Complex Networks and Telecommunications : Third Edition

Lake Como School of Advanced Studies - 3-7 July 2023

Home

Complex networks and telecommunications
3rd edition: Towards 6G

Following the tradition of the successful previous editions, this biannual event aims at representing a landmark in the dissemination of current results and trends in new telecommunications systems. The goal is to expose the participants to a wide range of topics, forming a system view of the evolving scenario.

Topics covered will therefore cover the constraints and opportunities provided by novel radio access techniques but also

This edition of the school will bring together recognized experts which will be able to provide insights on the future trends and the most relevant research topics. As such, it will provide a unique opportunity for young researchers but also for experienced ones willing to challenge themselves with the friendly and interactive atmosphere provided by the location.

The promise of *next*G systems is to support seamless and realistic human communications as well as massive machine communications enabling services in support of a better life. The 6G system will not only increase the data rate or extend coverage although these will remain fundamental aspects. Exploitation of new frequency bands and novel transmission techniques will have to be matched with distributed 'smart' control techniques able to somehow anticipate 'user' needs to reduce latency and adapt to the varying requirement and mixes. 6G will not only be related to 'moving data around' but will require the integration of sensing, localization, mobility management in the distributed control engine calling for the need of an intrinsically secure and privacy preserving eco-system

Speakers are selected among some of the top researchers in the area as well as from ongoing Horizon Europe projects, providing an up to date trans-disciplinary vision of the fundamental tools towards this vision.

School organizing committee

- Favalli, Lorenzo, Associate Professor, University of Pavia, Italy, email lorenzo.favalli@unipv.it
- Calvanese Strinati, Emilio, Smart Devices & Telecomm. Strategy Program Director Internat. Research Programs CEA-LETI, MINATEC email calvanese-strinati@cea.fr
- Zorzi Michele, Full Professor, University of Padova, Italy, email zorzi@dei.unipd.it

Technical sponsors

- Università di Pavia – Department of Electrical, Biomedical and Computer Engineering
- Università di Padova – Department of Information Engineering
- CEA Leti

Financial support

- IEEE Communications Society
- CEA Leti
- Fondazione Alessandro Volta
- Lake Como school of Advanced Studies

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School Organization

The school will cover some selected hot topics in the evolution of telecommunications networks. All speakers have worldwide recognition of being at the top in their fields so as the event is projected to be of a very high level.

Every speaker is assigned a 'slot' with three slots/day plus one fourth slot left for students presentations. Students are invited to propose their own presentations which will be possibly grouped according with the topic of the day to maximize interaction with the speakers.

We will have a half day on Monday afternoon with introductory topics and trends at large. The remaining three and a half days will be centered respectively on

- Semantic and goal-oriented communications: this novel paradigm tends to move beyond the traditional agnostic representation and transport of information, mimicking the process of human cognition and communication.
- Distributed and edge-intelligence: as in a biological nervous system, decentralized reasoning brings reaction close to the network periphery. This model not only reduces latency but paves the way to a new paradigm where not only intelligence aids network management, but the network itself enables new forms of reasoning.
- Novel access techniques: this more 'traditional' networking approach covers several advances in materials, technology, and architecture. Topics covered under this stream will be massive and holographic MIMO, Reconfigurable Intelligent Surfaces, joint localization and sensing, integrated terrestrial and non-terrestrial networks, and the exploitation of very high (THz) frequencies.

Slots will be reserved for attendees willing to discuss their research activity.

On Friday afternoon an exam will be organized for all those who will need credits.

If you need any detail or support, please see the contact page.

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Speakers' Bio

- **Egidio D'Angelo**, obtained the degree in Medicine as a fellow of Collegio Ghislieri in Pavia. Then, during his career in electrophysiological research, he completed an MD in Neurology. His main scientific interests include the function of neurons, synapse and networks of the brain, with a special interest for cellular and synaptic mechanisms of synaptic plasticity. He is currently Full Professor of Physiology at the Dept. of Brain and Behavioral Sciences of the University of Pavia – Director of the Neurophysiology Unit, Director of the Brain Connectivity Center (BCC) of the IRCCS C. Mondino of Pavia, Coordinator of the PhD in Biomedic Sciences of the University of Pavia (dedicate web site DRBS), Member of the Directory Board of SIF (societa Italiana di Fisiologia), Co-director of the Human Brain Project (HBP) Member of Centro Fermi (Rome), Director of the Erice School "Brain Cells and Circuits: Camillo Golgi".

