Chapter V

Enabling Programmable Ubiquitous Computing Environments: A Middleware Perspective

Christine Julien, The University of Texas at Austin, USA
Sanem Kabadayi, The University of Texas at Austin, USA

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 gener-
ally 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 ubiq-
uitous 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 ap-
lications, 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 simpli-
fying 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 environ-
ment who access locally sensed information on demand. This is exactly the vision

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