# Part One

# Pervasive Computing and Systems

# 1

# Introduction

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## 1.1 Pervasive Computing and Its Significance

Ubiquitous computing (nowadays also referred to as pervasive computing) was a revolutionary paradigm and technology introduced nearly a decade ago in a seminal 1991 paper by Mark Weiser [1] in these terms: 'the method of enhancing computer use by making many computers available throughout the physical environment, but making them invisible to the user', based upon the following vision [1]: 'The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it'. The essence of this vision was the dream of having an environment where traditional networking technologies will complement new advanced computing and wireless communication capabilities, while being integrated gracefully with human users' needs.

Thanks to the Internet and the ubiquitous presence of wearable computers, sensor networks, radio frequency identification (RFIDs) tags, and embedded devices, this vision is now heading towards the reality of a world where using information and communication technologies in our daily lives will not be limited only to high speed distributed computers, but will also extend to intelligent and smart devices [2]. Examples of such devices are scientific instruments, home appliances and entertainment systems, personal digital assistants, mobile phones, coffee mugs, key chains, digital libraries, human body, to name a few, interconnected anytime, seamlessly, and available transparently anywhere, constituting our novel computing network infrastructure. Pervasive computing is aiming at improving significantly the human experience and quality of life [3] without explicit awareness of the underlying computing technologies and communications.

## 1.2 Research Trends in Pervasive Computing and Networking

In recent years, there have been a number of research developments and technologies that have emerged in areas such as Internet technologies, mobile and distributed computing, handheld devices, computer hardware, wireless communication networks, embedded systems and computing, wireless sensor networks, software agents, human-computer interfaces, and the like. These advances have led to the emergence of several pervasive computing and networking applications. A typical example of such applications is the introduction of pervasive healthcare systems [4], where RFIDs and sensor network technologies have enabled the introduction of computing and communicating capabilities into devices that were considered traditionally as passive physical objects [5], allowing their ubiquitous presence in an environment not originally designed to handle them. Of course, this type of integration and advantage

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also poses several research challenges that are yet to be addressed [6]. Indeed, the research path towards making pervasive computing a complete reality is still long and winding.

Current research in pervasive computing [7] includes, but is not limited to: (1) heterogeneity and interoperability of computing devices, communication technologies, and software services – today's computing systems are made of various types of entities, mandating the need for designing incentive schemes for ensuring cooperation and collaboration among them [8]; (2) autonomic concepts of pervasive computing and networks [9] – in today's networking environment, enabling a network with self management and self-healing capabilities, and allowing it to cope with the rapid growth of the Internet and their complexities, is a key concern; (3) transparency and pro-activeness [8], [10], in existing computing devices – the development of computing tools has led to the introduction of situation-awareness requirements [11] in the computing world, where it is now envisaged that users of a system can negotiate for a quality of service that accommodates their profiles and applications; (4) location-awareness, scalability, and mobility [11] – in today's computing world, having explicit operator control when dealing with the interaction of entities is no longer a necessary requirement, and context-awareness has been proposed as an innovative novel paradigm for this type of intelligent computing model; (5) security, privacy and trust [12–17] – in today's computing environments, information exchange among the various entities involved brings a means of collaboration, context-based and other types of services, that can lead to a high risk of privacy breach when collaborators use their private information or objects. Protecting each entity as well the environment and information exchange are but a few of the challenges.

## 1.3 Scanning the Book

The book is organized into 19 chapters, each chapter written by experts on the topic concerned. These chapters are grouped into *three parts*.

**Part 1** is devoted to topics related to the design, implementation, and/or management of pervasive computing applications and systems. It is composed of nine chapters: Chapters 1–9.

**Chapter 1** introduces the book's content, organization and features, and its target audience.

**Chapter 2** promotes the idea that interoperability among independently designed and deployed systems is a critical precursor to the development of pervasive systems. An overview of the tools and techniques that can be utilized to this end is presented, with emphasis on mobile agent technologies and platforms for dynamic reconfiguration and interoperability of sensor networks.

**Chapter 3** focuses on the need for discovery mechanisms as a prerogative for accessing resources and services in a pervasive system. The existing approaches and models for discovery of services are discussed, as well as their suitability for pervasive systems.

**Chapter 4** focuses on the potential offered by pervasive computing and networking technologies in the area of education, by proposing a thorough review of existing and emerging pervasive learning tools, technologies and applications for mobile and pervasive education.

**Chapter 5** deals with service management in pervasive computing environments. The approaches and techniques for managing services in such environments are reviewed thoroughly and a novel framework for analysing the functionalities of service management is proposed.

**Chapter 6** promotes the idea of using wireless sensor cooperation as a key enabling technology for objects to cooperate in pervasive computing environments. The techniques for sensor and mobile sensor cooperation in an intra-wireless sensor network are presented, as well as methods for enabling coordination across mobile entities and wireless sensor networks.

**Chapter 7** presents multi-hop cognitive radio networks as a vital paradigm in opportunistic pervasive communications. Several MAC layer protocols for multi-hop cognitive radio networks are surveyed, along with related design challenges and open research issues.

**Chapter 8** focuses on the design and development of wearable sensor networks for pervasive healthcare systems. A thorough review of available solutions is presented, as well as an analysis of the technological aspects of such designs. This topic is presented at a level of detail that is not found elsewhere in the literature.

