μParts: Low Cost Sensor Networks at Scale

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ABSTRACT

This paper presents the μPart wireless sensor system especially designed for settings requiring a high population of sensors. Those settings can be found in actual research of indoor activity recognition and ambient intelligence as well as outdoor environmental monitoring. μParts are very small sensor nodes (10x10mm), with wireless communication, enabling the setup of high density networks at low cost and with a long life time. Basic configuration capabilities like sensor type and sampling rate provide enough flexibility while keeping the system easy to deploy and affordable at the same time.

Keywords

low cost wireless sensor network, particle computer

INTRODUCTION

Networked sensor systems have attracted more and more attention in the last years. Various systems were developed in research and industry (e.g. Motes, Smart-Its, EYES, Ember, MITes, U3, BT-Nodes). The typical architecture of those systems includes wireless sensor nodes that typically communicate over multi-hop radio links. The embedded microcontroller often preprocesses the data or takes over important tasks of the applications distributed across the network. These systems aim to support research in various disciplines such as healthcare, environmental monitoring and ubiquitous computing in general. In the latter they typically support monitoring and tracking of people and objects and their activity or interaction.

DENSE SENSOR NETWORKS FOR RESEARCH

Taking a closer look into the typical use of the above mentioned sensor network in nowadays, activity recognition and ambient intelligence [1] are the major use cases of sensor networks for indoor setting. Outdoor settings mostly focus on large area coverage with multi-hop communication. For both fields of application, it is of high interest to increase the number of independent sensors above a critical number. The authors of [1] could track people and recognize their activity using very simple sensors that only distinguish between binary values such as “moving” and “resting”. They concluded that the algorithms would work more robust and accurate once the number of sensors is significantly increased. This aspect of research using dense settings of sensor networks promotes a *new and alternative system design* of a sensor network, that focuses more on these requirements and reflects the experiences researchers have collected with existing sensor networks.

For large-scale and dense real-world deployment of a sensor network, some properties of the individual sensor nodes and the system as a whole must be rethought. In [2] the authors implemented a sensor node system only transmitting RF pulses according to the intensity of movement. While this is extremely bounded to one application, researchers require more flexibility. We now summarize the important features to realize a setting that exceeds the experiments possibilities with nowadays available sensor networks.

- **Low price**. Sensor networks are today available for typically between 100€ and 200€ per sensor node. Settings that use more than 100 sensor nodes quickly produce investment costs that prohibit to carry out the desired research or require to reuse a set of sensors for different purposes. Therefore, the target price for a single sensor node should be significantly reduced. The μParts have a target price of around 15€ per node.
- **Limited computation.** Even though most of the sensor networks available today carry a programmable microcontroller, the local capability of computation is often only used for data transport. The application software often requires complex data processing that is typically implemented on high performance machines like desktop PCs.
- **Configuration.** To realize a flexible system that can be used in various settings for different purposes, a certain minimum capability of configuration is essential. This configuration normally includes solely the choice of sensor and the sensor’s sampling rate.
- **Simple sensors.** The complexity of an individual sensor can often be balanced out by the use of many simple sensors. Theses simple sensors cut down the cost and also produce very easy to interpret data.
- **Long lifetime.** Especially large scale settings with high numbers of sensor nodes involved require a long life

time. A setting with e.g. 1000 sensor nodes running for several years with an individual sensor node lifetime of one year would in average require 3 battery replacements per day. This is unacceptable especially for highly embedded settings where sensor nodes are integrated into furniture or placed in other difficult to reach locations.

- **Topology.** The optimal topology for a sensor network is very application dependent. Nevertheless, in many settings the radio distances are small enough that multi-hop communication is not necessary. It is also possible to separate the sensor nodes from the pure networking nodes and build a system of sensor nodes and additional routers. The ratio between the costly routers and the sensor nodes is typically very small.

The above mentioned properties are crucial for research that requires large settings and/or dense sensor node population. Nowadays sensor networks provide capabilities for settings where nodes are mobile and need to transport data over a long distance via multi-hop communication. However, most of the technical features are not continuously used in the deployed systems resulting in unnecessary higher costs and size of the single network end-points. It also negatively affects the overall lifetime of such sensors. As a consequence, the computational power and communication capability is then often artificially reduced by introducing sleep times and low duty-cycle TDMA protocols.