- **Emilio Calvanese Strinati**, Dr. Emilio Calvanese Strinati obtained his Engineering Master degree in 2001 from the University of Rome 'La Sapienza' and his Ph.D in Engineering Science in 2005. He then started working at Motorola Labs in Paris in 2002. Then in 2006 he joint CEA/LETI as a research engineer. From 2007, he becomes a PhD supervisor. From 2010 to 2012, Dr. Calvanese Strinati has been the co-chair of the wireless working group in GreenTouch Initiative which deals with design of future energy efficient communication networks. From 2011 to 2016 he was the Smart Devices & Telecommunications European collaborative strategic programs Director. Between December 2016 and January 2020 is was the Smart Devices & Telecommunications Scientific and Innovation Director. Since February 2020 he is the Nanotechnologies and Wireless for 6G (*New-6G*) Program Director focusing on future 6G technologies. In December 2013 he has been elected as one of the five representative of academia and research center in the NetWorks 5G PPP ETP. From 2017 to 2018 he was one of the three moderators of the 5G future network expert group. Between 2016 and 2018 he was the coordinator of the H2020 joint Europe and South Korea 5GCHAMPION project that showcased at the 2018 winter Olympic Games, 5G technologies in realistic operational environments. Since July 2018 he is the coordinator of the H2020 joint Europe and South Korea 5G-AllStar project. Since 2018 he holds the French Research Director Habilitation (HDR). In 2021 he started the coordination of the H2020 European project RISE-6G, focusing on the design and operation of Reconfigurable Intelligent Surfaces in future high frequency 6G networks. Since February 2021 he is also the director of the New-6G (Nano Electronic & Wireless for 6G) initiative ; dedicated to the required convergence between microelectronic & telecom, hardware & software, network & equipment for upcoming 6G technologies. E. Calvanese Strinati has published around 150 papers in international conferences, journals and books chapters, given more than 200 international invited talks, keynotes and tutorials. He is the main inventor or co-inventor of more than 65 patents. He has organized more than 100 international conferences, workshops, panels and special sessions on green communications, heterogeneous networks and cloud computing hosted in international conferences as IEEE GLOBECOM, IEEE PIMRC, IEEE WCNC, IEEE ICC, IEEE VTC, EuCnC, IFIP, EUCNC and European Wireless. He is the general chair of EUCNC 2022.

- **Antonio Clemente**, received the B.S. and M.S. degrees in telecommunication engineering and remote sensing systems from the University of Siena, Siena, Italy, in 2006 and 2009, respectively, the Ph.D. degree in signal processing and telecommunications, and the "Habilitation à Diriger des Recherches" degree from the University of Rennes 1, Rennes, France, in 2012 and 2021, respectively. From October 2008 to May 2009, he realized his master thesis project at the Technical University of Denmark (DTU), Lyngby, Denmark, where he worked on spherical near-field antenna measurements. His Ph.D. project has been realized at CEA-Leti, Grenoble, France. In 2012, he joined the Research and Development Laboratory, Satimo Industries, Villebon-sur-Yvette, France. Since 2013, he is a Research Scientist at CEA-Leti. From 2016 to 2018, he was the Technical Coordinator of the H2020 joint Europe and South Korea 5G-CHAMPION project. He has authored or co-authored more than 150 papers in international journals and conferences and received 21 patents. He has been involved in more than 35 national, European, and international research projects. His current research interests include fixed-beam and electronically reconfigurable electromagnetic surfaces, millimeter-wave and sub-terahertz antenna-in-package (AiP), antenna array synthesis and modeling, periodic or quasiperiodic structures, near-field focused systems, antenna theory and fundamental limitations, and near- and far-field antenna measurements. Dr. Clemente serves as a reviewer for the numerous IEEE and IET journals in the field of microwave, antennas, and propagation. He received the Young Scientist Award (First Prize) during the 15th International Symposium of Antenna Technology and Applied Electromagnetics (ANTEM 2012) and the Best Antenna Design and Applications Paper Award during the 13th European Conference on Antennas and Propagation (EuCAP 2109). He was a co-recipient of the EuMC Young Engineer Prize at EuMC 2021, the Best Paper Award at JNM 2015 (19emes Journées Nationales Microondes), and the 2019 ETRI Journal Best Paper Award. In 2019, he was a finalist for the "Microwave Prize" at the European Microwave Conference (EuMC 2019).

