Optimization of Mobile RFID Platforms: A Cross-Layer Approach.

Ramiro Samano Robles and Atílio Gameiro

Institute of Telecommunications, Aveiro, Portugal

Summary

RFID (Radio Frequency Identification) is the generic term used for systems that make use of radio frequency signals (RF) for purposes of identification and tracking of objects, humans or animals [1]. Due to recent advances in radio-frequency transceivers and micro-system architectures, RFID is gaining preference as the dominant identification solution. In comparison with legacy technologies, RFID provides automated identification in non-line of sight environments, increased item-level information storage, and added value solutions such as sensing of environmental parameters [2]. Also, the rapid evolution of mobile terminals has paved the way for a full or partial integration of RFID functionalities in their advanced processors, thus further facilitating deployment of RFID solutions [3]. For these reasons RFID is expected to finally break the barrier between the virtual world of computers and the physical world of objects.

However, RFID is still facing a few obstacles towards massive consumer adoption, mainly in terms of cost, standardized interfaces, consumer acceptance, and reliability problems. Current advances to solve these issues are taking place at a different pace across different areas and layers of RFID architectures. Furthermore, standards cannot be developed at the same rate, thereby being subject to constant modifications and revisions. The result of this complex heterogeneous landscape is a potential compatibility problem or suboptimal performance figures when deploying algorithms from different layers, researchers or manufacturers [2]. For example, an algorithm developed at the physical layer of RFID systems may become less reliable or even ineffective if it is not accompanied by an appropriate optimization or analysis at the medium access, networking or middleware layers. In addition, recent trends towards integrating readers into mobile telecommunication networks have further expanded the spectrum of solutions, variables and potential applications [2]. Therefore, there is an urgent need for a global overview on the main trends, solutions and algorithms taking place in different research areas and in different layers of the architecture of RFID systems [3].

To fill this gap, this book chapter aims at identifying the main trends, gaps and new research issues at different layers and areas of RFID systems, and to place them in a global context by analyzing their potential interactions with each other. The algorithms will also be analyzed in terms of complexity and their impact on cost of hardware platforms. To further reinforce the outcome of this research, a detailed analysis of reader reliability issues, their causes and how different algorithms and developments help improve such reliability levels will be included. This cross-layer and cross-area analysis will result in a better understanding of the operation of RFID and in the end it will lead to a proper optimization and cost reduction of reader platforms. Particular emphasis will be made on issues brought by enabling reader platforms with mobility features such as the problems of reader collision and hardware optimization in resource and bandwidth constrained environments. Examples of algorithms that get benefit from this cross-layer optimization will also be provided. A brief overview of the contents of the research proposal follows.

RFID reader architectures and interfaces

To address optimization of reader platforms it is first necessary to define the elements of an RFID system, a generic architecture, and the functionalities of the platform. A generic RFID system is composed of tags, readers and a middleware platform (see left side of Figure 1). In a mobile RFID system a proxy element can be further inserted (see right side of Figure 1 and Figure 2). Functionalities of the reader platform will be divided into subsets and they will be potentially hosted by one or more elements of the architecture. An example of this task division is displayed in the right side of Figure 1 and another one in Figure 2. Some of these tasks, however, are exclusive of certain elements of the architecture. For example, ID and memory storage are exclusive tasks of tags. The aim of this approach is to investigate ways to optimizing reader architectures while preserve reading reliability levels and reducing cost.

