Guest Editorial Special Issue on Software Defined Networking for Internet of Things

THE TECHNOLOGY of Internet of Things (IoT) has been gaining great popularity in recent years, as it provides an effective and immediate bridge between the physical world and the virtual objects in the cyber space, which can lead to innovative applications and services with high efficiency and productivity. However, IoT is just at the beginning stage of a longer journey. In-depth research and development efforts on systems, networks and architectures of IoT for efficient large-scale deployments are still required to fill the gaps between the current performance and service requirements, particularly with the predicted importance of IoT in the upcoming years, improved connectivity and communication among numerous devices will become necessary and critical.

Software defined networking (SDN), which separates the control and data planes of networking devices, offers exceptional flexibility in programmability and enormous potentials for optimization of network resource usage. Thus, SDN is an attractive technology to fill these gaps by enabling new ways of IoT communications and services through simple, but smart, open, and powerful networking devices and systems with adaptive and scalable functionalities. SDN-based IoT can provide attractive solutions to address many challenges dealing with the overwhelming service requests and data flows generated by IoT devices, such as distributed collaborative heterogeneous identification schemes, service virtualization and elasticity, automated management, maintenance, and upgrades, and rapid and seamless network resource optimization in response to environment changes by scaling up (or down) services, and so on. To address these challenges, we have planned this special issue and hoped it could offer a venue where researchers from both academia and industry can publish premier articles on the recent advances in SDN-IoT theory, techniques, application and implementations.

In this special issue, we have received a total of 22 submissions, and after rounds of careful reviews, we chose 8 papers for publication. Among accepted submissions, the paper entitled "A Software-Defined Surveillance System with Energy Harvesting: Design and Performance Optimization" proposes a work on optimization of sleep schedules in surveillance systems where energy harvesting sensor nodes (EHSs) and nonenergy harvesting sensor nodes (NHSs) coexist. In the proposed surveillance system, a centralized controller which illuminated from the concept of SDN collects the contextual information and determines the sleep schedules of EHSs and NHSs on the basis of those information. For the purpose of minimizing the number of active sensor nodes while providing sufficient surveillance performance, the authors formulate the whole process as a constraint Markov decision process problem and obtain its optimal policy by linear programming, and finally the number of active sensor nodes can be reduced up to 90% while providing the required level of target monitoring probability.

An adaptive transmission architecture and approach is given in the paper "Adaptive Transmission Optimization in SDN-based Industrial Internet of Things with Edge Computing." As opposed to the present works which could not handle the increasing requirement for exchange of data with different delay flows among different smart devices, in their work, a clustered data transmission framework involved with SDN and edge computing is adopted. The SDN-driven architecture for IoT in the context of edge computing could facilitate the management of limited communication resources. To adapt data flows with different time consumption demands, an optimum routing is selected from the candidate path set by employing the path difference degree. The coarse-grained and the fine-grained strategy are combined aiming to establish an effective transmission path by an adaptive power method and thus obtain low latency.

The paper entitled "PRSFC-IoT: A Performance and Resource Aware Orchestration System of Service Function Chaining for Internet of Things" uses the service function chaining (SFC) service which is a typical and successful case of SDN and network function virtualization to define a sequence of heterogeneous virtual network function instance for processing the massive data flows which belong to users' applications flexibly. These service chains can make the service network of IoT more efficient, more scalable and more economical. Particularly, the authors formulate the problem of performance and resource aware SFC orchestration with an optimization model, and give an approximation optimization algorithm to achieve the guarantees of deadline and packet rate while avoiding resource idleness. They also build a prototype system named PRSFC-IoT upon OpenStack for online SFC orchestration, and this prototype demonstrates its significant advantages against the existing greedy based solution.

Aiming at evaluating the security level of Cloud-IoT (cloud and IoT), the authors of the paper entitled "A Software Defined Network-Based Security Assessment Framework for

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CloudIoT" develop an end-to-end security assessment framework based on SDN. Specially, in order to simplify the network controls and focus on the analysis about the data flow through CloudIoT, they develop a three-layer framework by integrating SDN and CloudIoT, which consists of 23 different indicators to describe its security features. Depending on these indicators, interviews from industry and academic can effectively evaluate the security level of Cloud-IoT, and thus facilitating the selection of Cloud-IoT.

