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THE APPLICATION OF BLUETOOTH IN THE SMART-ITS SENSOR NETWORK

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Abstract

Using reduced power and likely without the support of a central system, potential ubiquitous computing devices would need to connect with other smart devices in an ad hoc manner. However, in the area of ubiquitous computing, no single communication system has so far developed itself: many existing wireless communication systems appear to lack robustness, use too much electricity, or need networks to be a viable contender. We have incorporated a Bluetooth module into the first prototype of a distributed sensor network node, built within the European Smart-Its research project, to test the suitability of the latest and promising Bluetooth protocol for certain connectivity requirements. Although Bluetooth allows stable and easy ad hoc communication, preliminary studies indicate that better support for symmetric communication and slave-to-slave communication may benefit from the Bluetooth standard.

Keywords: *Frequency Hopping Spread Spectrum (FHSS), Logical Link Control and Adaptation Protocol (L2CAP), RS232, Smart-Its, UART, USB.*

I. INTRODUCTION

Everyday objects are augmented with computational and connectivity technologies in the vision of ubiquitous computing to make them "smart." Although such items maintain their original use and appearance, their augmentation will boost and extend their use effortlessly, opening up new interaction patterns and applications. The aim of the Smart-Its project is to bring smartness to real-world. While a single Smart-It is able to perceive background data from its embedded sensors, through exchanging this knowledge, a federation of ad hoc linked Smart-Its can acquire mutual understanding [1]. Sharing knowledge requires adequate networking equipment, which, in order to be compatible with the unobtrusive design of the applications, can ideally be wireless. Because in a Smart-Its sensor network there is no central authority, nodes within the network must therefore be able to communicate in an ad hoc way, i.e. without previous knowledge of each other and without the assistance of a context infrastructure (however they may consume services when available) [2]. In addition, connectivity technology must be stable, scale well and utilize the autonomous device's limited resources effectively. Finally, the networking technologies employed should conform to a commonly used standard to take advantage of current environmental communication facilities. These needs have sparked a hunt for the Smart-Its sensor network to find a suitable connectivity technology. We agreed to take a closer look at the new Bluetooth standard as a possible candidate after a quick survey of the current technologies.

Bluetooth is an evolving networking protocol that offers ad hoc configuration of at most eight working units of master/slave piconets [3]. It facilitates random relations between devices without needing knowledge of each other a priori. Bluetooth facilitates data sharing between systems over a nominal distance of up to 10 metres. Both piconet users share the gross data speeds of 1 Mbps. In the license free 2.4 GHz ISM range (2.400-2.484 GHz), Bluetooth works and uses frequency hopping spread spectrum (FHSS) to mitigate concerns of interference [4]. The technology is geared towards low energy consumption and addresses the retail consumer market with low costs and worldwide supply. We have designed a small number of Smart-Its prototypes with Bluetooth communications to investigate the realistic application of this networking technology and to determine its suitability for ubiquitous computing in general and the Smart-Its project in particular [5]. While the usable prototype helped us to get a clear first look at the use of Bluetooth in custom-built applications, the lack of support in our pre-series Bluetooth modules for many of the key features did not enable us to obtain final results in terms of its suitability. Instead, in the future, we expect to do more tests, ideally with more advanced components from a variety of different manufacturers.

The Smart-Its Prototype:

In a post-hoc way, the purpose of the Smart-Its initiative is to incorporate "smartness". By adding lightweight, unobtrusive, and autonomous computing devices to them, it aims to embed computation into real-world objects. This products, the Smart-Its, combine technologies for sensing, encoding, and connectivity that can be applied to the objects to which they are connected [6]. While a single Smart-It is able to perceive background data from the embedded sensors, through exchanging this knowledge, a federation of ad hoc linked Smart-Its can acquire mutual understanding. Thus, a federation of Smart-Its augmented objects may construct a shared context that can be used by environmentally positioned applications and services [7]. In an anti-credit-card fraud mode, for example, implementation scenarios of mutual knowledge of Smart-Its have been identified where a Smart-It-enabled credit card only operates if a large amount of Smart-It-enabled personal objects such as clothes or car keys are present, making the card worthless when lost or stolen. Our specifications for a Smart-It node will be described in the next pages, defining the components incorporated into our first prototype and giving an overview of the circuit board and system software of the device.