- **Marcello Caleffi** (Senior Member, IEEE) is an Associate Professor with the DIETI Department, University of Naples Federico II, where he co-lead the Quantum Internet Research Group. He is also with the National Laboratory of Multimedia Communications, National Inter-University Consortium for Telecommunications. From 2010 to 2011, he was with the Broadband Wireless Networking Laboratory with the Georgia Institute of Technology, as a Visiting Researcher. In 2011, he was also with the NaNoNetworking Center in Catalunya (N3Cat) with the Universitat Politecnica de Catalunya, as a Visiting Researcher. Since July 2018, he held the Italian National Habilitation as a Full Professor of Telecommunications Engineering. His work appeared in several premier IEEE Transactions and Journals, and he received multiple awards, including the best strategy, the most downloaded article, and the most cited article awards. In 2022, he has been awarded with the IEEE Communications Society "Best Tutorial Paper Award" 2022 for the paper "When Entanglement Meets Classical Communications: Quantum Teleportation for the Quantum Internet." He currently serves as an Editor for IEEE Transactions on Wireless Communications and IEEE Transactions on Quantum Engineering. Previously, he served as an Editor/Associate Technical Editor for IEEE Communications Magazine and IEEE Communications Letters. He has served as the chair, the TPC chair, and a TPC member for several premier IEEE conferences. In 2017, he has been appointed as as Distinguished Lecturer from the IEEE Computer Society and he has been elected treasurer of the IEEE ComSoc/VT Italy Chapter. In 2019, he has been also appointed as a member of the IEEE New Initiatives Committee from the IEEE Board of Directors.

- **Giuseppe Bianchi** is a Full Professor of Telecommunications and Network Security at the University of Roma Tor Vergata since January 2007. He is also the founder and current Director of the CNIT National Laboratory of Network Assurance and Monitoring. Before his current appointments, he held positions at Politecnico di Milano and the University of Palermo, and visiting positions at Washington University in St. Louis, Columbia University in New York, Maynooth National University of Dublin, and UCLA in Los Angeles. In 2016, he was awarded an Honorary Chair Professorship at the National Taiwan University of Science & Technology. Professor Bianchi has held coordinating positions for six European projects, has chaired the PhD program in Electronics and Telecommunications Engineering, and has coordinated the Bachelor and Master degrees in Internet Engineering in Rome Tor Vergata. His research interests encompass network security, network programmability, wireless networks, and in most generality any activity related to the design, analysis, and monitoring of networked systems. He has documented his research through more than 300 publications in international venues, which have amassed over 20,000 citations according to Google Scholar. He has received numerous awards, including the ACM SIGMOBILE Test-of-Time Award in 2017 for his pioneering work on Wi-Fi system performance

- **Jean-Claude Belfiore** graduated from Ecole Supérieure d'Electricité (Supelec), got his "Doctorat" (PhD) from Telecom Paris and the "Habilitation à diriger des Recherches" (HdR) from Université Pierre et Marie Curie (UPMC). From 1989 to 2015, he has been with Telecom Paris as a full Professor in the Communications & Electronics department. In 2015, he joined the Mathematical and Algorithmic Sciences Lab of Huawei as the head of the Communication Science Department. Jean-Claude Belfiore has made pioneering contributions in modulation and coding for wireless systems (especially space-time coding) by using tools of number theory. He is also one of the co-inventors of the celebrated Golden Code of the Wi-Max standard. Jean-Claude Belfiore is author or co-author of more than 200 technical papers and communications and has served as advisor for more than 30 Ph.D. students. He was Associate Editor of the IEEE Transactions on Information Theory for Coding Theory and has been the recipient of the 2007 Blondel Medal. Since November 2015, Jean-Claude Belfiore has joined Huawei Paris Research Center. He has been involved in 5G standardization process, essentially in Channel Coding (Polar Codes for 5G). He is now working in wireless communications for 6G, on artificial reasoning and future wireless networking for intelligent machines.

