MAP-I: Doctoral Program in Informatics
2012-13 Edition

Mobile Computing: Software Architectures and Devices

José Maria Fernandes[1]   João Paulo Cunha   Ana Aguiar

UAveiro   UPorto   UPorto

May, 20th , 2012

Abstract: This document describes a Ph.D. level course, corresponding to a curriculum unit credited with 5 ECTS. It corresponds to a joint UAveiro-UPorto proposal for Curricular Unit on Paradigms of Computing in the joint MAP-i doctoral program in Informatics. It is presented the programmatic component, the lecturing team.

A. Programmatic Component

1. Theme, Justification and Context

Handheld devices promise to dominate the future of computation as a result of the rapid convergence of computers and mobile phones. Among the existing mobile operating systems, both Android and iOS are the popular options, particularly with developers because of its high level API that allows easy integration with hardware (e.g. GPS, accelerometers, etc) and the availability of web services (e.g. maps). Although initially designed for mobile devices, they are becoming appealing for its other usages (e.g. tablets) because of numerous features found primarily in more 'powerful' enterprise solutions.

However mobile computing sometimes is not perceived as a discipline by itself and often there is a lot confusion namely between:

- development solutions and actual frameworks (e.g. Java is used in Android and J2ME);
- scope of execution (e.g. application runtime vs operation system);
- ecosystem and the actual framework features (e.g. iOS vs Android);
- protocols and physical networks (e.g. TCP vs wifi/Bluetooth);

---

[1] Coordinator

- running and being usable (e.g. battery autonomy, human interface);
- level of abstraction within the mobile system and the IT environment (e.g. resource and communication).

In this course our objective is to address these intertwined perspectives on mobile computing from a software engineering and architecture perspective addressing:

1. Software requirements and design must take into consideration the user experience, namely usability, that besides UI conception must also take into consideration harder parameters: autonomy, battery, and connectivity;
2. Software design patterns: while in traditional software system these are some times considered optional, in most mobile computing frameworks they are in the core and must be understood in order to be able to provide functional solutions;
3. Software architecture: mobile computing solutions were often seen as "autonomous" but nowadays they are part of IT systems. Understanding the role of mobile application implies understanding their role and dependencies within a system namely how they interact with the different components – this perspective is given by software architectures;
4. Connectivity and devices: mobile devices offers a new paradigm as the programmers can now use specific devices and sensors as OS resources (e.g. accelerometers, gyroscope, camera) and explore connectivity options (e.g. wifi, Bluetooth, zigbee) that allows interacting with localized entities either embedded (e.g. RFID) or at other IT level. This new reality clearly offers challenges at the programming integration level and at the applications/system conception and models. As mobile devices evolve and provide more and more connectivity options, they are becoming the center of the concept of "Internet of Things" ; In this course, this thematic will be discussed.

Justification

The present course is the natural sequence on the team expertise in this area. Its genesis has its roots in more that 7 years of experience and teaching in mobile computing and software engineering of some members of the team.

This course is proposed a Curricular Unit Paradigms of Computing in the joint MAP-i doctoral program in Informatics although it contains programming oriented modules in mobile frameworks that could be enclosed in a Technologies Curricular Unit. In this course context, these are addressed as mobile computing paradigm instantiations that support the high level concepts assimilation.

In this course we include some tested practices already used that in our opinion allows not only to address the more abstract concepts but also to understand them. An example of these practices are the application projects implemented in two different frameworks (Android and iOS). Besides enhancing the common approaches and differences it also helps students understand the impact of each of them in actual applications. The course design takes this into account by addressing in the last module transversal essays where students, besides the theoretical knowledge, already have implemented mobile applications and experienced the subtleties of real mobile devices application implementations.

The course will also cover aspects of mobile computing related to the multiple embedded sensors and heterogeneous connectivity available in mobile devices. Besides offering a perspective of the possibilities opened by this combination, like participatory and collaborative sensing application, the course will offer an overview of the different wireless communication possibilities and insight into the

main trade-offs involved in their use, aiming at providing students with the necessary knowledge to make informed decisions when designing or implementing mobile computing components or platforms.

It was also motivated by our interest in addressing mobile computing using a software engineering and architecture systematic approach. Part of this course is inspired in a course designed, proposed and lectured by José Maria Fernandes at Carnegie-Mellon (ISR/SCS) under the faculty exchange CMU-Portugal program - "17623 – Software Engineering in Mobile Computing" (Fall 2010). As the present course is an evolution on the 17623 course, it is our objective to pursue accreditation in the dual CMU-Portugal PhD program.

