



UNIVERSITÀ DI PISA  
**DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE**  
**Dottorato di Ricerca in Ingegneria dell'Informazione**

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Doctoral Course

**“The Industrial Internet of Things: analysis of existing solutions and research perspectives”**

Dr. Francesca Righetti, Prof. Carlo Vallati

*University of Pisa - Italy*

**Short Abstract:** The Industrial Internet of Things (IIoT) will leverage on heterogeneous wireless network technologies to integrate in a seamless manner Cyber-Physical Systems (CPS) into existing information systems. Among the different solutions to ensure reliable and timely communication, the 6TiSCH architecture defined by the IETF is gaining research interest. 6TiSCH relies on the IEEE TSCH MAC protocol and includes the IETF suite of protocols to provide IPv6 connectivity for constrained wireless devices to integrate them with existing information systems. In this course, we will first introduce the different communication technologies for the IIoT and then we will carry out a comprehensive analysis of the 6TiSCH architecture to assess its performance and highlight the open research issues. In the last part of this course, we will overview how IIoT networks can be integrated with cloud platforms, introducing also the paradigm of fog computing to show how it can support industrial applications by enabling the execution of applications in proximity of CPS.

**Course Contents in brief:**

- Introduction to the Industrial IoT (IIoT)
- Overview of communication technologies for IIoT (5G, WiFi, TSCH, ...)
- IETF 6TiSCH Architecture
  - Protocols
  - Scheduling (Centralized, Distributed, Autonomous, Hybrid)
  - Performance
  - Security
- Integration of IIoT devices into Cloud platforms
- Edge/Fog Computing for IIoT applications
- Some relevant use cases

**Total # of hours of lecture: 20**

## References:

- [1] P. Thubert, An Architecture for IPv6 over the Time-Slotted Channel Hopping Mode of IEEE 802.15.4 (6TiSCH), RFC 9030 (Informational) (May 2021).
- [2] F. Righetti, C. Vallati, G. Anastasi and S. Das, "Performance Evaluation the 6top Protocol and Analysis of its Interplay with Routing," 2017 IEEE International Conference on Smart Computing (SMARTCOMP), 2017, pp. 1-6, doi: 10.1109/SMARTCOMP.2017.7947029.
- [3] F. Righetti, C. Vallati, S. K. Das and G. Anastasi, "An Experimental Evaluation of the 6top Protocol for Industrial IoT Applications," 2019 IEEE Symposium on Computers and Communications (ISCC), 2019, pp. 1-6, doi: 10.1109/ISCC47284.2019.8969590.
- [4] D. Fanucchi, F. Righetti, C. Vallati, B. Staehle and G. Anastasi, "Improving Link Quality Estimation Accuracy in 6TiSCH Networks," 2019 Sixth International Conference on Internet of Things: Systems, Management and Security (IOTSMS), 2019, pp. 243-250, doi: 10.1109/IOTSMS48152.2019.8939167.
- [5] F. Righetti, C. Vallati, S. K. Das, and G. Anastasi. 2020. An Evaluation of the 6TiSCH Distributed Resource Management Mode. ACM Trans. Internet Things 1, 4, Article 23 (November 2020), 31 pages. <https://doi.org/10.1145/3395927>
- [6] F. Righetti, C. Vallati, S. K. Das and G. Anastasi, "Analysis of Distributed and Autonomous Scheduling Functions for 6TiSCH Networks," in IEEE Access, vol. 8, pp. 158243-158262, 2020, doi: 10.1109/ACCESS.2020.3020153.
- [7] F. Righetti, C. Vallati, A. Gavioli and G. Anastasi, "Performance Evaluation of Adaptive Autonomous Scheduling Functions for 6TiSCH Networks," in IEEE Access, vol. 9, pp. 127576-127594, 2021, doi: 10.1109/ACCESS.2021.3112266.
- [8] G. Carignani, F. Righetti, C. Vallati, M. Tiloca and G. Anastasi, "Evaluation of Feasibility and Impact of Attacks Against the 6top Protocol in 6TiSCH Networks," 2020 IEEE 21st International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM), 2020, pp. 68-77, doi: 10.1109/WoWMoM49955.2020.00027.
- [9] C. Vallati, F. Righetti, G. Tanganelli, E. Mingozzi, G. Anastasi, "Analysis of the interplay between RPL and the congestion control strategies for CoAP", Ad Hoc Networks, Volume 109, 2020, <https://doi.org/10.1016/j.adhoc.2020.102290>.
- [10] Bonomi, F., Milito, R., Zhu, J., & Addepalli, S. (2012, August). Fog computing and its role in the internet of things. In Proceedings of the first edition of the MCC workshop on Mobile cloud computing (pp. 13-16).