The security problem is also addressed in the paper entitled "TNGuard: Securing IoT Oriented Tenant Networks Based on SDN," where the infrastructures allocated to a certain tenant is called a tenant network (TN). While the integration of IoT with the technology of SDN and cloud computing provides a more flexible network, it also brings problems such as security uncertainty the traditional security equipment could not handle. The most important unfathomed problem lies in that the work flow inside TNs should not be affected by a privileged administrator (namely cloud administrator). To this end, the authors adopt a modular design methodology and present a platform-independent concretization of the TN abstraction (dubbed TNGuard), which isolates the system components into three kinds of zones: 1) the cloud controller zone; 2) the cloud administrator zone; and 3) the tenant administrator zone. A prototype of TNGuard in the Xen using the Ryu SDN controller is implemented and the corresponding experiments demonstrate its small performance overhead.

The authors of the paper entitled "Software Defined Networking for Energy Harvesting Internet of Things" exploit SDN to simplify and optimize network management in the energy harvesting IoT, of which the network lifetime has the potential to be prolonged, and they name this structure as software defined energy harvesting IoT (SEANET). In SEANET, the data plane, energy plane and control plane are decoupled, aiming to jointly optimize control of the data flows and bi-directional energy flows. Besides, another two main contributions are put forward to replenish the structure.

1) For secure communications (i.e., reduce packet loss), the multiweighted subject logic is leveraged to evaluate reputation values of nodes, and then data packets are relayed among the nodes with higher reputation values and sufficient energy.
2) Toward flexible energy scheduling, a Nash bargaining game is formulated to solve the benefit allocation problem for energy trading. Eventual numerical results indicate that SEANET could improve data traffic by reducing packet loss, optimize energy utilization and save energy.

The privacy issue in SDN-based mobile healthcare social networks are investigated in the paper entitled "Toward Privacy-Preserving Symptoms Matching in SDN-Based Mobile Healthcare Social Networks." Certainly, with the help of SDN architecture, the flexibility and performance of data flows between smartphones and healthcare center can be improved. However, a major challenge is how to achieve privacy-preserving (refer to privacy-protected, efficient and time-saving) symptom matching process before establishing social interaction with other patients in MHSNs. Thus, the authors propose blind signature-based privacy-preserving symptom matching schemes for SDN-based MHSNs. In such scheme, both the coarse-grained matching (using the Bloom filter to achieve the efficient matching) and fine-grained matching (using the similarity degree of two users) are taken without any trusted third party, and the RSA-based blind signature are employed for privacy protection. The security, performance analysis and the practical implementation demonstrate the feasibility of this scheme.

The last paper entitled "Traffic Load Minimization in Software Defined Wireless Sensor Networks" combines the SDN with wireless sensor networks to handle the traditional routing problem by decoupling the control plane from the data plane and achieve traffic load minimization (TLM). However, the limited routing strategy in SDWSNs imposes a great challenge in fulfilling the minimum traffic load. Therefore, the authors adopt several steps to cope with that challenge.

1) Formulate the objective function of TLM problem and the constraints of the load of sensor nodes, and then analyze the similarities of packets between source and relay sensor nodes.
2) Use the Levenberg–Marquardt algorithm to solve the formulated TLM problem.
3) Propose the flow splitting optimization (FSO) algorithm to find an optimal routing path from source sensor node to sink node, and ensure the traffic load of SDWSNs is minimum.

After the above procedures, FSO algorithm shows that it could achieve less redundant packet transmissions and higher packet delivery ratio in simulation results.

To conclude, we are very grateful to all the authors for their valuable contributions to this SI, and to all the reviewers for their timely and rigorous reviews. In addition, we would like to take this opportunity to thank the Editors-in-Chief of the journal for their help in the whole publication process. We expect that this Special Issue can help both industry and academic research communities better understand the recent advances and potential research directions on the topic of "Software Defined Networking for Internet of Things."

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