- ***George C. Alexandropoulos*** received the Engineering Diploma (Integrated M.S.c), M.A.Sc., and Ph.D. degrees in Computer Engineering and Informatics from the School of Engineering, University of Patras, Greece in 2003, 2005, and 2010, respectively. He has held senior research positions at various Greek universities and research institutes, and he was a Senior Research Engineer and a Principal Researcher at the Mathematical and Algorithmic Sciences Lab, Paris Research Center, Huawei Technologies France, and at the Technology Innovation Institute, Abu Dhabi, United Arab Emirates, respectively. He is currently an Assistant Professor with the Department of Informatics and Telecommunications, School of Sciences, National and Kapodistrian University of Athens (NKUA), Greece. His research interests span the general areas of algorithmic design and performance analysis for wireless networks with emphasis on multi-antenna transceiver hardware architectures, full duplex radios, active and passive Reconfigurable Intelligent Surfaces (RISs), integrated communications and sensing, millimeter wave and THz communications, as well as distributed machine learning algorithms. He currently serves as an Editor for IEEE Transactions on Communications, IEEE Wireless Communications Letters, Frontiers in Communications and Networks, and the ITU Journal on Future and Evolving Technologies. Prof. Alexandropoulos is a Senior Member of the IEEE Communications, Signal Processing, Vehicular Technology, and Information Theory Societies, the vice-chair of the EURASIP Technical Area Committee on Signal Processing for Communications and Networking, as well as a registered Professional Engineer of the Technical Chamber of Greece. He is also a Distinguished Lecturer of the IEEE Communications Society. He has participated and/or technically managed more than 15 European Union (EU), international, and Greek research, innovation, and development projects. He is currently NKUA's principal investigator for the *EU* H2020 RISE-6G and the *SNS JU* TERRAMETA projects dealing with RIS-empowered smart wireless environments and THz RISs, respectively. For the former project, he also serves as the dissemination manager, whereas, for the latter, as the technical manager. He has received the best Ph.D. thesis award 2010, the IEEE Communications Society Best Young Professional in Industry Award 2018, the EURASIP Best Paper Award of the Journal on Wireless Communications and Networking 2021, the IEEE Marconi Prize Paper Award in Wireless Communications 2021, the Best Paper Award from the IEEE GLOBECOM 2021, and the IEEE Communications Society Fred Ellersick Prize 2023. More information is available at www.alexandropoulos.info.

- **Paolo Di Lorenzo** is an Associate Professor in the Department of Information Engineering, Electronics and Telecommunications, at Sapienza University of Rome. He received the M.Sc. and Ph.D. degrees (magna cum laude) in Telecommunication Engineering in 2008 and 2012, respectively, both from Sapienza University of Rome. From September 2010 to April 2011, he held a research appointment in the Department of Electrical Engineering, University of California at Los Angeles. From May 2015 to February 2018, he was Assistant Professor in the Department of Engineering, University of Perugia, Italy. From March 2018 to February 2021, he was a Tenure Track Assistant Professor in the Department of Information Engineering, Electronics and Telecommunications, Sapienza University of Rome, Italy. His primary research interests lie in the areas of signal processing theory and methods, adaptation and learning, distributed optimization, (beyond)graph signal processing, wireless edge intelligence, goal-oriented and semantic communications. He has actively participated in several FP7 and H2020 European projects as WP leader, and he is principal investigator of the research unit (Sapienza – CNIT) for the H2020 European project entitled: RISE-6G, Reconfigurable Intelligent Sustainable Environments for 6G Wireless Networks. He is recipient of the 2022 EURASIP Early Career Award, with citation "for contributions to the field of distributed signal processing, optimization, and learning over networks". He has received three best student conference paper awards, which were sponsored by the IEEE signal processing society and the European association for signal processing (EURASIP). He was also recipient of the 2017 GTTI award for the best doctoral thesis in information and communication technologies. He serves as an Associate Editor for the IEEE Transactions on Signal Processing and, previously, for the IEEE Transactions on Signal and Information Processing over Networks and for the EURASIP Journal on Advances in Signal Processing. He is an IEEE senior member. He is a member of the IEEE signal processing society and of EURASIP.