µPart: THE TECHNICAL SYSTEM

With the µPart-System, we present a sensor network that is built on a minimum hardware and software basis. This system just fulfills the minimum requirement to enable research supporting the above mentioned areas. The small and cost-efficient design enables large-scale settings with high sensor density, but without the need of a high monetary investment. The capability of reconfiguration promotes it for the flexible use in research and opens up a wide area of use cases.

The µPart sensor node (Figure 1) comprises a PIC microcontroller with 1.2k Flash ROM and 64 byte RAM, two sensors, RF transmitter and a battery integrated on a 10x10 mm PCB footprint. Current sensor configuration are light, tilt, temperature, motion and acceleration. The communication interface transmits sensor data with 19.2 kBit/s in the European 868MHz ISM band.

Figure 1: A µPart Sensor Node (1 cm³ incl. battery)

The µPart sensor nodes are supported by a network of routing nodes as depicted in Figure 2.

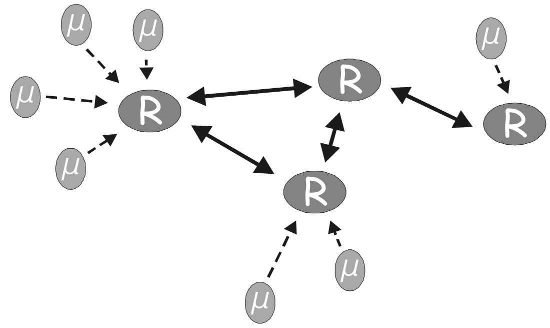

Figure 2: The µPart network topology, consisting of µPart end-nodes and routers

The routers implement the communication for data transport and self-organizing overlay functionalities. They act like a traditional sensor network with out-sourced sensors. The µParts as well as the routers encode data as strictly-typed tuples using our ConCom [3] language. This typing allows the integration of µPart networks in heterogeneous settings where applications benefit from µParts' dense sensor information as well as from other sources. The µParts seamlessly integrate into the particle computer[1] network.

REMOTE CONFIGURATION OF µPARTS

With the use of the light sensor on the µParts, configuration is possible through the transmission of modulated light. This modulated light can be produced by a flickering image or short video played on any screen of a PDA, computer or DVD player etc. The µPart is then simply held in front of the screen and can receive the modulated light transporting the configuration information. This also enables a mass configuration of the µPart System by simply shining on a large group of µParts with a modulated light source (such as a computer screen). The use of a screen as configuration interface has the advantage of ubiquitous availability and needs no extra hardware avoiding any compatibility problems.

REFERENCES

1. D.H. Wilson and C. Atkeson. Simultaneous Tracking and Activity Recognition (STAR) Using Many Anonymous, Binary Sensors. Proceedings of PERVASIVE 2005, Munich, Germany, May 2005
2. J. Paradiso, M. Feldmeier. Ultra-Low-Cost Wireless Motion Sensors for Musical Interaction with Very Large Groups. Presented at the UBICOMP 2001 Workshop on Designing Ubiquitous Computing Games, Atlanta GA, Sept. 2001.
3. A. Krohn, M. Beigl, C. Decker, P. Robinson, T. Zimmer, ConCom – A language and Protocol for Communication of Context, Technical Report ISSN 1432-7864 2004/19

[1] http://particle.teco.edu

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DEMONSTRATIONS DESCRIPTION

Title:

µParts: Low Cost Sensor Networks at Scale

Project Description (100 words max):

Demonstration of the µPart system, a very small and low-cost sensor network

PRESENTATION HISTORY

- Christian Decker, Albert Krohn, Michael Beigl, Tobias Zimmer
The Particle Computer System [pdf]
IPSN Track on Sensor Platform, Tools and Design Methods for Networked Embedded Systems (SPOTS). Proceedings of the ACM/IEEE Fourth International Conference on Information Processing in Sensor Networks 2005, Los Angeles, USA

- Michael Beigl, Albert Krohn, Tobias Zimmer and Christian Decker:
Typical Sensors needed in Ubiquitous and Pervasive Computing [pdf]
First International Workshop on Networked Sensing Systems (INSS) 2004, Tokyo, Japan, June 22-23. 2004, pp 153-158

The demonstration shows a technology, which is a further development of the particle computer system. It is especially targeted to settings with high density and reduces the cost and physical size significantly. The µPart System has not been shown before in public.

