Guest Editorial
Special Issue on Internet-of-Things for Smart Cities

THE CITIES in the world are in the process of quick transition toward more smart, automatic, responsive, and flexible societies. The Internet-of-Things (IoT) are expected to improve the intelligence of the cities, promote the interaction between the human and the environment, enhance the reliability, resilience, operational efficiency, and energy efficiency, as well as reduce costs and resource consumption. The development, adoption, and application of IoT technology into smart cities is of huge interest. Local authorities have partnered with startups, technology companies, research institutions, and universities to test and deploy IoT across all dimensions of urban life such as smart grid (SG), smart buildings, water management, connected healthcare and patient monitoring, environment/climate monitoring, connected cars, and smart transportation.

New IoT architectures and technologies are required to promote better engagement and participation of citizens, and guarantee high quality of service and low maintenance. Extensive research on IoT in smart cities is taking place on environmental sensors, cloud computing technology, and big data analysis. It facilitates a multidisciplinary approach for developing integrated solutions and creating novel applications to build a sustainable smart society. However, there are many emerging research challenges on IoT for smart cities that need in-depth investigations. The goal of this Special Issue is to provide researchers, developers, and practitioners from both academia and industry with the recent advances and key results on IoT for smart cities.

We received a total of 119 submissions, and after a rigorous reviewing process, 33 papers were accepted to appear on this Special Issue. The accepted papers cover state-of-the-art research and development in different aspects of IoT for smart cities, including infrastructure and application, energy management, big data analytics, sensor technology, communications networks, healthcare, testbed and experiment experiences, information security and privacy, and others.

The paper entitled "Sensor Fusion for Public Space Utilization Monitoring in a Smart City" introduces data processing modules for capturing public space utilization with renewable wireless sensor network platform using pyroelectric infrared (PIR) and analog sound sensors. The authors first propose a calibration process to remove false alarm of PIR sensor due to the impact of weather and environment. This model has addressed different challenges such as false positives generated by PIR sensor and characterizing the noise signature from analog sound sensor. Finally, both sensors are fused to study a particular public space utilization to unveil its usage.

The paper "Internet of Things for Smart Railway: Feasibility and Applications" investigates the major challenges and opportunities associated with the smart railway infrastructure, and an IoT-based maintenance methodology has been discussed and verified. The authors propose the network architecture of IoT solution and evaluate the performance of the candidate radio access technologies for delivering IoT data in the aspects of power consumption and coverage by performing an intensive field test with system level implementations. In addition, the authors figure out the benefits that the IoT can bring based on the observation of use cases in interdisciplinary approaches.

The authors of the paper entitled "ISI: Integrate Sensor Networks to Internet with ICN" study the essential requirements for integrating sensor networks to the future Internet. This paper provides an architecture with gateways for paving a way for sensor networks to become a part of the ICN. Furthermore, they provide a naming scheme for the efficient operation of the resource constrained sensor networks, discuss the mobility, security, and communication patterns, and propose the most suitable choices for the integration.

An integrated framework with detailed implementation of an IoT platform is proposed in the paper entitled "Real-Time Urban Microclimate Analysis Using Internet of Things," which is built for real-time wireless sensor network data on the synergy of computational intelligence and visual methods, to analyze complex patterns of urban microclimate. A Bayesian maximum entropy-based method and a hyper-ellipsoidal model-based algorithm are developed in this proposed integrated framework to address the main challenges in urban microclimate analysis. The proposed integrated framework is verified using the dataset from an indoor and two outdoor networks of IoT devices deployed at two strategically selected locations.

The paper entitled "Bi-Directional Passing People Counting System Based on IR-UWB Radar Sensors" studies an impulse radio ultra-wideband radar sensors for counting the number of people passing through a passageway for each direction. The proposed system is implemented using two designed radar sensors and a Raspberry Pi2 module. Authors install the designed modules in the subway station to verify the performance of the proposd system. The results show that the counting errors are less than 10% except for a few cases.

In the paper entitled "PortoLivingLab: An IoT-Based Sensing Platform for Smart Cities," the authors present PortoLivingLab, a multisource sensing infrastructure that leverages on IoT technology to achieve city-scale sensing of

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four phenomena: weather, environment, public transport, and people flows. The authors also describe the architecture and composing elements of PortoLivingLab, highlighting the IoT technologies, and challenges faced. In addition, several proof-of-concept use cases (e.g., passenger flows from WiFi connections) that provide new insights into different components of an evolving and moving city have been presented.