- **Josep Miquel Jornet** is a Professor in the Department of Electrical and Computer Engineering, the director of the Ultrabroadband Nanonetworking (UN) Laboratory, and a member of the Institute for the Wireless Internet of Things and the SMART Center at Northeastern University (NU). He received a Degree in Telecommunication Engineering and a Master of Science in Information and Communication Technologies from the Universitat Politècnica de Catalunya, Spain, in 2008. He received the Ph.D. degree in Electrical and Computer Engineering from the Georgia Institute of Technology, Atlanta, GA, in August 2013. Between August 2013 and August 2019, he was in the Department of Electrical Engineering at the University at Buffalo (UB), The State University of New York (SUNY). In 2019, he joined NU and was promoted to Full Professor in the Spring of 2023. He is a leading expert in terahertz communications, in addition to wireless nano-bio-communication networks and the Internet of Nano-Things. In these areas, he has co-authored more than 220 peer-reviewed scientific publications, including 1 book and 5 US patents. His work has received more than 15,000 citations (h-index of 57 as of June 2023). He is serving as the lead PI on multiple grants from U.S. federal agencies including the National Science Foundation, the Air Force Office of Scientific Research and the Air Force Research Laboratory as well as industry. He is the recipient of multiple awards, including the 2017 IEEE ComSoc Young Professional Best Innovation Award, the 2017 ACM NanoCom Outstanding Milestone Award, the NSF CAREER Award in 2019, the 2022 IEEE ComSoc RCC Early Achievement Award, and the 2022 IEEE Wireless Communications Technical Committee Outstanding Young Researcher Award, among others, as well as four best paper awards. He is a senior member of the IEEE and an IEEE ComSoc Distinguished Lecturer (Class of 2022-2023). He is also the Editor in Chief of the Elsevier Nano Communication Networks journal and Editor for IEEE Transactions on Communications.

- ***Emanuela Raffinetti*** graduated in Business Economics in 2005 at the University of Pavia (Italy). She attended the II level International Master in "Methods for Management of Complex Systems" at IUSS of Pavia (Italy) in 2006. She finally pursued her PhD in Statistics in 2011 at Bocconi University of Milan (Italy). She was Post-Doc Research-Fellow in Statistics at the Department of Economics, Management and Quantitative Methods of the University of Milan (Italy) and subsequently Assistant Professor (Type A) of Statistics at the same Department. Since October 2021 she is Assistant Professor (Type A) of Statistics at the Department of Economics and Management of the University of Pavia. Her research activity is focused on: S.A.F.E. (*Sustainable, Accurate, Fair, Explainable*) Artificial Intelligence; predictive accuracy measures, Machine Learning model validation methods; assessment of operational and cyber risks; dependence analysis; sub-sampling methods; inequality measures for income distributions. She is also Associate Editor of the Frontiers in Artificial Intelligence journal.

- ***Vincenzo Sciancalepore*** is a Principal Researcher at NEC Laboratories Europe GmbH, Germany. He is currently focusing his activity in the area of Reconfigurable Intelligent Surfaces (RIS) and virtualized Radio Access Network. In the past he focused on network virtualization, network slicing and edge computing. He is the standard delegate of NEC actively contributing to the standard ETSI RIS (Reconfigurable Intelligent Surfaces) ISG. He is currently member of the IEEE Emerging Technologies Standing Committee (ETC) leading the initiatives on Reconfigurable Intelligent Surfaces as well as in the IEEE Mobile Communication Networks Standards Committee (IEEE MobNet-SC). He currently holds the italian habilitation as associate professor in telecommunications issued by MIUR. He has been involved in a number of European Projects and several published international Research Papers as well as Patents. Currently, he is actively leading a H2020-funded project called RISE-6G that will promote and deploy the novel technology, namely Reconfigurable Intelligent Surface (RIS), acting as Project Technical Manager. He is also member of IEEE ComSoc (S'11-M'15-SM'19). He received his M.Sc. degree in Telecommunications Engineering and Telematics Engineering in 2011 and 2012, respectively, whereas in 2015, he received a double Ph.D. degree from Politecnico di Milano and Universidad Carlos III de Madrid. From 2011 to 2015 he was Research Assistant at IMDEA Networks, focusing on inter-cell coordinated scheduling for LTE Advanced networks and device-to-device communication. He was also the recipient of the national award for the best Ph.D. thesis in the area of communication technologies (Wireless and Networking) issued by GTTI in 2015.