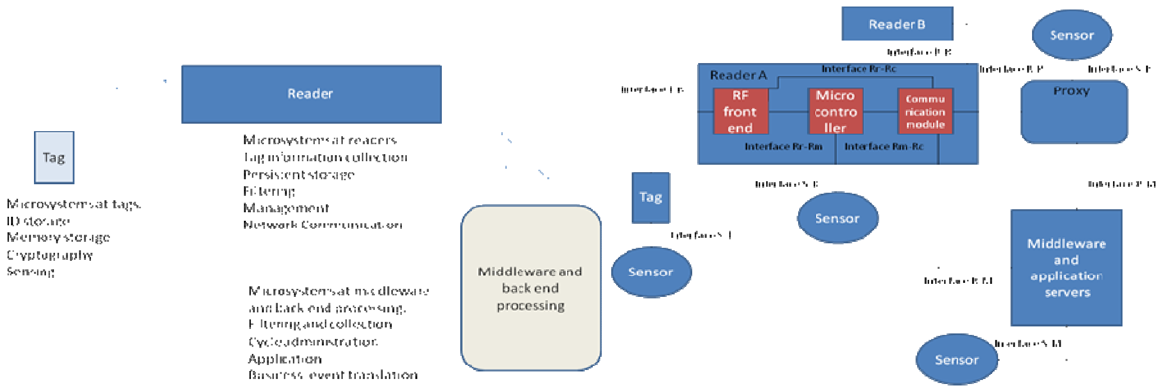

Figure 1 Reference model for (left) RFID systems and (right) mobile RFID micro-systems architecture.

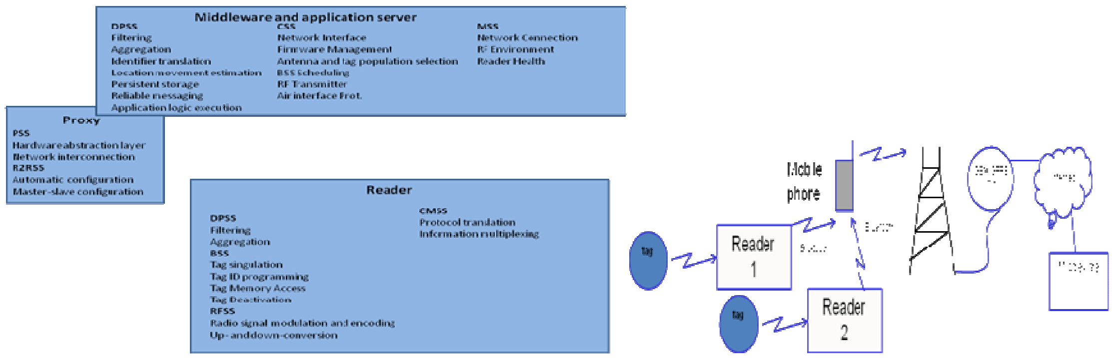

Figure 2 (left) An example of task subdivision in a mobile RFID platform and (right) A mobile RFID scenario.

PHY,MAC, Networking and cross-layer issues and solutions

Since most of the algorithms in an RFID platform aim at improving reading reliability levels, it is mandatory to study and classify the main causes of reading reliability impairments. For convenience we will classify these impairments into those at the physical layer (PHY), impairments at the medium access control layer (MAC), and impairments at upper layers (see left side of Figure 3). Examples of physical layer impairments are fading, multipath propagation, effects of metallic environments, tag distortion and tag coupling effects. At the MAC layer we mainly find tag-to-tag and reader-to-tag collision problems. A similar classification can be made for algorithms and schemes to improve reading reliability levels (see right side of Figure 3) with special mention of cross-layer algorithms. Physical layer algorithms include multiple antenna transceivers, improved antenna, tag and reader designs, etc. MAC algorithms are focused on tag and reader collision resolution algorithms and upper layer algorithms on middleware, context aware and tag estimation schemes. Further details of these algorithms are displayed in Figure 4, 5 and 6. Signal processing, tag and tag antenna solutions are displayed in Figure 4. Signal processing schemes are subdivided in those for the uplink and those for the downlink of the communication link. Right side of Figure 4 is dedicated to tag improvement schemes and in particular tag antenna design. Figure 5 shows different algorithms for the reader side and particularly for tag collision algorithms. Cross-layer tag collision algorithms have been found as a promising area of research. Figure 6 does a similar job but for reader collision algorithms, where it has been found that cross-layer solutions have been virtually unattended thereby being an open research topic. Left side of Figure 7 shows the cross-layer schematic representation to be followed in this book chapter. The aim is to combine physical, MAC and upper layer algorithms in a jointly manner so as to improve tag and reader collision management with minimum hardware complexity and bandwidth usage. Joint analysis of reader complexity versus bandwidth utilization in mobile communication networks will also be considered (see right side of Figure 7).