The paper entitled "Opportunistic Routing for Vehicular Energy Network" develops a method to construct all energy paths for a particular energy source-destination pair, followed by some analytical results of the method. It also describes how to utilize the energy paths to develop optimization models for different design goals and proposes two solutions. Furthermore, this paper develops a heuristic for the power loss minimization problem. The authors compare the performance of the three solution methods with artificial and real-world traffic networks and provide a comprehensive comparison in terms of solution quality, computation time, solvable problem size, and applicability.

The paper entitled "Offline and Online Search: UAV Multiobjective Path Planning Under Dynamic Urban Environment" considers a multiobjective path planning (MOPP) framework to explore a suitable path for a UAV operating in a dynamic urban environment. Two types of safety index maps are developed to capture static obstacles and unexpected obstacles that are unavailable in the geography map. Then an MOPP method is proposed by jointly using offline and online search. The experiment results verify the effectiveness of the proposed framework under the dynamic urban environment.

An anomaly detection framework (ADF) for large-scale, real-world environmental sensing systems is proposed in the paper entitled "ADF: An Anomaly Detection Framework for Large-Scale PM2.5 Sensing Systems." The framework comprises four modules, namely, time-sliced anomaly detection, real-time emission detection, device ranking, and mal-function detection. The authors demonstrate that the proposed framework can effectively identify outliers in the raw measurement data as well as infer anomalous events that are perceivable by the general public and government authorities.

The paper entitled "Virtualization in Wireless Sensor Networks: Fault Tolerant Embedding for the Internet of Things" conducts a framework for optimizing fault tolerance in virtualization in WSNs. An optimization problem is formulated considering fault tolerance and communication delay. An adapted nondominated sorting-based genetic algorithm (A-NSGA) is developed to solve the optimization problem. The major components of A-NSGA include chromosome representation, fault tolerance and delay computation, crossover and mutation, and nondominance-based sorting. The experiment results demonstrate that the framework effectively optimizes fault tolerance for virtualization in WSNs.

The paper entitled "Data Driven Congestion Trends Prediction of Urban Transportation" develops a smart traffic forecasting system based on SWARIMA model. This system is capable of accepting the real-time traffic data stream for the congestion prediction, in addition, the authors reduce the actual running parameters to three attributes: 1) speed; 2) time; and 3) location information. When faced with the challenges of real-time traffic congestion, the system can timely and effectively calculate the congestion trends and provide three reliable elastic intervals: 1) warning; 2) congestion; and 3) mitigation, which has significance to improve traffic condition and alleviate urban road congestion.

The paper entitled "A Collaborative Internet of Things Architecture for Smart Cities and Environmental Monitoring" conducts an architecture, namely SenSquare, to handle the heterogeneous data sources coming from open IoT platform and crowdsensing campaigns, and display a unified access to users. The authors deal with heterogeneous data classification, Mobile Crowdsensing management for environmental data, information representation and unification, and IoT service composition and deployment. Finally, the results demonstrate the capabilities of SenSquare through both a mobile and a desktop client.

The paper entitled "Dynamic Resource Caching in the IoT Application Layer for Smart Cities" proposes a novel energy aware and latency guaranteed dynamic resource caching (EASE) scheme to enable the broker to cache suitable resources such that the energy savings from the servers are maximized, while the average delay for publishing the contents of the resources to the corresponding clients is minimized. The authors demonstrate the performances of EASE via simulations as compared to other two caching strategies, i.e., caching preferred and caching non-preferred.

The paper entitled "Modular and Personalized Smart Health Application Design in a Smart City Environment" presents a versatile and flexible approach to integrate smart health applications with the connectivity of the IoT, facilitating the use of machine learning and improving the complexity of context-aware designs. This approach to IoT applications exposes shareable intermediate context and increases reusability while reducing computational complexity. The authors implement their approach with three interconnected case studies, demonstrating the versatility of the approach as well as up to 65% latency improvements with minimal accuracy loss.

In the paper entitled "Semisupervised Deep Reinforcement Learning in Support of IoT and Smart City Services," a semi-supervised deep reinforcement learning model is proposed, which fits smart city applications as it consumes both labeled and unlabeled data to improve the performance and accuracy of the learning agent. The authors focus on smart buildings and apply the model to indoor localization based on the signal strength. The model learns the best action policies that lead to a close estimation of the target locations with an improvement of 23% in terms of distance to the target and at least 67% more received rewards compared to the supervised deep reinforcement learning model.

The paper entitled "Throughput Maximization and Fairness Assurance in Data and Energy Integrated Communication Networks" describes a typical data and energy integrated network (DEIN), capable of simultaneously transmitting the data and energy to user equipments (UEs). The functions of UEs in this DEIN involves two aspects: 1) harvesting the energy from the DL transmission by adopting the

power splitting technique and 2) exploiting the harvested energy for accomplishing their uplink data transmissions. Two optimization problems are formed by maximizing the sum-throughput and fair-throughput and solved by the classic method of Lagrange multipliers in close-form.