- **Michele Zorzi**, was born in 1966, and has been a Professor of Telecommunications at the School of Engineering of the University of Padova since 2003. He received the Laurea Degree and the Ph.D. in Electrical Engineering from the University of Padova, Italy, in 1990 and 1994, respectively. Prior to his current appointment, he was a faculty member at the Politecnico di Milano (1993-1996), a Research Scientist at the Center for Wireless Communications, University of California at San Diego (1995-1996), and an Associate Professor (1998-2000) and then Professor (2000-2003) at the University of Ferrara. He has many international contacts and collaborations, and has been PI or co-PI of numerous research projects, both in Europe and in the US, as well as more than 20 other projects funded by different funding agencies and industrial companies.
His research is focused on the field of wireless communications and networking, and has resulted in more than 600 papers in refereed journals and international conferences (see Google Scholar). He received several best paper awards for his activities, including the prestigious IEEE Communications Society Best Tutorial Paper Award in 2008 and IEEE Communications Society Stephen O. Rice Best Paper Award in 2018, and has been invited several time as a keynote speaker or a panelist. He is coauthor of four patents and is co-founder of two start-up companies, one of which was successfully acquired. Since 1998 he has supervised more that 35 PhD students and post-docs. Students who graduated under his supervision have held or have been offered faculty/post-doc/staff positions at institutions/companies including the following: Stanford, USC, UCSD, University of Padova, University of Pisa, DLR (German Aerospace Center), Rohde-Schwartz, CTTC (Barcelona), Woods Hole Oceanographic Institution, UCLA, Qualcomm R&D, ICTH, UC Irvine, Purdue, Huawei, u-blox.

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Program & Abstract

Summer school on Complex Networks and Telecommunications July 3-7-2023

	Monday 3	Tuesday 4	Wednesday 5	Thursday 6	Friday 7
9.00 - 10.45		**Giuseppe Bianchi:** Common pitfalls in securing network protocols – a.k.a. what a network researcher not specifically expert in security should be aware of	**George Alexandropoulos:** Reconfigurable Intelligent Surfaces: From Programmable Wireless Propagation to Holographic MIMO	**Emilio Calvanese Strinati:** 6g semantic commmunications: the role of expressive languages	**Antonio Clemente:** Programmable electromagnetic surfaces: from modelling to functional prototypes and PoCs
		break	break	break	break
11.15 - 13.00	Registration	**Egidio D'Angelo:** From the human brain to artificial intelligence	**Paolo di Lorenzo:** Wireless Edge Intelligence: From Edge Learning to Goal-oriented Communications	**Vincenzo Sciancalepore:** Openness: The new paradigm shift in 6G networks	**EXAM***
	Lunch	Lunch	Lunch	Lunch	
14.15 - 16.00	**Favalli / Calvanese:** school intro	**Emanuela Raffinetti:** Explainability of Artificial Intelligence methods: new perspectives	**Josep Jornet:** Terahertz Communications: From the Near Field to Satellite Networks	**Michele Zorzi:** Non-Terrestrial Networks in the 6G Era: Challenges, Opportunities, Technologies, and Trends	
break	break	break	break	break	
16.15 - 18.00	**Jean-Claude Belfiore:** Topos for semantic communications	**Marcello Caleffi:** Quantum Internet: Wiring the Weirdness	**Students' presentations**	**Students' presentations**	

