Future Generation Computer Systems 75 (2017) 82–84

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Editorial

Cyber-physical systems, internet of things and big data

Sergio F. Ochoa [a], Giancarlo Fortino [b], Giuseppe Di Fatta [c]

[a] Computer Science Department, University of Chile, Chile
[b] Department of Informatics, Modeling, Electronics, and Systems, University of Calabria, Italy
[c] Department of Computer Science, University of Reading, UK

ARTICLE INFO

Article history:
Received 17 December 2015
Received in revised form 29 January 2016
Accepted 30 January 2016

ABSTRACT

Advances in wireless communication, in computing and in sensing devices, along with the cost reduction of these technologies, have prompted and accelerated the development of Cyber-Physical Systems that adopt the Internet of Things paradigm to provide several types of services, such as surveillance, weather monitoring, management of vehicular traffic, control of production activities, etc. The development and the adoption of these systems are still facing various challenges that the research community and the industry are actively trying to solve. On one hand, the development challenges are mainly related to security, robustness, availability, adequate performance and energy consumption optimization. On the other hand, the use of these systems produces large amounts of fine-grained data that need to be processed and interrelated, typically requiring big data analytics for the extraction of useful knowledge that can be used by the software services controlling these systems. This paper introduces the novel contributions for the design, implementation and use of these systems, which are part of the special issue on Cyber-Physical Systems, Internet of Things and Big Data.

1. Introduction

Cyber-Physical Systems (CPS), Internet of Things (IoT) and Big Data are three concepts that are tightly intertwined in the new generations of cooperative solutions, where people, autonomous devices and the environment interact with each other to reach specific goals. The CPS emerge from the integration of embedded computing devices, smart objects, people and physical environments, typically tied by a communication infrastructure. Examples of these systems are smart transportations systems, smart grids, smart factories, smart buildings and homes, and smart vehicles.

The IoT paradigm refers to a world-wide network of interconnected heterogeneous objects that are uniquely addressable and interact among them using standard communication protocols [1]. These objects include several artefacts, e.g., sensors, actuators, RFID tags, embedded computers, and mobile devices. Beyond such a networking-oriented definition, IoT can be seen as a paradigm that enables to build loosely-coupled decentralized systems through the cooperation among smart objects [2]. These objects may act as intelligent agents with some level of autonomy, cooperate on-demand with other agents, and exchange information with human users and other computing devices within the interconnected cyber-physical infrastructure [3].

The large-scale nature of IoT-enabled CPS raises several big data challenges, ranging from system-level management and control to data analytics. The system-level challenges are typically related to methods for controlling global systems, making more effective the implementation and evolution of large-scale management platforms, or defining appropriate control interfaces for IoT technologies. The wide spread of IoT-based solutions are driving more and more data into enterprises, therefore big data analytics has become an essential component for extracting valuable information. This represents an opportunity that also brings several challenges to data processing systems for improving data collection, cleaning and storage, and performing real-time analytics. Next sections briefly introduce the articles that are part of this special issue, and brings new knowledge to the design, implementation and use of IoT-enabled CPS.

2. Contributions related to the design of IoT-enabled CPS

The IoT-enabled CPS are strongly coupled to the communication infrastructure that supports the interactions among the participating devices; therefore, the quality attributes of the network directly affect the performance and behavior the CPS. In several scenarios (like monitoring of physical infrastructure or control of production activities) these systems use a large-scale and dynamic network infrastructure to support the communication and coordination among their components. Managing such an infrastructure is a challenge since node churn and failures may negatively affect

E-mail addresses: sochoa@dcc.uchile.cl (S.F. Ochoa), g.fortino@unical.it (G. Fortino), g.difatta@reading.ac.uk (G. Di Fatta).

http://dx.doi.org/10.1016/j.future.2017.05.040
0167-739X/

the overlay network topology by downgrading the efficiency and accuracy of the CPS that use it. Moreover, there exists the risk of a permanent loss of global connectivity that would prevent the correct convergence of applications. The paper entitled "*Robust and Efficient Membership Management in Large-scale Dynamic Networks*", by Poonpakdee and Di Fatta [4], presents an epidemic membership protocol named EMP+ (Enhanced Expander Membership Protocol) that is fault-tolerant and scalable. This protocol has unique features that are not present in any other available protocol: (1) it addresses some real networks issues and is suitable for asynchronous and dynamic networks, (2) it limits the negative effects of message interleaving events, (3) it incorporates a novel mechanism for global connectivity recovery, and (4) it removes dead links quickly.

In search of ways for extending the lifetime of low-power wireless networks that support CPS solutions, many researchers devise algorithms to optimize the transmission power. Yet, although manufacturers develop nodes with various levels of transmission power, insights on how to best use those levels are missing. The issue is not only the dependence of existing methods on unstable link quality metrics. The paper entitled "*Impact of Transmission Power Control in Multi-hop Networks*", by Kotian et al. [5], argues that the biggest barrier is the isolation of Layers 2 and 3 from Layer 1. It is one of a handful studies that sheds light on how MAC and routing protocols react to changes in transmission power. The authors argue about the need to find a stable power level, minimizing frequent changes, which have detrimental effects on energy efficiency and routing-level stability.

