

# Preface

Wireless networks of moving objects have drawn significant attention recently. These types of networks consist of a number of autonomous or semi-autonomous wireless nodes/objects moving with diverse patterns and speeds while communicating via several radio interfaces simultaneously. Examples of such objects include smartphones and other user mobile devices, robots, cars, unmanned aerial vehicles, sensors, actuators, etc., which are connected in some way to each other and to the Internet. With every object acting as a networking node generating, relaying, and/or absorbing data, these networks may serve as a supplementary infrastructure for the provision of smart, ubiquitous, highly contextualized and customized services and applications available anytime-anywhere-anyhow. Achieving this will require global interworking and interoperability amongst objects, which is not typical today. To overcome current shortcomings, a number of research challenges have to be addressed in this area, ranging from initial conceptualization and modelling, to protocols and architectures engineering, and development of suitable tools, applications and services, and to the elaboration of realistic use-case scenarios by taking into account also corresponding societal and economic aspects.

The objective of this book is, by applying a systematic approach, to assess the state of the art and consolidate the main research results achieved in this area. It was prepared as the Final Publication of the COST Action IC0906 “Wireless Networking for Moving Objects (WiNeMO).” The book contains 15 chapters and is a showcase of the main outcomes of the action in line with its scientific goals. The book can serve as a valuable reference for undergraduate students, post-graduate students, educators, faculty members, researchers, engineers, and research strategists working in this field.

The book chapters were collected through an open, but selective, three-stage submission/review process. Initially, an open call for contributions was distributed among the COST WiNeMO participants in June 2013, and also externally outside the COST Action in September 2013 to increase the book quality and cover some missing topics. A total of 23 extended abstracts were received in response to the call. In order to reduce the overlap between individual chapters and at the same time increase the level of synergy between different research groups working on similar problems, it was recommended by the book editors to some of the authors to merge their chapters to ensure coherence between them. This way, 18 contributions were selected for full-chapter submission and 17 full-chapter proposals were received by the set deadline. All submitted chapters were peer-reviewed by two independent reviewers (including reviewers outside the COST Action), appointed by the book editors, and after the first round of reviews 16 chapters remained. These were revised according to the reviewers’ comments, suggestions, and notes, and were resubmitted for the second round of reviews. Finally, 15 chapters were accepted for publication in this book.

The book is structured into three parts. Part I, entitled “Communications Models, Concepts, and Paradigms,” contains seven chapters dedicated to these aspects of

paramount importance for the successful functioning and operation of any type of network, and especially so of the new network types such as WiNeMO. A new generic techno-business model, based on a personal IPv6 (PIIPv6) address embedded in an X.509 digital certificate, is put forward in the first chapter entitled “A New Techno-Business Model Based on a Personal IPv6 Address for Wireless Networks of Moving Objects.” The authors argue that the new globally significant, network-independent PIPv6 address will enable real number ownership and full anytime-anywhere-anyhow portability for future generations of WiNeMO and could serve as a long-term node/object identity, thus enabling an advanced secure mobility and participation of the node/object in a variety of evolving dynamic, fluid wireless mobile network scenarios. The proposed model can also serve enhanced authentication, authorization, and accounting (AAA) functionality, through which commercially viable ad hoc and open mesh-networking solutions are realizable. The latter is an important result as commercially viable solutions are sorely lacking for these kinds of networks.

The next chapter, “Information-Centric Networking in Mobile and Opportunistic Networks,” describes the emerging information centric networking (ICN) paradigm for the Future Internet, which could support communication in mobile wireless networks as well as opportunistic network scenarios, where end-systems have spontaneous but time-limited contact to exchange data. The authors identify challenges in mobile and opportunistic ICN-based networks, discuss appropriate solutions, and provide preliminary performance evaluation results.