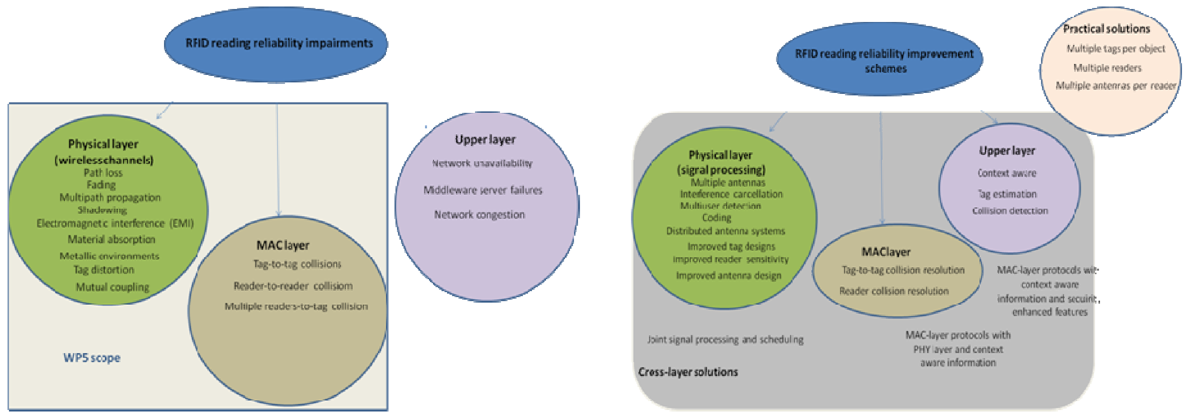

Figure 3 Classification of RFID reliability impairments (left) and algorithms to improve reliability (right).

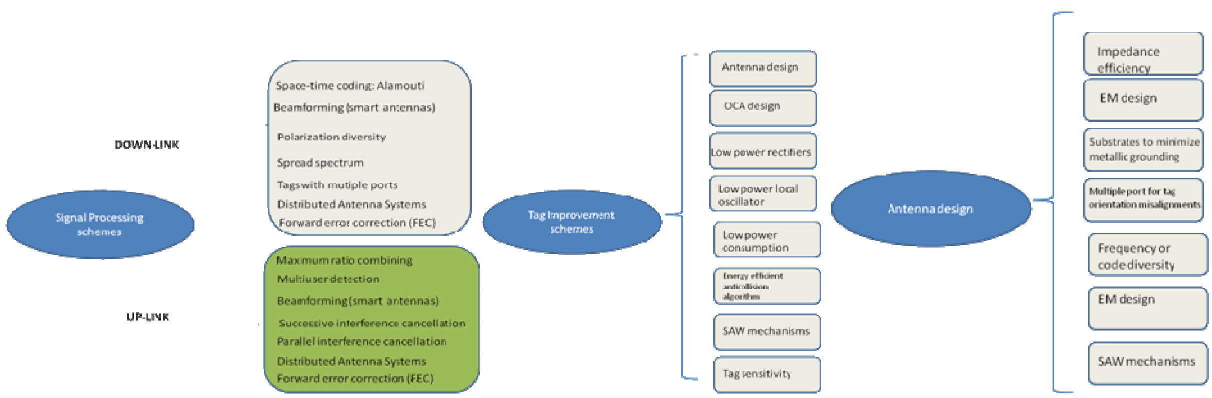

Figure 4 Signal processing schemes (PHY layer) for improvement of RFID reading reliability (left), and tag (middle) and tag antenna (right) improvement schemes.