Concerning the management of events in distributed networks that support event-based CPS, the paper entitled "*A Distributed Event-Based System based on Compressed Fragmented-Iterated Bloom Filters*", by Muñoz and Leone [6], proposes a method for the construction of a novel architecture of Fragmented-Iterated Bloom Filters, which can be deployed at broker nodes of a distributed event-based system in order to route events in a network of constrained sensing devices. The approach is compared to standard Bloom filters and the obtained results show that the proposal tends to be more efficient both in terms of memory usage and computation, and it also decreases the probability of false positives.

3. Contributions related to the implementation of IoT-enabled CPS

It is well-known that the implementation of IoT-enabled CPS is an important challenge for software engineers, due the number of functional and non-functional requirements usually involved in the development of these systems. In this sense the article entitled "*COMFIT: A Development Environment for the Internet of Things*", by de Farias et al. [7], contributes to address this challenge by providing an integrated development environment grounded on the paradigms of model-driven development and cloud computing. This tool supports code generation, simulations and code compilation of IoT-enabled applications. COMFIT is composed of two major modules: (1) the App Development Module and (2) the App Management and Execution Module. The first one allows developers to design applications using high abstraction artifacts (models), creating thus a separation between these two concerns. The second module implements model-driven engineering mechanisms that allow developers to automatically transform the models into code. In this sense, COMFIT provides an environment where no additional configurations are needed to properly compile or simulate the generated code. This integrated environment support the development lifecycle of IoT-enabled applications by hosting the work products partially in the client and in the cloud. COMFIT was evaluated in terms of development effort, quality of generated code, and scalability into a laboratory environment and the obtained results were high promising.

In order to help address the security aspects usually involved in these systems, the article entitled "*QoS Guaranteeing Robust Scheduling in Attack Resilient Cloud Integrated Cyber-Physical System*" proposes a security framework and a robust and attack resilient scheduling mechanism for cloud integrated cyber-physical systems [8]. Although the stability and operational capability of CPS usually have high priority in these systems, their security play a key role in the quality of service that they provide, since security vulnerabilities can negatively affect the speed and effectiveness of data processing. Therefore, counting on a scheduling mechanism, invulnerable to security attacks, is needed to efficiently utilize the scalable processing components as provided by a cloud computing platform. Trying to deal with this issue the authors propose a new learning procedure that uses Bayesian Networks to aid the scheduling algorithm. This proposal uses game theoretic principles to proactively understand the behavior of an attacker based on the strategic decisions made by the defender, and thus it provides a robust scheduling mechanism that schedules tasks based on the decisions made from the output of the game.

The joint use of body sensor networks and cloud technologies is a frequent recipe to support CPS that involve nodes mobility (e.g., people or vehicles). Aligned with it, the paper entitled "*Cloud-based Activity-aaService Cyberphysical Framework for Human Activity Monitoring in Mobility*", by Gravina et al. [9], proposes a full-fledged cyber-physical framework, to support community, online and off-line human activity recognition and monitoring in mobility. This tool addresses the lack of cloud-assisted body area network platforms and applications supporting monitoring and analysis of human activity for single individuals and communities. The framework also provides powerful and flexible programming abstractions for the rapid prototyping of efficient human activity-oriented applications. The effectiveness of this proposal was evaluated through the development of several prototypes related to physical activity monitoring, step counting, physical energy estimation, automatic fall detection, and smart wheelchair support. Moreover, the application development time, code reuse, system interoperability, long-term storage, security, and scalability enabled by construction were considered to determine the effectiveness of this framework. The obtained results are highly encouraging and they show that the Activity-aaService framework is suitable to support the development of this type of systems.

4. Contributions related to the use of IoT-enabled CPS

It is well-known that the CPS usually generate large amounts of data that should be processed properly to get valuable and on-time information. The paper entitled "*Scalable Regular Pattern Mining in Evolving Body Sensor Data*", by Tanbeer et al. [10], presents a novel data mining approach to mine the inherent regularity of several body sensor parameter readings related to vital sign data of a patient. This mechanism allows systems to monitor health conditions and generate valuable information to support the decision making process of patients and medical personnel. In particular, the authors present the design and implementation of an efficient and scalable regular pattern mining technique that can mine the complete set of periodically/regularly occurring patterns in body sensor data streams. Several simulations were performed on both real and synthetic data to validate the efficiency of the proposed scalable regular pattern mining technique and compare it with other similar approaches.

A work related to the previous one is presented in the paper entitled "*Scalable Real-Time Classification of Data Streams with Concept Drift*" [11], in which the authors present a nearest neighbor approach for classifying real-time data streams based on statistical summaries. Particularly the article proposes a classifier that adapts to concept drifts and is robust to noise. The classification algorithm is competitive to its alternatives and naturally parallel. The article also reports the development of a parallel version of the classifier that was implemented using open source technologies. Such a version was evaluated empirically and the obtained results show that the proposal is scalable with respect to the workload and number of used processing nodes. The paper also includes a discussion on the use of open source technologies for data stream processing.

