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Chapter V

Enabling Programmable Ubiquitous Computing Environments: A Middleware Perspective

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Abstract

Emerging pervasive computing scenarios involve client applications that dynamically collect information directly from the local environment. The sophisticated distribution and dynamics involved in these applications place an increased burden on developers that create applications for these environments. The heightened desire for rapid deployment of a wide variety of pervasive computing applications demands a new approach to application development in which domain experts with minimal programming expertise are empowered to rapidly construct and deploy domain-specific applications. This chapter introduces the DAIS (Declarative Applications in Immersive Sensor networks) middleware that abstracts a heterogeneous and dynamic pervasive computing environment into intuitive and accessible programming constructs. At the programming interface level, this requires exposing some *aspects of the physical world to the developer, and DAIS accomplishes this through a suite of novel programming abstractions that enable on-demand access to dynamic local data sources. A fundamental component of the model is a hierarchical view of pervasive computing middleware that allows devices with differing capabilities to support differing amounts of functionality. This chapter reports on our design of the DAIS middleware and highlights the abstractions, the programming interface, and the reification of the middleware on a heterogeneous combination of client devices and resource-constrained sensors.*

Introduction

As networked computing capabilities become increasingly ubiquitous, we envision an instrumented environment that can provide varying amounts of information to applications supporting mobile users immersed within the network. While such a scenario relies on low-cost, low-power miniature sensors, it deviates from existing deployments of sensor networks, which are highly application-specific and generally funnel information to a central collection service for a single purpose. Instead, solutions for ubiquitous computing must target future scenarios in which multiple mobile applications leverage networked nodes opportunistically and unpredictably. To date, most application development for ubiquitous computing has been limited to academic circles. One significant barrier to the widespread development of ubiquitous computing applications lies in the increased complexity of the programming task when compared to existing distributed or even mobile situations. Sensor nodes, which provide computational platforms embedded in the environment, are severely resource-constrained, in terms of both computational capabilities and battery power, and therefore, application development must inherently consider low-level design concerns. This complexity, coupled with the increasing demand for ubiquitous applications, highlights the need for programming platforms (i.e., middleware) that simplify application development.

As will be described in more detail in later sections, much existing work in simplifying programming in sensor networks focuses on application-specific networks where the nodes are statically deployed for a particular task. Ubiquitous computing requires a more futuristic (but not unrealistic) scenario in which sensor networks become more general-purpose and reusable. While the networks may remain domain-specific, ubiquitous computing applications that will be deployed are not known *a priori* and may demand varying capabilities from the environment. Finally, existing applications commonly assume that sensor data is collected at a central location to be processed and used in the future and/or accessed via the Internet. Applications for ubiquitous computing, however, involve users immersed in a network environment who access locally sensed information on demand. This is exactly the vision

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