This is followed by the chapter entitled “User-Centric Networking: Cooperation in Wireless Networks,” which addresses the cooperation in wireless networks, based on the recently emerged, self-organizing paradigm of user-centric networking (UCN), whereby the user controls and carries wireless objects with integrated functionality, which today is part of the network core, e.g., mobility- and resource management. The user becomes more than a simple consumer of networking services, being also a service provider to other users. Resource sharing via cooperative elements, based on specific sharing incentives, is another aspect of this paradigm. The chapter provides UCN notions and models related to the user-centricity in the context of wireless networks. The authors also include recent operational data derived from the available user-centric networking pilot.

The concept of cooperation is also treated in the next chapter “Cooperative Relaying for Wireless Local Area Networks.” By stating that future wireless systems will be highly heterogeneous and interconnected, which motivates the use of cooperative relaying, the authors describe the state of the art in this area with the main focus on media access control (MAC) layer design, analysis, and challenges, and go on to explain how cooperative networks can be designed as highly dynamic network configurations comprising a large number of moving nodes.

It is well known that clustering of moving objects in ad hoc wireless networks could increase the network scalability and improve efficiency, enabling the objects to simplify communication with their peers. While most of the clustering algorithms and protocols are applicable in WiNeMO, there are specific challenges induced by mobility. The next chapter, entitled “Clustering for Networks of Moving Objects,” presents an overview of the technical challenges and currently available solutions to this problem. The chapter reviews the current scholarly works on clustering for moving objects, identifies the

main methods of dealing with mobility, and analyzes the performance of the existing clustering solutions for WiNeMO.

As node mobility heavily influences the operation of wireless networks, where signal propagation conditions depend on the nodes' location and thus may cause drastic changes in data transmission and packet error rates, the authors of the next chapter, entitled "New Trends in Mobility Modelling and Handover Prediction," argue that the accurate representation of the user mobility in the analysis of wireless networks is a crucial element for both simulation and numerical/analytical modelling. The chapter discusses mobility models used in simulating the network traffic, handover optimization, and prediction, along with alternative methods for radio signal propagation changes caused by client mobility.

Analytically capturing the operation of carrier sense multiple access with collision avoidance (CSMA/CA) networks is the theme of the next chapter entitled "Throughput Analysis in CSMA/CA Networks Using Continuous Time Markov Networks: A Tutorial." The authors use a set of representative and modern scenarios to illustrate how continuous time Markov networks (CTMN) can be used for this. For each scenario, they describe the specific CTMN, obtain its stationary distribution, and compute the throughput achieved by each node in the network, which is used as a reference in the discussion on how the complex interactions between nodes affect the system performance.

Part II, entitled "Approaches, Schemes, Mechanisms and Protocols," contains four chapters. The first two chapters address energy saving and awareness, which are particularly important for mobile devices with limited energy capability, because battery lifetime is expected to increase only by 20 % in the next 10 years. The chapter entitled "Energy-Awareness in Multihop Routing" discusses how the current multihop routing approaches could still be utilized by enriching them with features that increase the network lifetime, based on the energy-awareness concept. The authors cover notions and concepts concerning multihop routing energy-awareness, show how to develop and apply energy-awareness in some of the most popular multihop routing protocols, and provide input concerning performance evaluation and realistic specification that can be used in operational scenarios, demonstrating that the proposed approaches are backward compatible with the current solutions.

Considering the energy as the most prominent limitation of end-user satisfaction within the anytime-anywhere connectivity paradigm, the next chapter, "An Overview of Energy Consumption in IEEE 802.11 Access Networks," provides readers with insights on the energy consumption properties of these networks and shows the way for further improvements toward enhanced battery lifetime. Through experimental energy assessment, the authors demonstrate the effectiveness of the power-saving mechanisms and the relevance of wireless devices' state management in this regard.

By identifying the need for capacity increase in 4G cellular systems for the support of a diverse range of services, the chapter "Resource Management and Cell Planning in LTE Systems" introduces a new soft frequency reuse (SFR) scheme, which is able to increase the cell capacity, by considering the impact of different scheduling schemes and user mobility patterns. The authors describe an implementation of a consistent SFR scenario in both NS-3 and OMNeT++ environments, and propose an analytical approach for the evaluation of the cell capacity with SFR.