A similar approach is presented in the article entitled "*TOLA: Topic-Oriented Learning Assistant Based on Cyber-Physical System and Big Data*", by Song et al. [12], that proposes a big data-driven approach to discover students' learning patterns and guide courses improvement. This proposal was initially conceived to analyze and support the online learning evolution of students. In TOLA (Topic-Oriented Learning Assistant) particular topic features are extracted from MOOC forum through Latent Dirichlet Allocation, which then is incorporated to other hybrid features. TOLA can automatically classify the threads in MOOC course forum, so that professors can make targeted comments, while students can find desirable content quickly.

The use of CPS in particular application scenarios is also an aspect addressed in this special issue. For instance, the article entitled "*Technologies of Internet of Things applied to an Earthquake Early Warning System*", by Zambrano et al. [13], proposes the scalable use of smartphones in order to alert and prevent the population in case of earthquakes. The smartphones are used as sensors in a scalable way providing measurements to a distributed infrastructure connected to public communication networks. The proposed platform relies in the huge amount of smartphones used by the population and in the quality of the accelerometers and GPS positioning. The communication protocol used by smartphones is MQTT, so it can be integrated in different standard IoT platforms. The calculation is based is the use of Kruskal Wallis mechanism that allows the management of several groups of samples of seismic data. The proposed system has been tested using different smartphones and the obtained results indicate that the alert messages may reach on-time the target population (i.e., various seconds ahead), by reducing thus the number of potential victims.

5. Conclusions

This paper introduces the special issue on Cyber-Physical Systems, Internet of Things and Big Data. These three intertwined concepts are involved in the new generations of collaborative solutions; particularly, in those considering devices heterogeneity and ad hoc interactions. The research community has recognized the complexity of designing and implementing these systems, and also processing the large amount of data they produce. In order to contribute address these challenges we have selected ten articles that contribute advance the current knowledge in several aspects related to the design, implementation and use of IoT-enabled CPS.

The guest editors want to gratefully acknowledge the referees of this special issue for the high quality of the reviews. We want also to thanks the authors for the effort spent in improving and extending the original proposals. Finally, we would like to thank the editor-in-chief and the people supporting the guest editors during this process.

References

[1] Information Society and Media Directorate general of the European Commission and the European Technology Platform on Smart Systems Integration. Internet of Things in 2020: A Roadmap for the Future. Accessed on 27 March 2017. Available online: http://www.smart-systems-integration.org/public/documents/publications/Internet-of-Things_in_2020_EC-EPoSS_Workshop_Report_2008_v3.pdf.

[2] G. Fortino, P. Trunfio, Internet of Things Based on Smart Objects, Technology, Middleware and Applications, Springer, ISBN: 978-3-319-004907, 2014.

[3] Fortino G., Guerrieri A., Russo W. and Savaglio C., Integration of agent-based and cloud computing for the smart objects-oriented IoT, In Proc. of IEEE CSCWD 2014: 493–498.

[4] P. Poonpakdee, G. Di Fatta, Robust and efficient membership management in largescale dynamic networks, Future Gener. Comput. Syst. 75 (2017) 85–93.

[5] R. Kotian, G. Exarchakos, S. Stavrou, A. Liotta, Impact of transmission power control in multi-hop networks, Future Gener. Comput. Syst. 75 (2017) 94–107.

[6] C. Muñoz, P. Leone, A distributed event-based system based on compressed fragmented-iterated bloom filters, Future Gener. Comput. Syst. 75 (2017) 108–127.

[7] C.M. de Farias, I.C. Brito, L. Pirmez, F.C. Delicato, P.F. Pires, T.C. Rodrigues, I.L. dos Santos, L.F.R.C. Carmo, T. Batista, COMFIT: A development environment for the internet of things, Future Gener. Comput. Syst. 75 (2017) 128–144.

[8] B. Chejerla, S. Madria, Qos guaranteeing robust scheduling in attack resilient cloud integrated cyber physical system, Future Gener. Comput. Syst. 75 (2017) 145–157.

[9] R. Gravina, C. Ma, P. Pace, G. Aloi, W. Russo, W. Li, G. Fortino, Cloud-based activity-aaservice cyberphysical framework for human activity monitoring in mobility, Future Gener. Comput. Syst. 75 (2017) 158–171.

[10] S.K. Tanbeer, M.M. Hassan, A. Almogren, M. Zuair, B.-S. Jeong, Scalable regular pattern mining in evolving body sensor data, Future Gener. Comput. Syst. 75 (2017) 172–186.

[11] M. Tennant, F. Stahl, O. Rana, J. Gomes, Scalable real-time classification of data streams with concept drift, Future Generation Computer Systems 75 (2017) 187–199.

[12] J. Song, Y. Zhang, K. Duan, M.S. Hossain, S.K.M. Rahman, Tola: topic-oriented learning assistant based on cyber-physical system and big data, Future Gener. Comput. Syst. 75 (2017) 200–205.

[13] A.M. Zambrano, I. Perez, C.E. Palau, M. Esteve, Technologies of internet of things applied to an earthquake early warning system, Future Gener. Comput. Syst. 75 (2017) 206–215.