Course Context

In this course we cover the following subjects according to IEEE / ACM Computing Classification System:

(http://www.computer.org/portal/web/publications/acmtaxonomy)

> 3. Computer system organizations
> VIII. Mobile Computing
> II. Architectures
> III. Mobile communication systems
> IV. Mobile environments
> 4. Software/Software Engineering
> XI. Software architectures
> II. Domain specific architectures
> IV. Patterns
> XIII. Reusable Software
> XIV. Human Factors in Software Designs
> I. User interfaces
> 10. Computer applications
> IX. Mobile applications
> I. Location-dependent and sensitive
> II. Nomadic computing
> III. Multimedia applications and multimedia signal processing
> IV. Pervasive computing
> V. Wearable computers and body area networks
> VI. Wireless sensor networks

2. Objectives and Learning Outcomes

In this course, we will address the mobile computing from three different perspectives:

1. Software requirements and design
2. Software design patterns and software architecture
3. Connectivity, mobile networks and devices

During the course, a simple project will be implemented in Android and iOS frameworks. This project will support and instantiate the mobile computing concepts and specificities to better understand the conception, design, construction and deployment of mobile applications. Naturally, as part of IT system we also focus on basic web services/REST concepts as possible and natural mobile application resources. Parallels between Android, iOS and other solutions such as J2EE (an enterprise solution) will be established.

Upon successful completion of this curricular unit, students should be able to understand that mobile application should, from inception and design to deployment, take into consideration from user experience to architectural and design options either imposed by the application domain and by the IT technological environment:

- to recognize the impact of technical options in the application usability and connectivity
- to know the full process of developing a simple mobile application and understand how mobile framework design options condition that same process;
- to recognize and understand that besides the specific flavors, most mobile frameworks share several architectural and design patterns that can be found in enterprise level frameworks (e.g. .NET, J2EE)
- to know and explore the potential of the embedded resources not present in traditional IT frameworks namely localization (e.g. GPS, wireless network), accelerometers (e.g. motion, posture), ample connectivity options (e.g. Near Field Communications, WIFI, GPRS, SMS, Bluetooth).
- to identify the positive and negative aspects of the software process, through the acquisition, analysis, and interpretation of quantitative data;
- to explain the need for describing software systems with models, as a way to abstract from the system's complexity and to reason about its properties;

3. Course Contents

Module 1 – Introduction

In this introductory module, a generic approach to the course will be presented, approaching the new emerging engineering topic of mobile computing and devices. This module will cover the following topics:

- Brief history and present mobile devices market characterization

- Ubiquitous, nomadic and mobile computing

- Contexts aware mobile and wearable computing

- Mobile devices generic architectures and characteristics
- Mobile apps generic design and implementation requirements

Module 2 - Mobile computing: software engineering and architectures

As software related area, mobile computing shares and reuses knowledge from traditional software engineering process. However, due to its specificities and mobile framework design it not possible to approach mobile computing without a clear notion of the option made in the conception and design of the current mobile framework namely at the software design patterns and guidelines and at software architecture level:

1. Software design patterns: while in traditional software system these are some times considered optional, in most mobile computing frameworks they are in the core and must be understood in order to be able to provide functional solutions
2. Software architecture: mobile computing solutions were often seen as "autonomous" but nowadays they are part of IT systems. Understanding the role of mobile application implies understanding the role and dependencies of them within a system namely how they

We will address design patterns and architectural styles as multi scale patterns that, depending on the scope and scale, can have major impact at development level (e.g. how to access a given resource) or at architectural/performance level (e.g. singleton pattern vs. available bandwidth).

