# Delft University of Technology and Berkeley Wireless Research Center (UC Berkeley)

Research Exchange Proposal
Henk Sips, March 2001

## Overview

We propose an exchange between Koen Langendoen, a postdoc in the Ubicom project at Delft University of Technology and the Berkeley Wireless Research Center (UC Berkeley) headed by Jan Rabaey.

Koen would work as a visiting researcher within the PicoRadio group for 3 months in summer 2001 (June - August). Work concentrates on developing distributed localization algorithms for wireless sensor networks.

## Description of the sending institute

The Parallel and Distributed Systems (PDS) group at Delft University of Technology is headed by Henk Sips. The PDS group participates in the multidisciplinary Ubiquitous Communications (UbiCom) research program aiming at specifying and developing wearable systems for mobile multimedia communications. At present, approximately 28 people, including faculty, grad students, and programmers, are involved in Ubicom.

Ubicom currently depends on a fixed infrastructure supporting mobile communications (i.e. a network of base stations). We like to extend the domain of Ubicom to include ad-hoc peer-to-peer communications. This calls for the development of small radio systems that can be part of small light-weight wearable systems.

## Description of the receiving institute

The Berkeley Wireless Research Center (BWRC) is a research unit operating as a part of the Electronics Research Laboratory in conjunction with the department of Electrical Engineering and Computer Science at the University of California, Berkeley. Research activities are directed by the scientific directors (professors

Robert Brodersen and Jan Rabaey). BWRC employs over 250 people itself and collaborates closely with researchers and technicians from leading wireless companies (Ericsson, Lucent, etc.).

BWRC is organized as a number of specific research groups addressing different aspects of the design of wireless communication devices. The PicoRadio group, which is most relevant to Ubicom, explores issues related to design and implementation of a prototype PicoNode. This includes: exploring the application space for PicoNode, examining communication vs. processing cost tradeoffs and task partitioning related to issues such as resource assignment and power consumption, developing interconnect mechanisms between macro circuit blocks at the electrical level (timing and meaning of signals between blocks), and building a single-chip implementation.

# Description of the postdoc

Koen Langendoen is a postdoc with ample programming experience in wired and wireless communications; he has (co-)authored many papers in this area. Within the Ubicom project he works on the Quality of Service aspects of wireless communications, in particular, on the trade-off between performance (throughput, bit-error-rate) and cost (power). He also supervises the construction of a pocket-sized experimental platform based on a low-power StrongARM processor, which will be used to measure the behavior of power-aware applications in a realistic setting.

Koen is about to become a faculty member. He would like to extend his Ubicom activities to the challenging domain of wireless sensor networks, in which low-power becomes even more important and self-configurability is a mandatory requirement. To realize his ambitions he has submitted a research proposal for the "NWO's vernieuwingsimpuls" (a Dutch program funding fundamental and innovative research).

# Research exchange plan

The improvements in digital circuitry technology allow for the integration of sensors, processing, and wireless communication onto a single chip in the near future. The resulting wireless sensors will be small, cheap and employed in large-scale networks for monitoring and control of the environment. Several well-known universities in the USA are working hard to achieve single chip integration by 2002-2003. Currently multi-chip prototypes, including the PicoRadio by UC Berkeley, are available in the labs.

Koen would like to get hands-on experience with the PicoRadio. In particular, he is interested in the problem of localizing individual sensor nodes in a large-scale network. Knowing the position is important for two reasons: 1) sensor data without a proper location is worthless, and 2) positioning information is very helpful for routing messages in the network. In return the network plays a crucial role in establishing the position of its nodes. The large number of nodes (hundreds, may be thousands) requires that nodes are capable of configuring themselves with little external help. Individual sensor nodes will be limited in their capabilities, leading to inaccurate positioning. By communicating information with their neighbors, however, much better (relative) positions can be obtained. For example, by measuring the strength of the incoming radio signals, a rough estimation of the distance to the sending node can be obtained; by combining multiple readings from different nodes a 3D-position can be computed (tri-angulation).

The inter-play between communication and positioning algorithms is a research area that is largely unexplored. Key to success is combining information from different sources (multi-modal sensor processing) and different nodes (collaboration). Exactly which algorithms and combinations will be studied by Koen is still to be determined based on available hardware (PicoRadio) and knowledge at BWRC. Koen will briefly visit Jan Rabaey to discuss the possibilities.

# Deliverables

Koen's intention is to collaborate closely with researchers from the PicoRadio group, which should result in a joint paper. Due to the relatively short length of his summer visit, the paper will most likely be completed when Koen is back in Delft.

Koen will document his experience at the PicoRadio group in a technical report, which is due a month after the exchange completes (September). He will also inform the Ubicom project by giving a talk at the regular UbiCom colloquium series (once per month).

# Future

UC Berkeley is one of the few places where both the hardware (SmartDust project) and software (PicoRadio project) for wireless sensor nodes are developed. Participating in an exchange program with the Berkeley Wireless Research Center (PicoRadio group) provides the Ubicom project a unique opportunity to get familiar with future devices (small wireless sensors) that may be employed in

smart environments for pervasive computing. In a later stage (prototype) sensor nodes developed at Berkeley could be easily acquired and employed by Ubicom when demonstrating the use of smart environments in an experimental setting. The applications developed within Ubicom will provide important feedback to the Berkeley researches who concentrate on the development of hardware and low-level systems software.

# Time frame

Koen would like to visit BWRC for 3 months in summer 2001 (June-August). This period of the year is ideal for carrying out research since university faculty at Berkeley has no teaching obligations. To utilize his relatively short summer visit most efficiently, Koen intends to pay Jan Rabaey in Berkeley a short visit in spring 2001 (1 week) to discuss the exact project that he will be carrying out in collaboration with BWRC researchers. This allows him to prepare while being in Delft, which reduces start-up overheads at Berkeley considerably.

# Budget

The estimated costs for Koen's stay in Berkeley are as follows:

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|---|---|
| round trip airfare | $2 \times$ \$750 |
| hotel/food/etc | \$200/day, for one week |
| housing | \$600/month, for 3 months |
| food | \$450/month, for 3 months |
| local transportation | \$75/month, for 3 months |

This sums to a total of \$6275 (approx. \$2100/month). If the the budget turns out to be wrong (in either direction), it will be corrected at the end of the 3 months visit. In addition, Henk Sips will be visiting Berkeley once, for about one week.

| | |
|---|---|
| round trip airfare | \$750 |
| hotel/food/etc | \$200/day, for one week |

The total estimated budget is therefore \$8425 (\$6075 + \$2150).