Wireless Networks 8, 187–197, 2002

The Anatomy of a Context-Aware Application

ANDY HARTER, ANDY HOPPER *, PETE STEGGLES, ANDY WARD and PAUL WEBSTER
AT&T Laboratories Cambridge, 24a Trumpington Street, Cambridge CB2 1QA, UK

Abstract. We describe a sensor-driven, or sentient, platform for context-aware computing that enables applications to follow mobile users as they move around a building. The platform is particularly suitable for richly equipped, networked environments. The only item a user is required to carry is a small sensor tag, which identifies them to the system and locates them accurately in three dimensions. The platform builds a dynamic model of the environment using these location sensors and resource information gathered by telemetry software, and presents it in a form suitable for application programmers. Use of the platform is illustrated through a practical example, which allows a user's current working desktop to follow them as they move around the environment.

Keywords: mobile computing, sentient computing, context-aware computing, location sensors, resource monitoring, middleware, spatial indexing, CORBA, visualisation, HCI

1. Introduction

The essence of mobile computing is that a user's applications are available, in a suitably adapted form, wherever that user goes. Within a richly equipped networked environment such as a modern office the user need not carry any equipment around; the user-interfaces of the applications themselves can follow the user as they move, using the equipment and networking resources available. We call these applications *Follow-me* applications.

Follow-me applications are a special case of context-aware applications [9]. A context-aware application is one which adapts its behaviour to a changing environment. Other examples of context-aware applications are "construction-kit computers" which automatically build themselves by organising a set of proximate components to act as a more complex device, and "walk-through videophones" which automatically select streams from a range of cameras to maintain an image of a nomadic user.

Typically, a context-aware application needs to know the location of users and equipment, and the capabilities of the equipment and networking infrastructure. In this paper we describe a sensor-driven, or *sentient*, computing platform that collects environmental data, and presents that data in a form suitable for context-aware applications.

The platform we describe has five main components:

- A fine-grained location system, which is used to locate and identify objects.
- A detailed data model, which describes the essential real-world entities that are involved in mobile applications.
- A persistent distributed object system, which presents the data model in a form accessible to applications.
- Resource monitors, which run on networked equipment and communicate status information to a centralised repository.
- A spatial monitoring service, which enables event-based location-aware applications.

Finally, we describe an example application to show how this platform may be used.

2. Indoor location sensing

An ideal location sensor for use in *indoor* environments would possess several important properties. Not only would it provide fine-grain spatial information at a high update rate, but would it also be unobtrusive, cheap, scalable and robust. Unfortunately, the indoor environment is a challenging one in which to implement such a system. Radio-based location techniques (e.g., GPS [1]), which are successful in the wide area, are afflicted by severe multipath effects within buildings. Electromagnetic methods (e.g., [3]) suffer interference from monitors and metal structures, whilst optical systems (e.g., [4,13]) require expensive imaging detectors, and are affected by line-of-sight problems in environments containing opaque objects. However, location systems that use ultrasonic techniques appear to have many desirable properties, and one such system that has been developed at our laboratory [14,15] is described below.

2.1. Principles

Small units called *Bats*, shown in figure 1, are attached to equipment and are carried by personnel. Bats consist of a radio transceiver, controlling logic and an ultrasonic transducer. The current version measures 5 cm $\times$ 3 cm $\times$ 2 cm and weighs 35 g. Each Bat has a globally unique identifier. *Ultrasound receiver units*, shown in figure 2, are placed at known points on the ceiling of the rooms to be instrumented. Receivers are connected by a wired daisy-chain network.

* Also: Laboratory for Communications Engineering, Cambridge University Department of Engineering, Trumpington Street, Cambridge CB2 1PZ, UK.