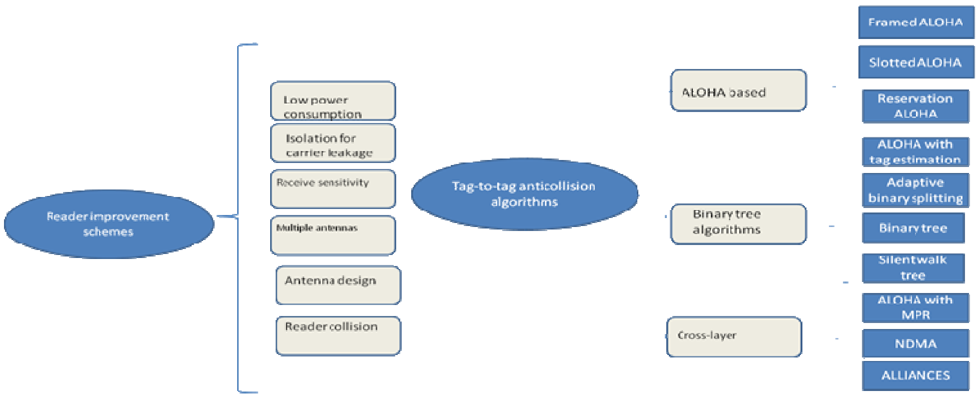

Figure 5 Reader improvement schemes (left) and classification of tag-to-tag anti-collision algorithms (right).

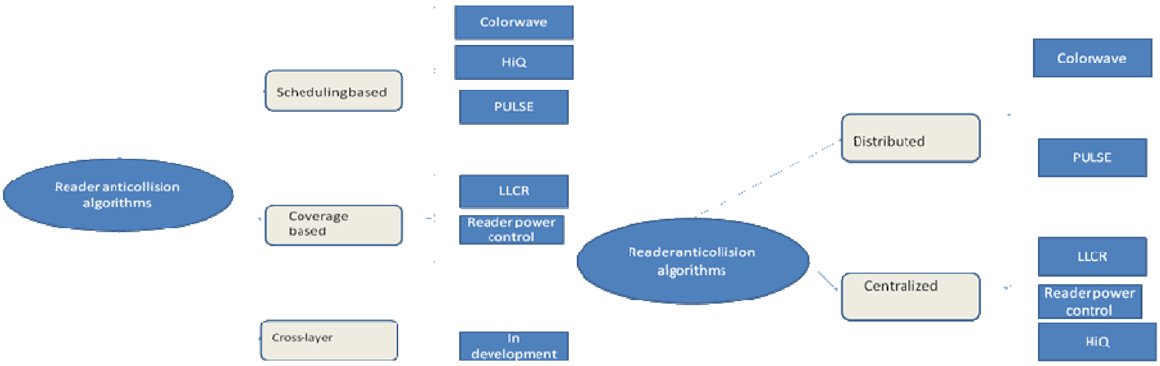

Figure 6 Classification of reader collision algorithms.

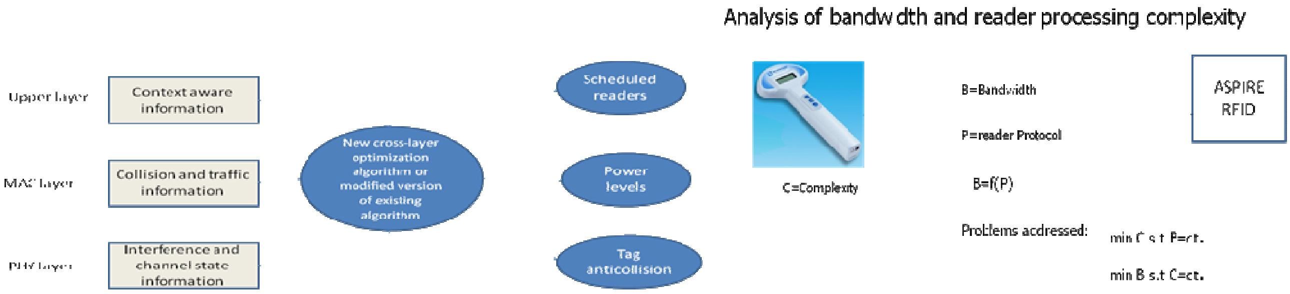

Figure 7 (left) Schematic representation of the different classes of cross-layer solutions and (right) analysis of bandwidth versus reader processing complexity.

1. C.Floerkermeier, C. Roduner, and M. Lampe, "RFID Application development with the Accada middleware platform," IEEE Systems journal, vol. 1, No. 2, December 2007.
2. ASPIRE deliverable D5.3 Reading reliability report, 2010, www.
3. ASPIRE deliverable D5.1 Optimized Microsystems and RFID readers, 2010. w