Components:

Commercial Bluetooth solutions are available as transceiver modules that are self-contained. They are shielded subsystems designed for use as peripherals for add-ons. They have an integrated CPU, various memory types, as well as baseband circuits and radio circuits. The modules include the lower layers of the Bluetooth protocol tack with a common Host Controller Interface (HCI), while the higher layers of the protocol, as well as software, and must be implemented on the host device [8]. Even a limited standalone Bluetooth node also requires an extra host CPU to run applications and the related higher levels of the Bluetooth protocol, because the in-system CPU and memory are not usable for downloading user-specific implementations. For UART, RS232, and USB, the transport layers for connectivity between the Bluetooth module and the host device are standardized. Tech tests of the Ericsson ROK 101 007 module were the only units usable at the time (January 2001). We picked the Atmel ATMega103L microcontroller as our host CPU to run the higher Bluetooth protocol layers and applications. With an 8-bit RISC core with up to 4 MIPS at 4 MHz, a serial UART as well as multiple control modes, the unit is in-system programmable. 128 Kbytes of Flash memory and 4 Kbytes of internal SRAM make up the embedded memory. Up to 64 Kbytes of data memory can be enlarged, using only two external elements, the SRAM and an address latch. External memory is explicitly addressable, i.e. without paging, by the 16-bit data-memory address bus. While a less powerful processor with less memory could have theoretically have transmitted sensor information to the Bluetooth module, we opted to use a more powerful device to allow more complex pre-processing on-board.

System Software:

In C, the device functionality is introduced, providing low-level drivers, a basic scheduler (which facilitates application activity incident-driven arrangement) and the Bluetooth protocol stack host component. For all UART ports, analogue to digital converters, general purpose IO, random number generator, system clock, and sensors, there are system based drivers. A single open source and many commercial versions of the host component of the Bluetooth stack are available at the time of project launch (January 2001). There were very high system specifications for the commercially available software stacks, both in terms of required operating system features (particularly multi-threading) as well as programme and data memory provisions. The introduction of open source was geared at Linux environments and microcontroller specifications were also not taken into account [9]. Previous computing experience, however, has shown that roughly 2 Kbytes of storage memory would be adequate for limited deployment, much of which is used as buffer space. We chose to use the open source implementation because all options were similarly acceptable (or very inappropriate), not least because of its immediate availability. From the open source Linux implementation to our microcontroller environment, we ported the host portion of the Bluetooth protocol stack. Funded layers are HCI and the Logical Link Control and Adaptation Protocol (L2CAP). The Linux version of the Bluetooth stack includes multi-threading and serial port access capability. In our scheme, the scheduler and the low-level drivers take control of these tasks. The restricted memory space of the microcontroller was the key hurdle in the porting process.

II. DISCUSSION

How well is today's Bluetooth adapted for ad hoc networking? Bluetooth is the first de-facto interface for ad hoc networking, brought on by several independent organizations in a collaborative endeavor. It was originally developed as a technology for cable replacement and can function well in that domain of use. Its peculiar architecture, however, makes it less ideal for other implementations in the ad hoc networking domain. In addition, the industry continues to have trouble providing modules with the quantity and consistency that the consumer requires. The first products were released at the end of 1999, and only appeared at the end of 2000 [10]. And when we began our project in early 2001, vendors continued to offer pre-releases of their Bluetooth modules that were not yet completely designed to the standard.

III. CONCLUSION

Several variables have led to the tremendous exposure that Bluetooth has gained in recent months. As one of the first international standards available, using the piconet connectivity model, it simplifies ad hoc networking considerably. Bluetooth systems can be used world-wide without modifications by using the publicly accessible ISM band. The technology of frequency hopping makes transmissions strong against narrow-band interference (which might be frequent within the ISM band). While Bluetooth modules are currently very costly, prices are expected to drop to approximately USD 5 per device once full-scale mass production runs. Future Bluetooth modules (i.e. entirely designed to spec) are initially planned as a cable replacement technology and would be better adapted for situations where a strong master computer (usually a laptop, PDA or cell phone) connects effortlessly to a variety of peripherals (e.g., a printer, mouse OR keyboard). With data speeds of up to 1 Mbps, for ubiquitous computing devices such as basic sensor networks, Bluetooth often provides more than adequate bandwidth.

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