## CV of the Teacher

Prof. **Carlo Vallati** is Associate Professor at the Department of Information Engineering of the University of Pisa. He received a Master's Degree (magna cum laude) and a PhD in Computer Systems Engineering in 2008 and 2012, respectively, from the University of Pisa. In 2010, he visited the Computer Science department of the University of California at Davis. He is co-author of +70 peer-reviewed papers in international journals and conference proceedings. He has been involved in multiple national and international research projects, and in several research projects supported by private industries. He has served as a program committee member for more than 30 international conferences and workshops and as Workshop Chair for the IEEE IoT-SoS and IEEE SmartSys workshops. He has served as TPC Co-Chair for IEEE SMARTCOMP 2020 and as General

Vice Chair for PERCOM 2022. He is on the editorial board of three international journals, the “Ad Hoc Networks”, Elsevier, “Journal of Reliable Intelligent Environments”, Springer and “Applied Sciences”, MDPI. He is the coordinator of the Cloud Computing, Big Data and Cybersecurity Crosslab founded in the framework of the Departments of Excellence (“Dipartimenti di Eccellenza”) funded by the Italian Ministry of Education, University and Research (“Ministero dell’Istruzione dell’Università e della Ricerca”).

Dr. **Francesca Righetti** is a Postdoctoral Research Fellow at the Information Engineering Department at the University of Pisa. She received the Bachelor’s and Master’s Degrees in Ingegneria Informatica and Computer Engineering from the University of Pisa, Pisa, Italy, in 2014 and 2017, respectively. She got her PhD in Information Engineering at the University of Pisa in 2021. Her research interests include Wireless Sensor Networks, and their applications, Internet of Things (IoT) and Industrial Internet of Things (IIoT). She took part in national and international projects, including the EdgeFlooding project (<https://ngiatlantic.eu/funded-experiments/edgeflooding-exploiting-edge-computing-real-time-monitoring-and-detection-flash>), founded by NGI Atlantic, the SmarT INtelliGent RAILwaY (STINGRAY) project with the ISTI-CNR, Pisa (<https://stingray.isti.cnr.it/>), and the “ECOAP: Experimental assessment of congestion control strategies for the Constrained Application Protocol” project, funded by the European Commission’s Horizon 2020 Programme under grant agreement n645274 (<http://www.wishful-project.eu/OC5results.html>). She has served as a TPC for different international conference and workshops, including IEEE SMARTCOMP, IEEE CCNC, IEEE MSN, IEEE MELECON, and she organized the Seventh IEEE International Workshop in Smart Service Systems (<http://smartsys2022.dii.unipi.it/>), co-located with IEEE SMARTCOMP 2022.

## Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell’Informazione, Largo Lucio Lazzarino 1, 6th floor, Pisa*

Tentative Schedule:

- Introduction to the Industrial IoT (IIoT) (1 hour)
- Communication technologies for IIoT (5G, WiFi, TSCH, ...) (3 hours)
- IETF 6TiSCH Architecture (10 hours)
- Integration of IIoT devices into Cloud platforms (1 hour)
- Edge/Fog Computing for IIoT applications (3 hours)
- Some relevant use cases (2 hours)

Day1 – 8:30-12:30

Day2 – 8:30-12:30

Day3 – 8:30-12:30

Day4 – 8:30-12:30

Day5 – 8:30-12:30