ENVISIONED INTERACTION

1)

People visiting our demo will be able to interact with the sensor nodes. They will be able to take them in their hand and watch e.g. sensor values on a screen in real time.

We give examples how the small sensor nodes can be embedded into objects.

For the practical management of visits, we plan to have a good number of µPart sensor nodes (>20) to hand them out to interested people. We will have several screens to show the sensor data of the nodes.

The configuring with the help of a screen will also be shown. Here, a visitor takes a µPart sensor node and holds it in front of a screen to change the configuration of the µPart. The screen (laptop) will play a small video with flickering light. This light can be detected by the µPart's light sensor and be interpreted as configuration information.

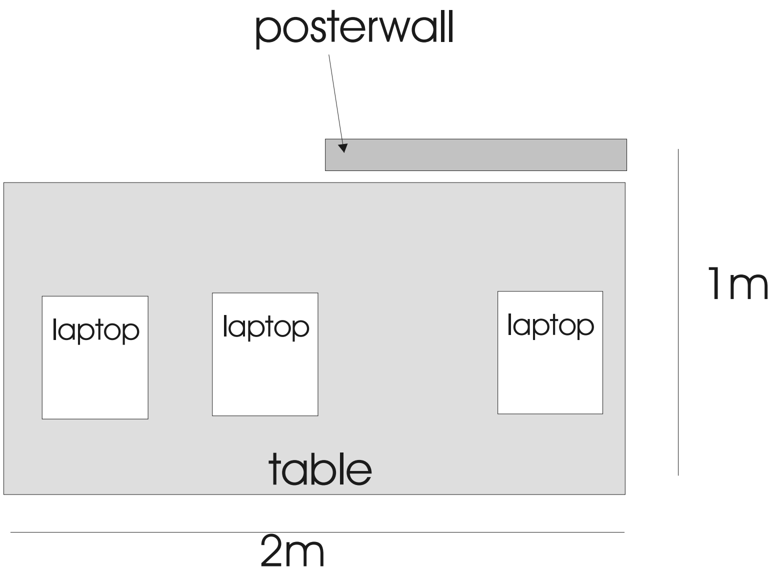
Optional 2)

We plan to extend the demo to a larger scale such as to cover the major conference area with wireless infrastructure of the µPart system. People carrying a µPart node can continuously be monitored and can watch their sensor values over a complete day. This will show the usefulness of the platform for longer-term experiments and give the people already an idea of how sensor values change during different activities of a conference day.

Figure 1: A µPart Sensor Node (1 cm^3 incl. battery)

TECHNICAL REQUIREMENTS

Floor Plan



The power outlet for the laptop can be at any point on or above or below the table. No special requirements. Internet access is necessary. As the demo is based on battery-powered objects, no further power outlet is necessary.

Space

The demo will require the mentioned space for a table plus some surrounding space for people standing and interacting with the system.

Acoustical

Noise is no issue. We will not produce any special sound nor is sound crucial to us.

Lighting

Nothing special. Normal in-door conditions.

Time

In the case 2) of the envisioned interaction, the demo would run during the whole conference.

For case 1): people can watch and interact with the system and catch the major ideas within one minute. The technology of sensor networks is nothing new to the community. Only the size and some technical innovations.

Computational Equipment

The demo will include three laptops and a bunch of small sensor nodes.

Networking

Wired internet connection is necessary. The typical bandwidth is very low. Latency is not critical.

RADIO FREQUENCIES

The demonstration works in the European ISM Band @868 Mhz. Although this frequency is not ISM band in Japan, we collected information on the band usages and license issues. The µPart system falls under the “low power” licensing for japan and will therefore not cause any interference with any other users of the band as the radio of the µParts can only propagate some meters.

POWER

Two plugs for laptops.

POSTER

Typical poster size ~(1x1m). We will mount the poster on the poster wall behind the table