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Data Processing in Cyber-Physical-Social Systems Through Edge Computing

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Abstract

© 2013 IEEE. Cloud and Fog computing have established a convenient and widely adopted approach for computation offloading, where raw data generated by edge devices in the Internet of Things (IoT) context is collected and processed remotely. This vertical offloading pattern, however, typically does not take into account increasingly pressing time constraints of the emerging IoT scenarios, in which numerous data sources, including human agents (i.e., Social IoT), continuously generate large amounts of data to be processed in a timely manner. Big data solutions could be applied in this respect, provided that networking issues and limitations related to connectivity of edge devices are properly addressed. Although edge devices are traditionally considered to be resource-constrained, main limitations refer to energy, networking, and memory capacities, whereas their ever-growing processing capabilities are already sufficient to be effectively involved in actual (big data) processing. In this context, the role of human agents is no longer limited to passive data generation, but can also include their voluntary involvement in relatively complex computations. This way, users can share their personal computational resources (i.e., mobile phones) to support collaborative data processing, thereby turning the existing IoT into a global cyber-physical-social system (CPSS). To this extent, this paper proposes a novel IoT/CPSS data processing pattern based on the stream processing technology, aiming to distribute the workload among a cluster of edge devices, involving mobile nodes shared by contributors on a voluntary basis, and paving the way for cluster computing at the edge. Experiments on an intelligent surveillance system deployed on an edge device cluster demonstrate the feasibility of the proposed approach, illustrating how its distributed in-memory data processing architecture can be effective.

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Keywords

Apache NiFi, big data, cyber-physical-social system, edge computing, horizontal and vertical offloading, Internet of People, Internet of Things, stream processing

References

[1] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, Internet of Things (IoT): A vision, architectural elements, and future directions,'' Future Gener. Comput. Syst., vol. 29, no. 7, pp. 16451660, 2013.

[2] G. Merlino, S. Arkoulis, S. Distefano, C. Papagianni, A. Puliato, and S. Papavassiliou, Mobile crowdsensing as a service: A platform for applications on top of sensing clouds,'' Future Gener. Comput. Syst., vol. 56, pp. 623639, Mar. 2016.

[3] X. Masip-Bruin, E. Marín-Tordera, G. Tashakor, A. Jukan, and G.-J. Ren, Foggy clouds and cloudy fogs: A real need for coordinated management of fog-to-cloud computing systems,'' IEEE Wireless Commun., vol. 23, no. 5, pp. 120128, Oct. 2016.

[4] N. Choi, D. Kim, S.-J. Lee, and Y. Yi, A fog operating system for user-oriented IoT services: Challenges and research directions,'' IEEE Commun. Mag., vol. 55, no. 8, pp. 4451, Aug. 2017.

[5] C. C. Byers, Architectural imperatives for fog computing: Use cases, requirements, and architectural techniques for fog-enabled IoT networks,'' IEEE Commun. Mag., vol. 55, no. 8, pp. 1420, Aug. 2017.

[6] S. Yang, IoT stream processing and analytics in the fog,'' IEEE Commun. Mag., vol. 55, no. 8, pp. 2127, Aug. 2017.

[7] Z. Wen, R. Yang, P. Garraghan, T. Lin, J. Xu, and M. Rovatsos, Fog orchestration for Internet of Things services,'' IEEE Internet Comput., vol. 21, no. 2, pp. 1624, Feb. 2017.

[8] R. Vilalta et al., End-to-end SDN orchestration of IoT services using an SDN/NFV-enabled edge node,'' in Proc. IEEE Opt. Fiber Commun. Conf. Exhibit. (OFC), Mar. 2016, pp. 13.

[9] A. Botta, W. de Donato, V. Persico, and A. Pescapé, On the integration of cloud computing and Internet of Things,'' in Proc. Int. Conf. Future Internet Things Cloud (FiCloud), 2014, pp. 2330.

[10] O. Skarlat, S. Schulte, M. Borkowski, and P. Leitner, Resource provisioning for IoT services in the fog,'' in Proc. IEEE 9th Int. Conf. Service-Oriented Comput. Appl. (SOCA), Nov. 2016, pp. 3239.

[11] B. I. Ismail et al., Evaluation of docker as edge computing platform,'' in Proc. IEEE Conf. Open Syst. (ICOS), Aug. 2015, pp. 130135.

[12] J. Miranda et al., From the Internet of Things to the Internet of people,'' IEEE Internet Comput., vol. 19, no. 2, pp. 4047, Mar./Apr. 2015.

[13] L. Atzori, A. Iera, G. Morabito, and M. Nitti, The social Internet of Things (SIOT)When social networks meet the Internet of Things: Concept, architecture and network characterization,'' Comput. Netw., vol. 56, no. 16, pp. 35943608, 2012.

[14] F.-Y. Wang, The emergence of intelligent enterprises: From CPS to CPSS,'' IEEE Intell. Syst., vol. 25, no. 4, pp. 8588, Aug. 2010.

[15] J. Zeng, L. T.Yang, M. Lin, H. Ning, and J. Ma, Asurvey: Cyber-physicalsocial systems and their system-level design methodology,'' Future Gener. Comput. Syst., Aug. 2016, doi: 10.1016/j.future.2016.06.034.

[16] G. Xiong et al., Cyber-physical-social system in intelligent transportation,'' IEEE/CAA J. Autom. Sinica, vol. 2, no. 3, pp. 320333, Jul. 2015.

[17] H. Qian, X. Wu, and Y. Xu, Intelligent Surveillance Systems, vol. 51. Springer, 2011, doi: 10.1007/978-94-0-7-1137-2.

[18] M. Valera and S. A. Velastin, Intelligent distributed surveillance systems: A review,'' IEE Proc.-Vis., Image Signal Process., vol. 152, no. 2, pp. 192204, Apr. 2005.

[19] The Internet of Things: Capturing the Accelerated Opportunity. Accessed: Oct. 15, 2014. [Online]. Available: http://blogs.cisco.com/digital/theinternet-of-things-capturing-The-accelerated-opportunity

[20] X. Li, R. Lu, X. Liang, X. Shen, J. Chen, and X. Lin, Smart community: An Internet of Things application,'' IEEE Commun. Mag., vol. 49, no. 11, pp. 6875, Nov. 2011.

[21] F. Longo, D. Bruneo, S. Distefano, G. Merlino, and A. Puliato, Stack4Things: A sensing-and-actuation--s-A-service framework for IoT and cloud integration,'' Ann. Telecommun., vol. 72, nos. 12, pp. 5370, 2016.

[22] G. Merlino, D. Bruneo, F. Longo, S. Distefano, and A. Puliato, Cloudbased network virtualization: An IoT use case,'' in Ad Hoc Networks, N. Mitton, M. E. Kantarci, A. Gallais, and S. Papavassiliou, Eds. Cham, Switzerland: Springer, 2015, pp. 199210.