**Chapter 9** describes the main standards and technologies that are currently available for pervasive computing applications, focusing on wireless connections for the lower layers and middleware for the higher layers. Two examples of pervasive applications are illustrated. The first concerns access to computing services in a remote area and the second deals with home-based telemedicine systems.

**Part 2** focuses on topics related to pervasive networking security. It is composed of four chapters: Chapters 10–13.

**Chapter 10** discusses in depth the aspects and issues of security and privacy of pervasive networks. Prototype systems that attempt to solve these issues are also presented.

**Chapter 11** focuses on wormhole attacks in pervasive wireless ad hoc and sensor networks. An analysis of this type of attack is presented, and current mitigating solutions designed to avoid them are discussed.

**Chapter 12** discusses the concept of collaborative defense against Internet worm attacks. A comparative study of two major collaboration schemes for distributed defense is reported, leading to the design of a novel three-layered network model suitable for the evaluation of collaborative schemes. The impact of these schemes on network infrastructure security at the system level is also discussed.

**Chapter 13** discusses the role of smart devices and intelligent systems in fulfilling the vision of pervasive computing from the perspective of a user's context. The components of these systems are analysed, and a taxonomy is proposed based on predefined criteria.

**Part 3** focuses on pervasive networking and communications issues. It is composed of six chapters: Chapters 14–19.

**Chapter 14** focuses on the current state of research addressing autonomic concepts in pervasive networks. An overview of the architectures and applications of ubiquitous and pervasive networks is presented, along with the application of autonomic computing principles. The benefits of cross-layer design approaches with autonomic capabilities are also discussed.

**Chapter 15** promotes the idea of using component adaptation as a key solution to eliminate mismatches between existing components and their particular reuse contexts in a pervasive computing system. A framework in the form of an adaptive architecture that can be used to resolve functional dependency among components while enabling delay adaptation is introduced.

**Chapter 16** focuses on the problem of sensor scheduling in order to guarantee sensing coverage in pervasive wireless sensor networks. A survey of the existing protocols for computing sensor spatial density to achieve coverage or k-coverage in such networks is proposed.

**Chapter 17** deals with the problem of quality of service (QoS) provisioning – in terms of bandwidth, access and transfer delay – in pervasive computing environments. A discussion of the architectural blueprints and mechanisms to support QoS in a self-organizing framework – both automatically and configuration-free – is provided.

**Chapter 18** addresses the issues of QoS for fixed Point-to-Multi-Point 802.16 systems, by proposing a novel framework consisting of an uplink scheduler, a call admission control module and a frame allocation scheme in order to resolve these issues.

**Chapter 19** reports on some of the major challenges for implementation frameworks that can be anticipated when used for pervasive networking. A survey of a few representative approaches to using frameworks in implementing protocols and services is presented.

Below are some of the important features of this book, which, we believe, make it a valuable resource for our readers:

- This book is designed, in structure and content, with the intention of making it useful at all levels of learning.
- The chapters are authored by prominent academicians/researchers and practitioners, with solid experience in wireless networking and pervasive computing, who have been working in these areas for many years and have a thorough understanding of the concepts and practical applications of these fields.

- The authors are distributed worldwide in a large number of countries and most of them are affiliated with institutions with a global reputation. This gives this book an international flavour.
- The authors have attempted to provide a comprehensive bibliography, which should greatly assist readers interested in delving deeper into the topics.
- Throughout the chapters, most of the core research topics of pervasive computing and networking are covered from both theoretical and practical viewpoints. This makes the book particularly useful for industry practitioners working directly with the practical aspects that enable the technologies in the field.
- To make the book useful for pedagogical purposes, all of the chapters are accompanied by a corresponding set of presentation viewgraphs. The viewgraphs can be obtained as a supplementary resource by contacting the publisher, John Wiley & Sons Ltd., UK.

We have tried to make the chapters of the book look as coherent and consistent as possible. However, it cannot be denied that owing to the fact that the chapters were written by different authors, it was not possible to achieve this task 100%. We believe that this applies to all edited books.

## 1.4 Target Audience

The book is aimed primarily at the student community. This includes students at both undergraduate and graduate level – as well as students having an intermediate level of knowledge of the topics, and those having extensive knowledge about many of the topics. To achieve this goal, we have attempted to design the overall structure and content of the book in such a manner that makes it useful at all learning levels. The secondary audience for this book is the research community, in academia or in the industry. Finally, we have also taken into consideration the needs of those readers, typically from the industries, who desire insight into the practical significance of the topics, expecting to learn how the spectrum of knowledge and the ideas is relevant to the real-life applications of pervasive computing and networking.

## 1.5 Supplementary Resources

As mentioned earlier, this book comes with *presentation viewgraphs* for each chapter, which can be used for classroom instruction by instructors who adopt the book as a text. Instructors are requested to contact the publisher, John Wiley & Sons Ltd., UK, for access to these supplementary resources.

## 1.6 Acknowledgments

We are extremely grateful to the 61 authors of the 19 chapters of this book, who have worked very hard to create this unique resource for the aid of students, researchers and community practitioners. As the individual chapters of this book are written by different authors, the responsibility for the contents of each of the chapters lies with the authors concerned.

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