In particular, the following topics will be considered:

- Multi-scale patterns: design patterns and architectural styles
- The impact of scale in the quality attributes: from the mobile application to the IT system
- From the mobile application to the IT system: thematic catalogs of patterns
- The parallels between mobile device frameworks and full fledge enterprise information system solutions: inter process communication and data sharing patterns

Module 3 – Sensors and Networking

Mobile devices possess a wide range of sensing (e.g. accelerometer, gyroscope, camera, GPS) and connectivity (e.g. cellular, WiFi, Bluetooth, NFC) capabilities that were typically not available on mobile phones and that are being instrumental to the development of a plethora of application ecosystems. Typical examples hereof are mobility support and remote healthcare applications, which will be further enabled by machine-to-machine communications. This module provide insight into each of these aspects, covering the following topics:

- overview of typical mobile device architecture, focusing on sensors and connectivity;

- characterisation the different connectivity possibilities typically available, differentiating between technology and protocols;

- wireless networking background and trade-offs, e.g. effects of wireless propagation, battery life, cellular vs local, centralized vs. ad-hoc networking, protocols, overheads for different types of wireless networks;

- mobile device as a gateway in machine-to-machine communications and the Internet of Things;

- participatory and collaborative sensing application architectures.

Module 4 and 5. Android and iOS case studies

During the course the same simple application will be implemented in both frameworks to enhance and illustrate specifies of these systems and better understand the conception, design construction and deployment of mobile applications. This application will rely on external resources namely webservices/REST in order to address not only the mobile application on its own but also as a part of an IT system. Based on our experience the dual framework approach enhances and clarifies specific differences between frameworks and the common approaches and solution in mobile computing.

In this module the following subject will be address in parallel with the application development:

- Basic building blocks: running elements and UI

- Inter process communication

- Connectivity with the outside world

This module will be the cornerstone of the course at will enable to materialize and test the content presented and discussed in the previous modules.

Tentative scheduling

module	Start (week)	Duration (weeks)	Content	deliverables
1. Mobile computing as new discipline	1	1	Historic perspective Mobile computing: Self sufficient vs. IT integrated Context aware mobile computing	
2. Common concepts of mobile computing	2	2	Software architecture Design patterns	
3. Sensors and Networking	4	2	Mobile devices systems' architectures Mobile networks and connectivity Machine-to-machine communications Participatory and collaborative sensing	Essays on module 1/2/3
4. Android	6	3	Basic building blocks: Running elements and UI Inter process communication Connectivity with the outside world	Essay android subject Android project
5 iOS	9	3	Basic building blocks: running elements and UI Inter process communication Connectivity with the outside world	Essay iOS subject iOS project
6. review and project presentation	12	1	Presentations and discussion	Review on transversal theme

4. Teaching Methods and Student Assessment

The best way to understand the specificities of mobile computing is to understand the main design options and experience it by actually implementing a software application. In the educational setting, this means:

- learning and identify the main patterns found mobile framework and IT system
- understand the impact of specific options on a given frameworks as developer, as an user and a part of an IT system;
- being able to understand and discuss the impact of design option in the quality features of a IT system that integrates a mobile;
- applying the knowledge acquired by implementing simple mobile application in two different frameworks to better understand the similarities and differences.

No textbook adequately covers the course's range of topics, so a diversity of bibliographic elements (books, journals and conference proceedings) will be used.

Classes

The class meetings are meant to be conversational, and we encourage students to ask questions and make comments. Some of the classes will be supported on subjects addressed and presented by students essays will support the discussion. Consequently, the discussion may follow tangents to the prepared lecture. These classes are conducted by all the elements of the lecturing team. Given the practical nature of both module 4 and 5, the class meetings, besides providing an opportunity to present and discuss details on the specific mobile framework, they also include hands on support on the simple application development.

Essays on mobile computing

During the course students will be asked to write two short essays and a review on a subject transversal to mobile computing.

The short essays will address two of the following three areas:

- mobile computing and software engineering (module 1, 2)

- Connectivity and devices (module 3)

- on specific subject on android or iOS (module 4 and 5)

Some of these essays will be presented (short presentations) during classes and serve as motivation to the class. Every student will perform at least one presentation.

The review will address subjects transversal to mobile computing (e.g patterns, UI , connectivity) that will be proposed to the students. The students will write a critical essay on the subject.

The grading of the essays is based on written documents and in the presentation. The essay will be defined until week 4 of the course.

Individual mobile application projects

Given the practical nature of both module 4 and 5, the class meetings will provide an opportunity to present and discuss details on the specifics of each framework.

Whilst the goal of the readings is to develop a critical but shallow view over a broad range of topics addressed in classes, the goal of the individual research project is to develop a more in depth understanding on a specific software engineering research topic, matching as much as possible each student interests, as well as the lecturers areas of expertise. Projects are designed to combine a state of the art analyses with an experimental assessment.

