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Future RFID technology and applications: visions and challenges

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Radio Frequency Identification (RFID) is an exciting, rapidly growing, multidisciplinary technology, which is capable of automatically and uniquely identifying objects or persons by radio frequency within certain proximity. It is emerging as one of most fundamental technologies to ubiquitous computing, Internet of Things, intelligent transport systems, and web of things owing its low cost, automatic identification and broad applicability. RFID has achieved widespread success in various domains, ranging from animal identification, asset tracking, highway toll collection, smart home appliances, supply chain management, to surveillance systems.

With massive RFID adoption, RFID presents a series of challenging issues that are significant and should be overcome before enjoying the benefits from RFID. These new challenges consist of energy-efficient data gathering and process in large-scale environments, software infrastructures for supporting Internet of Things, the interaction model for hand-held devices, the leading-edge innovations RFID applications, the business value and performance measurement, and security and privacy attacks.

This special issue presents six papers, selected from more than twenty submissions around the world. A submission might be considered for publication on this special issue after two round review processes. In each round review process, the submission goes through a rigorous review of at least three reviewers. As a result, this special issue brings the novel research papers ranging from modeling to applications, include routing protocol, authentication, security, and practice.

As we know, in practical scenarios, there are objects without any available ID, including objects unattached any ID itself, and objects attached ID but unreadable or untrustable, ID-based system solutions turn into inapplicable in such cases. The authors in the paper, ***Tree-Code Modeling and Addressing for Physical-world Objects***, named these objects as non-ID (nID) objects. Then, ID objects and nID objects coding and addressing become a noteworthy issue. In this paper, they focus on Physical-world objects (i.e., ID and nID) to present a combined coding and addressing solution. Concretely, (1) nID objects are described along with the typical advantages of applying nID solution; (2) a tree code structure (Tree-Code) is introduced to establish a unified ID objects and nID objects modeling scheme according to abstracted data elements; (3) Tree-Code based addressing scheme is presented with priority considerations. It indicates that nID-based IoT may provide a complement to ID-based IoT, making IoT adapt to heterogeneous networks.

The Border Gateway Protocol (BGP) is an inter-autonomous system and policy-based routing protocol, where each autonomous system can define its own policy independently. However, some defined policies may lead to the BGP networks that do not converge. In the second paper, ***Modeling and Analysis of the Convergence Property of the BGP Routing Protocol Using SPIN***, the authors present a methodology to verify the convergence property of the BGP networks using the SPIN model checker. Technically, the routing protocol and networks are abstracted and modeled in the PROMELA language, and then the convergence property is specified as LTL formulae and verified over the established model. The

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effectiveness of the proposed methodology is demonstrated by experiments and verification results.

To protect RFID systems against the relay attack, distance bounding protocols are commonly employed. Within such protocols, the reader estimates an upper bound for the physical distance between the tag and itself as well as authenticating the tag. In the fourth paper, ***Achieving an Appropriate Security Level for Distance Bounding Protocols over a Noisy Channel.*** *Its implementability over Low Cost RFID Tags*, the concept of a distance bounding protocol is introduced with five adjustable security parameters as a general case for these existing protocols. Moreover, an ultra-lightweight scheme based on the introduced distance bounding protocol is proposed which can be implemented on low cost RFID tags. Next, since RFID systems and distance bounding protocols are principally susceptible to noise, the security analysis of the introduced distance bounding protocol is performed over a noisy channel. With such analysis, the attacker's success probability due to mafia fraud and distance fraud attacks are obtained in a closed form through five security parameters and the probability of erroneous transmission. In this case, the proposed ultra-lightweight scheme provides the optimal attackers' success probabilities with the minimum number of iterations and minimum memory requirements for RFID tags compared with other existing distance bounding protocols.

The following three papers focus on the applications of RFID technology. Voice over Internet Protocol (VoIP) is a wide used technology for making telephone calls using an Internet connection instead of a regular phone line. In recent years, sensor technology is integrated with VoIP to make mobility possible. But it is difficult to keep the communication quality while the VoIP account is switched to new IP Address. For the reasons, the fifth paper, ***RFID-based Mobility for Seamless Personal Communication System in Cloud Computing***, aims to propose a RFID-based mobility for seamless personal communication system in cloud computing. The proposed system is designed with two main technologies: RFID and Session Initiation Protocol (SIP). By equipping every mobile device with a RFID component, the proposed system can monitor the position of the device. The VoIP connection for the mobile device is established by using SIP. By monitoring the position of the device, the connection is seamless since it can be rebuilt in advance. The traceability system is becoming more attractive, especially in the food supply chain. Currently, RFID and EPCglobal Network Standards are the best solution for faster, more accurate, and real-time data integration technique, which is became growing interested by the supply chain. The sixth paper, ***An RFID-based Traceability System***, proposes the adaptive RFID and EPCglobal Network Standards based traceability system. The traditional architecture has been enhanced by adding two new features, the lot management system and the EPCIS, to fulfill the missing data. The proposed traceability system has been applied in the rice supply chain. The critical activities that the data have to be captured are stated. The results from the traceability system with the additional features showed that, the proposed system can fulfill the basic global traceability in term of data requirement. In the seventh paper, ***Enabling RFID Technology for Healthcare: Application, Architecture, and Challenges***, the authors focus on the application of RFID in the healthcare. In the current healthcare system, the information collection problems are particularly challenged in patients lacking verbal communication or under other serious conditions. Information handover among medical staff can also introduce human errors which may place a patient's health and life at risk. RFID technology allows crucial personal information to be saved in a low-cost chip attached to the patient. The authors investigate and propose a scalable RFID-based architecture that can be deployed cost-effectively and at the same time supports the delivery of accurate and timely healthcare to all patients. The various components of our proposed architecture are presented and their potential benefits have also been identified.

In closing, the guest editors would like to acknowledge the contributions of the many experts who submitted their work, participated in the review process, and provided constructive and helpful comments to the authors to improve the technical content and presentation quality of the papers. We hope you will enjoy the papers in this collection.

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