Another example of WiNeMO are the networks involving unmanned aerial vehicles (UAV), which are growing in popularity along with the video applications for both military and civilian use. A set of challenges related to the device movement, scarce resources, and high error rates must be addressed in these networks, e.g., by implementing adaptive forward error correction (FEC) mechanisms to strengthen video transmissions. In the next chapter, “Improving Video QoE in Unmanned Aerial Vehicles Using an Adaptive FEC Mechanism,” such a mechanism is proposed. It is based on motion vector details to improve real-time UAV video transmissions, resulting in better user experience and usage of resources. The authors consider the benefits and drawbacks of the proposed mechanism, based on analysis of conducted test simulations with a set of quality of experience (QoE) metrics.

Part III, entitled “M2M Aspects of WiNeMO,” contains four chapters dedicated to machine-to-machine (M2M) communications. This is a specific strand of WiNeMO communications, which opens new horizons to the current concept of smart environments by enabling a new set of services and applications. One of the main M2M features is the large number of resource-constrained devices that usually perform collective communication. This particular feature calls for network solutions that support the data aggregation (DA) of groups of low duty cycling (LDC) devices. In relation to this problem, in the chapter entitled “Group Communication in Machine-to-Machine Environments,” - abbreviated as GoCAME, an architecture is set out that enables joint execution of DA and LDC. This is achieved by taking into account the two-way latency tolerance and multiple data types, and assuring concurrent execution of data requests and management of groups of nodes, thereby providing the best strategy for replying to each data request.

It is well established that a successful simulation platform should be based on a user-friendly framework and models that support virtualization in order to enable the incorporation of simulations into day-to-day engineering practice and thereby shrink the gap between real and virtual developing environments. With this in mind, the next chapter, “Simulation-Based Studies of Machine-to-Machine Communications,” presents two showcases – of using the ultra-wide band (UWB) and the IEEE 802.15.4a-based radio technologies in M2M applications – highlighting the necessity of trustworthy simulation tools for M2M communications. A novel open-source simulation framework “Symphony” is presented at the end as a possible solution for bridging the gap between simulation and real-world deployment.

Important participants in making M2M systems widely used and applicable in numerous real-life scenarios are the standardization organizations, which develop technical specifications addressing the need for a common M2M service layer, realized through various hardware and software implementations. The next chapter, “Communication and Security in Machine-to-Machine Systems,” presents current M2M standards and architectures with the focus on communication and security issues, while also discussing current and future research efforts addressing important open issues both with respect to aspects not covered by the current standards and in relation to research proposals, which could be integrated in the future versions of the M2M standards. A scheme that enables a unique identification of heterogeneous devices regardless of the technology used is also presented by the authors.

Continuing with security aspects, the final chapter, entitled “MHT-Based Mechanism for Certificate Revocation in VANETs,” introduces a public-key certificate revocation mechanism based on the Merkle hash tree (MHT), which allows for the efficient distribution of certificate revocation information in vehicular ad hoc networks (VANETs). Within the WiNeMO paradigm, this is another example involving M2M communications. The proposed mechanism allows each node, e.g., a road side unit or intermediate vehicle possessing an extended-CRL – created by embedding a hash tree in each certificate revocation list (CRL) – to respond to certificate status requests without having to send the complete CRL, thus saving bandwidth and time. The authors describe the main procedures of the proposed mechanism and also consider the related security issues.

The book editors wish to thank the reviewers for their excellent and rigorous reviewing work and their responsiveness during the critical stages to consolidate the contributions provided by the authors. We are most grateful to all authors who have entrusted their excellent work, the fruits of many years of research in each case, to us and for their patience and continued demanding revision work in response to the reviewers’ feedback. We also thank them for adjusting their chapters to the specific book template and style requirements, completing all the bureaucratic but necessary paperwork, and meeting all the publishing deadlines.

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