The paper entitled "Using Smart City Data in 5G Self-Organizing Networks" concentrates on self-organization techniques to improve handover efficiency using vehicular traffic data gathered in London. The two proposed algorithms in this paper exploit mobility patterns between cell coverage areas and road traffic congestion levels to optimize the handover bias in heterogeneous networks and dynamically manage mobility management entity loads to reduce handover completion times. The ability to choose the point in the tradeoff between handover frequency and offloading capability will be a key element in the design of self-organizing 5G networks.

The paper entitled "Hybrid PLC/Wireless Communication for Smart Grids and Internet of Things Applications" outlines important characteristics of hybrid power line/wireless data communication system for SG and the IoT applications. The authors highlight a connection between the capillarity of IoT and the communication infrastructure provided by SG. Furthermore, the environmental influence on wireless and power line communications has been investigated. Numerical results show that proposed hybrid approach offer a more reliable data transmission path when compared to the power line or wireless system working alone.

The paper entitled "Empowering Citizens Toward the Co-Creation of Sustainable Cities" aims at taking advantage of massive amounts of information and deployed technology as well as breaking down the potential digital barrier to make some easy-to-use tools available to the urban stakeholders. The results of two different experiments are presented in order to validate the approach and illustrate how the co-creation tools help users with different skills to carry out their experiments obtaining interesting results, and also how cities with or without existing IoT infrastructure are aided by the project.

A multitier fog computing model with large-scale data analytics service is presented in the paper "Multitier Fog Computing With Large-Scale IoT Data Analytics for Smart Cities." In the multitier fog computing model, there are both ad-hoc fogs with opportunistic computing resources and dedicated fogs with dedicated computing resources. In addition, QoS aware job admission control, offloading and resource allocation schemes are developed to provide QoS support for large scale data analytics services over multitier fogs. A scalable system level simulator is developed to evaluate the fog-based analytics service and the QoS management schemes. Simulation results demonstrate the efficiency of analytics services model over multitier fogs and the effectiveness of the proposed QoS schemes.

The paper entitled "Context Design and Tracking for IoT-Based Energy Management in Smart Cities" develops a context-aware management framework, where contexts are modeled as graphs and can be explicitly designed and their occurrences can be tracked down. This framework has been implemented, deployed, and tested in different situations, including troubleshooting, demonstration, reviewing, and performance analysis. Experiment results show that using context graphs that can be designed and tracked might be successfully used in the future system in order to help developers, administrators, and end-users to harness the wealth of information generated by highly scalable IoT systems.

A standard-based approach to design and implement a new fog computing-based framework, namely FogFlow, for IoT smart city platforms is proposed in the paper "*FogFlow:* Easy Programming of IoT Services Over Cloud and Edges for Smart Cities." FogFlow's programming model allows IoT service developers to program elastic IoT services easily over cloud and edges. Moreover, it supports standard interfaces to share and reuse contextual data across services. The authors describe three use cases and implement an example application for anomaly detection of energy consumption in smart cities. Furthermore, they analyze the performance of context management to see the feasibility of standard-based approach in the smart city scale.

The paper entitled "An Incentive Mechanism for Crowdsensing Markets With Multiple Crowdsourcers" proposes an incentive mechanism for crowdsensing with multiple crowdsourcers. The authors model the incentive problem as a noncooperative game where the contributors are the players and the crowdsourcers are the strategies. Moreover, they consider two different pricing mechanisms when the crowdsourcers fix the rewards in advance, or when the crowdsourcers dynamically set the rewards in order to maximize their own utilities. Elite strategy dynamics is proposed to compute a Nash equilibrium of the modeled game. Comprehensive simulation results are presented to evaluate the performance of the proposed incentive mechanism.

The security of the IoT is addressed in the paper "Policy-Based Secure and Trustworthy Sensing for the Internet of Things in Smart Cities." A policy-based secure and trustworthy sensing scheme for IoT named RealAlert is developed, in which the trustworthiness of both data and the IoT devices are evaluated based on both the reporting history and the context in which the data are collected using policy rules. Experimental results show that the RealAlert scheme can accurately assess the trust of the sensor nodes as well as data in IoT.

