a lorry driver could be given a Bluetooth-enabled mobile phone and smart products could inform their owners when they are damaged. Today’s tracking solutions also monitor products but information about physical parameters are only read out at certain locations. When a product informs the company that urgently needs this product when the damage occurs during transport, this could lead to a significant improvement of the supply chain. Damage of products can be determined during transport and a new product can be ordered instantly. Here, a company can communicate with the object during transport and observe the transport; it can also access history information of the product.

Technical Realization

The main components in the demonstration settings include two Bluetooth-enabled mobile phones – the R520m from Ericsson and the Nokia 6310i – and a Bluetooth module connected to a stationary PC that functions as Bluetooth access point for Bluetooth-enabled Smart-Its. Also, a Bluetooth-enabled PDA – the iPAQ H3870 – together with a small RFID reader is used as wireless RFID scanner. Furthermore, Bluetooth-enabled Smart-Its prototypes and several small RFID tags are used for the demonstrations. Figure 2 shows some of the components.

Figure 2: Some of the devices used in the experiments – a Bluetooth-enabled mobile phone (1), RFID tags (2), a Bluetooth access point (3), a Smart-Its (4), a Bluetooth-enabled iPAQ (5), and an RFID scanner (6)

Phone book entries and SMS templates are transferred to mobile phones by sending AT commands over a Bluetooth connection.

On the hardware side, the fixed infrastructure access point consists of a Bluetooth module connected to a PC with Internet connection and a mobile phone, which is connected to the PC via serial line. Smart-Its and other Bluetooth-enabled devices communicate with the infrastructure via the Bluetooth access point. When data are transferred over Bluetooth to the access point, they are processed by a Java program that stores received information into a tuple space. Services in the background infrastructure are implemented on the tuple space and made available to the smart objects via the Bluetooth access point.

The infrastructure access point also enables the Smart-Its to send and receive SMS messages. By using a separate mobile phone connected to the access point, SMS messages can be sent and received and can be easily processed by the background infrastructure. SMS messages are sent and received by transmitting AT commands to the phone. A Java program in the background infrastructure controls these processes.

Furthermore, the access point is used to write SMS templates and phone book entries to Bluetooth-enabled mobile phones over a Bluetooth connection.