Introduction to the Special Issue: Applications of Internet of Things

Chi-Hua Chen [1],*, **Eyhab Al-Masri [2]**, **Feng-Jang Hwang [3]**, **Despo Ktoridou [4]** and **Kuen-Rong Lo [5]**

[1]   College of Mathematics and Computer Science, Fuzhou University, Fuzhou 350100, China
[2]   School of Business & Economics, Wilfrid Laurier University, Waterloo, ON N2L 3C5, Canada;
      ealmasri@wlu.ca
[3]   School of Mathematical and Physical Sciences, University of Technology Sydney,
      Ultimo NSW 2007, Australia; Feng-Jang.Hwang@uts.edu.au
[4]   Department of Management and MIS, University of Nicosia, Nicosia 2417, Cyprus; ktoridou.d@unic.ac.cy
[5]   Telecommunication Laboratories, Chunghwa Telecom Co. Ltd., Taoyuan 326, Taiwan; lo@cht.com.tw
*   Correspondence: chihua0826@gmail.com; Tel.: +886-975292259

Abstract: This editorial introduces the special issue, entitled "Applications of Internet of Things", of Symmetry. The topics covered in this issue fall under four main parts: (I) communication techniques and applications, (II) data science techniques and applications, (III) smart transportation, and (IV) smart homes. Four papers on sensing techniques and applications are included as follows: (1) "Reliability of improved cooperative communication over wireless sensor networks", by Chen et al.; (2) "User classification in crowdsourcing-based cooperative spectrum sensing", by Zhai and Wang; (3) "IoT's tiny steps towards 5G: Telco's perspective", by Cero et al.; and (4) "An Internet of things area coverage analyzer (ITHACA) for complex topographical scenarios", by Parada et al. One paper on data science techniques and applications is as follows: "Internet of things: a scientometric review", by Ruiz-Rosero et al. Two papers on smart transportation are as follows: (1) "An Internet of things approach for extracting featured data using an AIS database: an application based on the viewpoint of connected ships", by He et al.; and (2) "The development of key technologies in applications of vessels connected to the Internet", by Tian et al. Two papers on smart home are as follows: (1) "A novel approach based on time cluster for activity recognition of daily living in smart homes", by Liu et al.; and (2) "IoT-based image recognition system for smart home-delivered meal services", by Tseng et al.

Keywords: Internet of things; smart transportation; smart home; data sciences; communications

1. Introduction

In recent years, the techniques of Internet of Things (IoT) have become more and more popular for collecting sensing data and building intelligent services and applications. Some organizations (e.g., oneM2M [1–6], AllSeen Alliance, and the Open Connectivity Foundation (OCF) [4,7–11], IEEE [12–16], etc.) were instituted to establish the standards and specifications of IoT for building an IoT ecosystem. These standards and specifications discuss the issues of data models, the unique identification of things, service descriptions and dependencies, discovery, trust management, communications, and real-time control and cyber-physical systems. For instance, the AllSeen Alliance and OCF designed discovery and advertisement mechanisms to send multicast packets to find the adapted devices, which include the target interface in a wireless local area network based on IEEE 802.11, or a personal area network based on IEEE 802.15 for building a self-organizing network. The devices can follow the data models and control methods in specifications to control other AllJoyn or OCF devices for IoT applications.

However, communications among the different techniques of IoT standards and specifications are significant challenges. Furthermore, the interoperation of services across platforms based on different IoT standards and specifications needs to be investigated. For example, the Interworking Proxy Entity (IPE) was designed to establish the connection of oneM2M, AllJoyn, OCF, and Lightweight M2M in oneM2M's Release 2 [1]. Some communication techniques have been proposed to collect the sensing data and control the devices via different IoT standards and specifications for the applications of agriculture [17–19], energy [20,21], enterprise [22,23], finance [24,25], healthcare [26,27], industry [28,29], public services [30,31], residency [32,33], retail [34,35], and transportation [36–40]. Therefore, the aim of this special issue is to introduce to the readers a number of papers on various aspects of IoT applications and techniques.

This special issue received a total of 26 submitted papers, with only nine papers being accepted. A high rejection rate of 65.38% of this issue from the reviewing process is to ensure that high-quality papers with significant results are selected and published. The statistics of the special issue are presented as follows.

- Submissions (26);
- Publications (9);
- Rejections (17);
- Article types: research article (8); review article (1).

The distribution of authors' countries is showed as follows.

- China (6);
- USA (4);
- South Africa (2);
- Bosna i Hercegovina (1);
- Colombia (1);
- Italy (1);
- Spain (1).

Topics covered in this issue include four main parts: (1) communication techniques and applications, (2) data science techniques and applications, (3) smart transportation, and (4) smart home. The four topics and accepted papers are briefly described below.

2. Communication Techniques and Applications

Four papers on sensing techniques and applications are as follows: (1) "Reliability of improved cooperative communication over wireless sensor networks", by Chen et al. [41]; (2) "User classification in crowdsourcing-based cooperative spectrum sensing", by Zhai and Wang [42]; (3) "IoT's tiny steps towards 5G: Telco's perspective", by Cero et al. [43]; and (4) "Internet of things area coverage analyzer (ITHACA) for complex topographical scenarios", by Parada et al. [44].

Chen et al. from China and USA in "Reliability improved cooperative communication over wireless sensor networks" considered that the nodes in the region far from the sink node in wireless sensor networks (WSNs) had much remaining energy. Therefore, this study proposed a reliability-improved cooperative communication data collection scheme to adopt unequal transmission powers in different places in WSNs, for the improvement of transmission reliability. Some analytical models were proposed to analyze the energy consumption and network reliability of data collection scheme. In experimental environments, numerical analysis and simulations were given to evaluate the proposed method, and the results showed that the end-to-end message fail delivering ratio of the proposed method is reduced by as least 50% [41].