Download the pdf version of the timetable here

STUDENTS' PRESENTATIONS

	Wednesday	July 5		
16.20	Mina Aghaei Dinani	HES-SO	Switzerland	Evaluation of gossip learning in dynamic setups
16.40	Nicola d'Ambrosio	Università Federico II di Napoli	Italy	Attack-defense strategies in challenging cybersecurity environments.
17.00	Andrea Vignali	Università Federico II di Napoli	Italy	Network Systems Testing Meets AI: How to Cut off Development Costs
17.25	Ingrid Huso	Politecnico di Bari	Italy	Design and Evaluation of Privacy-Oriented Data Dissemination Architectures and Communication Protocols

	Thursday	July 6		
16.15	Alessandro Traspadini	Università di Padova	Italy	Real-Time HAP-Assisted Vehicular Edge Computing for Rural Areas
16.30				
16.45				
17.00				
17.15				

Download the flash presentations schedule here

Abstract

George Alexandropoulos
Reconfigurable Intelligent Surfaces: From Programmable Wireless Propagation to Holographic MIMO.

Recent speculations for the upcoming 6G push the 5G performance indicators to unprecedented levels, envisioning THz frequency bands, devices with embedded sensing capabilities, and native artificial intelligence. These challenging features are expected to become a reality around 2030 and with a strong green footprint. In this talk, we will elaborate around the emerging technology of reconfigurable intelligent surfaces which is provisioned as the enabler of smart wireless environments, offering a highly scalable, low-cost, hardware-efficient, and almost energy-neutral solution for the dynamic control of the propagation of electromagnetic signals, as well as, very recently, their transmission and reception. We will discuss their evolution from programmable reflecting metamaterials to connected computational- and power-autonomous hybrid metasurfaces as well as metasurface-based holographic MIMO transceivers, emphasizing on their state-of-the-art configuration approaches and their imminent applications for communications, localization, sensing, and their integration.

Jean-Claude Belfiore
Topos for semantic communications.

This lecture is one of the first attempts to answer the question "How can intelligent machines efficiently communicate?" which is one of the main goals of the so-called "semantic Communication". I will present a joint work with Daniel Bennequin which shows our progresses towards a mathematical theory of semantic communication, inspired by the foundational works of Claude Shannon and Alexander Grothendieck. To communicate efficiently we need a language. Using category theory, we can define a category transporting the semantics of a language. We will see that the notion of semantics depends on many aspects that can be found in machine learning: Sampling (the data), structures (a kind of presemantic that will be carefully defined), .. Some important mathematical notions as Grothendieck Toposes and Stacks will be introduced through simple examples and we will see how neural networks can be modelled this way). Finally, after showing how a language is transported through the layers of a neural network, we will give a definition of semantic information measures which are not scalar quantities as in Shannon information theory, but spaces. Some examples will show the validity of such a definition. A semantic source coding theorem will finally be given.

Giuseppe Bianchi
Common pitfalls in securing network protocols – a.k.a. what a network researcher not specifically expert in security should be aware of.

Securing network access and communication protocols is a critical task in today's interconnected digital landscape. This lecture aims to highlight common pitfalls encountered when securing network protocols, providing essential knowledge to network researchers. We explore the dangers of improperly applied encryption, the limitations of popular cryptographic algorithms in specific contexts, and the importance of meticulous implementation to avoid vulnerabilities and oracle-type leakages which may completely break security. Real-world examples and lessons learned (also from renowned security protocols such as HTTPS/TLS) will be shared. By raising awareness of these pitfalls, attendees will gain the ability to identify and address security vulnerabilities, ultimately contributing to the development of more robust and secure networked systems.

Marcello Caleffi
Quantum Internet: Wiring the Weirdness.

Internet just turned 50: five decades that shaped the world we live in. Indeed, Internet itself evolved astonishingly since the beginning, from a network prototype consisting of a few static nodes in the early days to a leviathan interconnecting with billions of devices half of the world's population. Yet the fundamental assumption underlying Internet's design – i.e., transmitting messages that can be encoded in a sequence of classical bits – remained unchanged during these five decades. But the dawn of the engineering phase of quantum technologies is challenging Internet's fundamental assumptions. Quantum devices demand for communication primitives — namely, the ability to distribute entangled states and to transmit quantum information — governed by the laws of quantum mechanics. Hence, principles and phenomena with no counterpart in classical networks require a major network-paradigm shift to harness the quantum mechanics specificities. This talk aims at shedding light on the challenges and the open problems arising with the design of a protocol stack for the Quantum Internet

Emilio Calvanese Strinati
6G Networks Beyond Shannon Towards Semantic and Goal-Oriented.