The grading of individual research projects is based on an oral presentation including demonstration, and a final written report. The projects will be defined until week 4 of the course. Students are also encouraged to propose projects of their own.

5. Basic Bibliographic References

Given the fast rate of change on technologies and frameworks it is not possible to recommend specific bibliographic references on mobile computing frameworks with the risk of being quickly outdate. The following are two publication series frequently updated with new versions.

- Satya Komatineni , Dave MacLean, Pro Android 4, Apress
  - o ISBN13: 978-1-4302-3930-7
- David Mark , Jack Nutting , Jeff LaMarche, Beginning iOS 5 Development, Apress
  - o ISBN13: 978-1-4302-3605-4

The following bibliographic references are classical references on software engineering and software architecture that are the support for the overall contents of the course with focus on module 2 .

- Buschmann F, Meunier R, Rohnert H, Sommerlad P, Stal P. *Pattern-Oriented Software Architecture, Volume 1: A System of Patterns*, JohnWiley & Sons, 1996.

- Gamma E, Helm R, Johnson R, Vlissides J. *Design Patterns - Elements of Reusable Object-Oriented Software*, Addison-Wesley, 1995.

- Shaw M, Garlan D. *Software Architecture: Perspectives on an Emerging Discipline*, Prentice Hall, 1996.

B. Lecturing Team

1. Team Presentation

This course is supported by a team involving researchers from the University of Aveiro (José Maria Fernandes) and the University of Porto (João Paulo Cunha and Ana Aguiar).

The present course is the natural follow through on the team expertise on this area. Its genesis has is rooted in more that 7 years of experience and teaching in mobile computing and software engineering of the members of the team where mobile computing was not as an end in itself but as a part of IT system solutions with special feature and properties.

To note that this course is in the wake of a course designed, proposed and lectured by José Maria Fernandes in Carnegie-Mellon (ISR/SCS) under the faculty exchange CMU-Portugal program - "17623 – Software Engineering in Mobile Computing" (Fall 2010) that explored there approach. As the present course is an evolution on the 17623 course, it is our objective to pursue accreditation in the dual CMU-Portugal PhD program.

All team members are working, and have worked actively in the past few years, on topics that are directly related to the subjects covered by this course, as detailed below.

2. Coordinator

The coordinator of the unit is José Maria Fernandes.

3. Short Presentation of Team Members

In the sequel we introduce a brief presentation of each team member, which includes, for each of them, up to 5 key publications related to the scientific area in which this course is proposed. All CVs are supplied in separate PDF documents.

José Maria Amaral Fernandes is assistant professor at the Dep. of Electronics, Telecommunications and Informatics of the Universidade de Aveiro (UA) and is visiting professor at the Carnegie Mellon University (CMU). Since 1997, he is part of IEETA, an R&D institute of the University of Aveiro (http://www.ieeta.pt/sias) where he has been part of more than 10 projects mainly in neuroscience (e.g. EpilBI, MovEpil3D, FCT) and computer science with focus on mobile computing (e.g VitalResponder project - http://www.vitalresponder.org from CMU-Portugal program) and eScience (e.g. BING - http://www.brainimaging.pt - and GeresMED, FCT).

His lecturing activity has been focused on mobile computing (iOS and Android frameworks) and software development process from conception to deployment (e.g. Test Driven Development in the development of IT systems using enterprise level solutions supported on J2EE). Recently, under faculty exchange program in the context of the Carnegie Mellon-Portugal, he offered a course "17623 – Software Engineering in Mobile Computing" that represented a long waited merge of several lines of interest in both research and lecturing: (design) patterns in programming, modelling and software engineering and architecture applied to mobile computing. During the faculty exchange he started a collaboration with Prof. David Garlan (School of Computer Science, Carnegie Mellon University) focused on the problem of validation and automation of complex analysis workflows (in the scope of BING network) using architecture styles and type checking as high level tools for verification and orchestration. Currently he is also leading the advanced course on mobile computing to be offered 2012/2013 by the University of Aveiro.