Zhai and Wang from China, in "User classification in crowdsourcing-based cooperative spectrum sensing" defined and analyzed various types of honest users and malicious users in cognitive radio

networks. This study proposed a dynamical clustering method to analyze spectrum sensing reports, which are obtained based on crowdsourcing for the determination of user types. Furthermore, the malicious users can be detected and filtered out. In experimental environments, simulated records were generated to evaluate the proposed method, and the results showed that the user classification error of the proposed method is lower than the reputation-based classification method [42].

Cero et al. from Bosna i Hercegovina in "IoT's tiny steps towards 5G: Telco's perspective" proposed a methodological approach and an activity-based classification method to collect and discuss relevant literature for the analyses of IoT application classification (i.e., ticketing, monitoring, tracking, and managing/controlling), performance requirements (i.e., data rate, mobility, latency, connection density, reliability, positioning accuracy, coverage, and energy efficiency) and enabling technologies (i.e., wide and flexible bandwidth technology, advanced modulation, and coding, duplexing, multiple access and waveform, advanced interface management, access architecture related radio technologies, energy related technologies, and other technologies) in 5G networks. The 258 articles published in the period from 2012 to 2017 were analyzed to summarize the development guide of IoT in 5G networks for telecommunications companies [43].

Parada et al. from Italy and Spain in "An Internet of things area coverage analyzer (ITHACA) for complex topographical scenarios" designed and implemented a signal analyzer to analyze the signal of low power wide area networks and to automatically generate the signal coverage maps. This study used the Arduino Uno to implement terminal devices, which could collect geo-coordinates from global positioning system (GPS) receivers, and network signals from Sigfox networks. In experimental environments, the practical geo-coordinates and network signals of 400 spots on the Gran Canaria Island in Spain were collected and analyzed. The results showed that the average successful transmission is 97%, and signal coverage maps were drawn for smart city developers [44].

3. Data Science Techniques and Applications

One paper on data science techniques and applications is included as follows: "Internet of things: a scientometric review", by Ruiz-Rosero et al. from Colombia and USA [45]. The study proposed a methodological approach to collect and discuss relevant literature from two scholarly bibliographic databases (i.e., Clarivate Analytics Web of Science and Scopus) for the analyses of country, author, and research topics (i.e., applications, communication protocols, software processing techniques, device operating systems (OS) and hardware, and top trending topics). A Python script was implemented to analyze the relevant literature, and to generate several statistic charts for the visualization of trends. The 19,035 articles published in the period from 2002 to 2016 were analyzed to summarize the top trending topics (e.g., cloud computing, security, big data, wireless sensor networks, privacy, industry 4.0, fog computing, and software defined networking) of IoT [45].

4. Smart Transportation

Two papers on smart transportation are included as follows: (1) "An Internet of things approach for extracting featured data using an AIS database: an application based on the viewpoint of connected ships", by He et al. [46]; and (2) "The development of key technologies in applications of vessels connected to the Internet", by Tian et al. [47].

He et al. from China, USA, and South Africa in "An Internet of things approach for extracting featured data using an AIS database: an application based on the viewpoint of connected ships" used the evidential reasoning approach and proposed a nonlinear optimization method to analyze the means and variances of speed over ground, and course over ground for the detection of the movement direction of vessels. The proposed nonlinear optimization method can determine the value of weight coefficients for the improvement of classification accuracy. In experimental environments, 17,723 practical samples were collected from 1 November 2015 to 31 August 2016 to evaluate the proposed method, and the results showed that the average classification accuracy of the proposed method is 98.93% [46].

Tian et al. from China, USA, and South Africa, in "The development of key technologies in applications of vessels connected to the Internet" introduced the architectures, characteristics, applications and benefits, and challenges of Internet of vessels (IoV). Some IoV applications included the intelligent navigation of ships (e.g., unmanned ships), the intelligent management and service of vessels (e.g., electronic freight), and traffic flow prediction were summarized and presented for the demonstration of IoV trending topic. Furthermore, this study discussed IoV challenges and prospects, including safety mechanisms and transmission for the waterway traffic information, and advanced intelligent terminals for the illustration of future work [47].

5. Smart Home

Two papers on smart home are included as follows: (1) "A novel approach based on time clusters for activity recognition of daily living in smart homes", by Liu et al. [48]; and (2) "IoT-based image recognition systems for smart home-delivered meal services", by Tseng et al. [49].

Liu et al. from China in "A novel approach based on time clusters for activity recognition of daily living in smart homes" proposed a two-stage time clustering method to analyze practical sensing data for the detection of resident activities in home. In Stage 1, the practical sensing data can be clustered in accordance with temporal features; in Stage 2, some classification methods (e.g., naive Bayesian classifier, k-nearest neighbors, decision tree, and random forest) were applied to analyze the practical sensing data of each cluster, and to a generate classification model for each cluster. In experimental environments, the two open datasets from the "single-resident apartment data" provided by Washington State University were collected to evaluate the proposed method, and the results showed that the average classification accuracy of the proposed two-stage time clustering method is higher than the one-stage method without time clustering [48].

Tseng et al. from Taiwan in "IoT-based image recognition system for smart home-delivered meal services" proposed a statistical histogram-based k-means clustering method to segment images for reducing computation time. In the proposed method, a pre-process stage was considered to analyze the discrete probability density function of the gray scale values, and to generate a discrete statistical histogram for the extraction of image features. In experimental environments, the open dataset from the "Berkeley segmentation dataset: images" provided by the University of California, Berkeley was collected to evaluate the proposed method, and the results showed that the computation time of the proposed method is lower than the k-means clustering method [49].

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