The paper entitled "Occupancy Counting With Burst and Intermittent Signals in Smart Buildings" considers the use of WiFi probe requests that are continuously transmitted from WiFi enabled smart devices. To this end, WiFi Pineapple equipment is used for passively capturing ambient probe requests from WiFi devices, where no connectivity to a WiFi network is required. This information is then used to localize users within coarsely defined occupancy zones, and subsequently to obtain occupancy count within each zone at different time scales. The numerical results show that utilization of WiFi probe requests can be considered a viable solution tool for zone-level occupancy counting in smart buildings.

The paper entitled "Internet of Hybrid Energy Harvesting Things" surveys the various energy harvesting (EH) opportunities, proposes a hybrid EH system, and discuss energy and data management issues for battery-free operation. The authors

mathematically prove advantages of hybrid EH compared to single source harvesting. Furthermore, they point out the hardware requirements and present the open research directions for different network layers specific to hybrid energy things for smart city concept. Simulation tests show that the new framework with hybrid energy harvester can achieve lower drop rates for the same reporting frequency.

A novel unified method of automated object detection for urban surveillance systems is presented in the paper "IoT-Driven Automated Object Detection Algorithm for Urban Surveillance Systems in Smart Cities." The authors design a simple filter to effectively detect either vehicle license plates or vehicles, motivated by the observation that in the most cases the object is the highest energy frequency part of an image. The proposed method can help to detect object vehicles rapidly and accurately and can be used to reduce the data volume needed to be stored in the urban surveillance system.

The paper entitled "LASeR: Lightweight Authentication and Secured Routing for NDN IoT in Smart Cities" proposes and evaluates a novel, scalable framework for lightweight authentication and hierarchical routing in the NDN IoT (ND-NoT). The authors analyze the current state-of-the-art of routing and authentication in the ND-NoT. Scalability is achieved through a hierarchical network design with very little cryptographic or computational burden. Evaluation by simulations confirmed that LASeR requires minimal network overhead and achieves acceptable onboarding convergence times.

The paper entitled "An Ingestion and Analytics Architecture for IoT Applied to Smart City Use Cases" develops the hut architecture, a simple but scalable architecture for ingesting and analyzing IoT data, which uses historical data analysis to provide context for real-time analysis. The authors implement the proposed architecture using open source components optimized for big data applications. The proposed solution is flexible with regard to the choice of specific analysis algorithms and suitable for a range of different machine learning and statistical algorithms. They also demonstrate the solution on two use cases of real-world smart cities in transportation and energy management.

An approach for enabling easier composition of real-time data processing pipelines in smart cities is presented in the paper entitled "Complex Event Processing for City Officers: A Filter and Pipe Visual Approach." The proposed approach encompasses both a graphical editor and a sound methodology and workflow, to allow city operators to effectively design, develop, test, and deploy their own data processing pipelines. The entire approach has been contextualized and demonstrated through a use case for waste management for an ALMANAC project pilot held in Turin, Italy.

The paper entitled "From Micro to Macro IoT: Challenges and Solutions in the Integration of IEEE 802.15.4/802.11 and Sub-GHz Technologies" focuses on practical integration between Micro and Macro IoT approaches, providing architectural and performance details for a set of experimental tests carried out in the campus of the University of Parma. Low-power and long range devices act as gateways for Micro IoT networks to create a low cost and highly scalable IoT architecture, which fits with the requirements of typical smart city applications. In addition, the authors discuss the challenges and solutions of the proposed Micro-Macro integrated IoT systems.

In the paper entitled "A Fog Based Healthcare Framework for Chikungunya," a fog-assisted cloud-based healthcare system is developed for predicting and preventing Chikungunya virus using wearable sensor technology, decision tree, and temporal network analysis. The key point of this paper is to determine the probability of health index with respect to time of various events. Results show that the proposed system is highly effective in delivering healthcare services during the outbreak of Chikungunya virus. Moreover, alert generation based on real-time healthcare data further enhances the utility of the proposed system.

The paper entitled "Travelling Officer Problem: Managing Car Parking Violations Efficiently Using Sensor Data" uses a large real-world dataset with on-street parking sensor data from the local city council and establishes a formulation of the Travelling Officer Problem with a general probability-based model. The authors propose two solutions using a spatio-temporal probability model for parking officers to maximize the number of infringing cars caught with a limited time cost. Using real-world parking sensor data and Google Map road network information, the experimental results show that the proposed algorithms outperform the existing patrolling routes.

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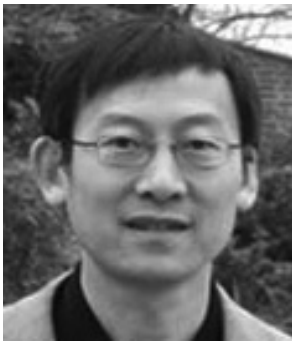

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