Key Publications:

- D. C. Teles, M. F. M. Colunas, J. M. Fernandes, I. C. Oliveira and J. P. S. Cunha (2012). iVital: A Real Time Monitoring System for First Response Teams Mobile Networks and Management. K. Pentikousis, R. Aguiar, S. Sargento and R. Agüero, Springer Berlin Heidelberg. 97: 396-404.
  - http://dx.doi.org/10.1007/978-3-642-30422-4_29
- Ribeiro, D. M. D., M. F. M. Colunas, et al. (2011). A real time, wearable ECG and continous blood pressure monitoring system for first responders. Engineering in Medicine and Biology Society,EMBC, 2011 Annual International Conference of the IEEE.
  http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6091736&isnumber=6089866
- V. Dwivedi, P. Velasco-Elizondo, J. Maria Fernandes, D. Garlan and B. Schmerl (2011). An Architectural Approach to End User Orchestrations Software Architecture. I. Crnkovic, V. Gruhn and M. Book, Springer Berlin / Heidelberg. 6903: 370-378.
  - http://dx.doi.org/10.1007/978-3-642-23798-0_39
- M. F. M. Colunas, J. M. A. Fernandes, I. C. Oliveira and J. P. S. Cunha (2011). Droid Jacket: Using an Android based smartphone for team monitoring. Wireless Communications and Mobile Computing Conference (IWCMC), 2011 7th International.
  - http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5974243&isnumber=5974162
- Fernandes, J., S. Tafula, et al. (2011). 3D-Video-fMRI: 3D Motion Tracking in a 3T MRI Environment Image Analysis and Recognition. M. Kamel and A. Campilho, Springer Berlin / Heidelberg. 6754: 59-67.
  - http://dx.doi.org/10.1007/978-3-642-21596-4_7

João Paulo Cunha is Associate Professor with "Agregação" at the Dep. of Electrical and Computer Engineering of the Faculty of Engineering, University of Porto. He is the PI of the "Innovative Biomedical Technologies" Lab and creator/leader (1997) of the "Healthcare Information and systems" R&D group at IEETA, University of Aveiro (www.ieeta.pt) and visiting professor at the Neurology Dep. of the University of Munich. Prof. Cunha is faculty member of the Carnegie-Mellon-Portugal program and was Faculty member of the Information Networking Institute (INI) of Carnegie Mellon University, Pittsburgh PA, USA between 2007 and 2009. He earned a degree in Electronics and Telecommunications engineering (1989) and a PhD in Electrical Engineering (1996) both at University of Aveiro, Portugal.

Prof. Cunha is senior member of the IEEE (2004) where he joined the Engineering in Medicine and Biology Society (EMBS) in 1986 as a student member. He is member and vice-president of the Portuguese Brain Imaging Network (ANIFC), member of the director's board of the Portuguese Biomedical Engineering Association and member of the following clinical neurophysiology associations: Portuguese League Against Epilepsy, the Portuguese EEG and Neurophysiology Association (non-MD member) and the European Epilepsy Academy (EUREPA). He is holder of several prizes, being the most relevant the "Best contribution to clinical epileptology - Claudio Munari award of excellence" delivered by European Epilepsy Academy (EUREPA) in 2002. He founded (2007) a spin-off company of his lab called Biodevices SA (www.biodevices.pt). Dr. Cunha is co-author of more than 200 publications, of which, in the last five year, he has co-authored 6 book chapters and 12 papers in international scientific journals cited on ISI. For more information, please go to http://goo.gl/flkC3.

Key Publications:

- A. S. Peters, J. Rémi, C. Vollmar, J. Gonzalez-Victores, J. P. S. Cunha, S. Noachtar. Dysprosody during Epileptic Seizures Lateralizes to the Non-Dominant Hemisphere. *Neurology*. 2011;77:1482-6. ISI Impact Factor = 8.176.

- Rémi J, Wagner P, O'Dwyer R, Cunha JPS, Vollmar C, Krotofil I, et al. Ictal Head Turning in Frontal and Temporal Lobe Epilepsy. *Epilepsia*. 2011;52:1447-51. ISI Impact Factor = 4.052.

- D. D. Ribeiro, L. S. Fu, L. D. Carlos, J. P. S. Cunha. A Novel Dry Active Bio-signal Electrode based on an Hybrid Organic-inorganic Interface Material. *IEEE Sensors Journal*. 2011;11:2241-5. ISI Impact Factor = 1.581.

- Z. Mirzadjanova, A. S. Peters, J. Rémi, C. Bilgin, J. P. S. Cunha and S. Noachtar, "Significance of Lateralization of Upper Limb Automatisms in Temporal Lobe Epilepsy: a Quantitative Movement Analysis," *Epilepsia*, vol. 51, pp. 2140-2146, 2010. ISI Impact Factor = 4.052.

- R. O'Dwyer, J. P. S. Cunha, C. Vollmar, C. Maurerer, B. Feddersen, R. C. Burgess, A. Ebner, and S. Noachtar, "Lateralizing Significance of Quantitative Analysis of Head Movements before Secondary Generalization of Seizures of Patients with Temporal Lobe Epilepsy " *Epilepsia*, vol. 48, pp. 524-530, 2007, ISI Impact Factor = 4.052.

- J. P. S. Cunha, M. Coimbra, P. Campos, and J. Soares, "Automated Topographic Segmentation and Transit Time Estimation in Endoscopic Capsule Exams," *IEEE Transactions on Medical Imaging*, vol. 27, pp. 19-27, 2008, ISI Impact Factor = 3.540.

- M. Coimbra and J. P. S. Cunha, "MPEG-7 Visual Descriptors - Contributions for Automated Feature Extraction in Capsule Endoscopy," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 16, pp. 628-637, 2006, ISI Impact Factor = 2.548.

Ana Cristina Costa Aguiar (paginas.fe.up.pt/~anaa) is an Assistant Professor with the Faculty of Engineering of the University of Porto (FEUP) since 2009 and a researcher at Instituto de Telecomunicações (IT) since 2010. She graduated in Electrical and Computer Engineering in 1998 from FEUP and received a PhD in Electrical Engineering (Telecommunication Networks) from the Technical University of Berlin in 2008. She was visiting faculty at the School of Computer Science at Carnegie Mellon University in Spring 2011. She does applied research on communications and networking systems. She is currently working on mobile sensing, vehicular networks, machine-to-machine communications, Internet of Things and data mining in the context of collaborative sensing. She is the principal investigator of the VOCE project (paginas.fe.up.pt/~voce.html) and collaborates in several other projects, namely Vital Responder (http://www.vitalresponder.pt/) and MISC (http://www.mitportugal.org/2008-projects/misc-massive-information-scavenging-with-intelligent-transportation-systems.html) among others.

Her graduate research focused on Quality of Service (QoS) support for heterogeneous data flows over wireless channels, traffic and wireless channel modelling, and prediction of wireless channel behaviour. She worked from May 2008 to December 2009 as a senior researcher in setting up Fraunhofer Portugal AICOS, working in applied research projects in the areas of wireless sensor networks and service-oriented architectures. As a result of her research work she has authored or co-authored several articles in peer reviewed conferences and journals, and holds a patent related to her work on wireless QoS support.

Key Publications

- "In VANETs We Trust? Characterizing RF Jamming in Vehicular Networks", O. Puñal, A. Aguiar, J. Gross, ACM VANET, Jun 2012

- "Leveraging Electronic Ticketing to Provide Personalised Navigation in a Public Transport Network", A. Aguiar, F. Nunes, M. Silva, P. A. Silva, D. Elias, IEEE Transactions on Intelligent Transportation Systems, vol. 12, nr. 4, 2012

- "Network-aware Biomedical Signal Processing: Loss Concealment or Loss Awareness", B. Barros, A. Aguiar, D. Lucani, International Conference on Health Informatics (HEALTHINF), 2012

- "Data Gathering for Sensing Applications in Vehicular Networks (Poster)", M. Nozari Zarmehri, A. Aguiar, IEEE Vehicular Networking Conference (IEEE VNC), Nov. 2011

- "OLBS: Offline Location Based Services", P. Coelho, A. Aguiar, J. C. Lopes, in Proc. of the 5th Int. Conf. on Next Generation Mobile Applications, Services and Technologies, Sep. 2011

- "A Mobile Sensing Architecture for Massive Urban Scanning", J. Rodrigues, A. Aguiar, F. Vieira, J. Barros, J. P. Cunha, in Proc. of the 14th International IEEE Annual Conference on Intelligent Transportation Systems, Oct. 2011

- "Channel Modeling", A. Schmitz, M. Schinnenburg, J. Gross, A. Aguiar, in *Modeling and Tools for Network Simulation*, K. Wehrle, M. Guenes, J. Gross (editors), ISBN 978-3-642-12330-6, 2010

- "An Interactive Content Service for Photo Frames in the Home", Carlos Lopes, Rui José, Ana Aguiar, in Proc. of the International Workshop on Ambient Assisted Living (IWAAL), 2011