This talk promotes the idea that including semantic and goal-oriented aspects in future 6G networks can produce a significant leap forward in terms of system effectiveness and sustainability. Semantic communication goes beyond the common Shannon paradigm of guaranteeing the correct reception of each single transmitted packet, irrespective of the meaning conveyed by the packet. The idea is that, whenever communication occurs to convey meaning or to accomplish a goal, what really matters is the impact that the correct reception/interpretation of a packet is going to have on the goal accomplishment. Focusing on semantic and goal-oriented aspects, and possibly combining them, helps to identify the relevant information, i.e. the information strictly necessary to recover the meaning intended by the transmitter or to accomplish a goal. Combining knowledge representation and reasoning tools with machine learning algorithms paves the way to build semantic learning strategies enabling current machine learning algorithms to achieve better interpretation capabilities and contrast adversarial attacks. 6G semantic networks can bring semantic learning mechanisms at the edge of the network and, at the same time, semantic learning can help 6G networks to improve their efficiency and sustainability.

Egidio D'Angelo
From the human brain to artificial intelligence.

The brain is thought to operate as a complex adaptive system generating an internal representation of the world that is continuously updated through a prediction/action/learning process. This process, coordinated with the management of brain states, is the basis of all brain functions and of intelligence. Current advances in neurophysiology and brain modelling are now allowing a precise representation and simulation of brain functions on multiple scales. Brain modelling is shedding light on the brain functioning principles and is promoting their application to biomedicine and artificial intelligence. In this talk I will address the principles of brain organization and function and the strategies for brain modelling and simulation. I will show solutions to the multiscale problem and I will show applications to virtual brains, neuromorphic computers and closed-loop controllers.

Paolo di Lorenzo
Wireless Edge Intelligence: From Edge Learning to Goal-oriented Communications.

This talk presents some theoretical, algorithmic, and practical aspects of wireless edge intelligence towards the 6G roadmap. We use a methodological approach, following the main historical steps that have led from edge learning to the emergent field of goal-oriented communications. To this aim, the talk will start introducing the mathematical tools needed to jointly and adaptively manage communication (e.g., bits, rates, powers, etc.) and computation (e.g., CPU cycles) resources, to fulfil a specific learning task with given latency, energy, reliability, and accuracy requirements. We will consider both inference and training of machine learning (ML) models at the wireless edge, encompassing several practical cases of interest such as, e.g., federated learning, offloading of (deep) learning tasks from single/multiple users, ensemble of learning algorithms, cooperative/non-cooperative learning. Finally, going beyond classical communication paradigms, we will touch on the very recent concept of goal-oriented communications, where the system design takes into specific account the goal (e.g., the learning task) for which communication takes place, with the final aim of transmitting the minimum amount of information that is strictly needed for the purpose of communication.

Josep Jornet
Terahertz Communications From the Near Field to Satellite Networks.

Current discussions on 6G point to one terabit-per-second (Tbps) as a reasonable goal for the peak bitrate of next generation wireless systems. To meet this goal, the adoption of the sub-terahertz and terahertz bands, which can provide ample bandwidth for both communication and sensing systems, has been proposed by academia and industry. Fortunately, in the last decade, the terahertz technology gap has been progressively closed through major advancements in electronic, photonic, and plasmonic technologies. In parallel, the propagation of terahertz signals has been studied through both physics-based and data- driven approaches, debunking some of the myths about the terahertz channel. Nevertheless, there are several communication roadblocks that need to be overcome to truly unleash the spectrum above 100 GHz. In this talk, a bottom-up approach is going to be followed to highlight innovative solutions and open challenges for terahertz communications and sensing systems on the ground, in the air and in space. Specific topics include novel graphene-based plasmonic device technologies; ultrabroadband waveforms designs that can not only overcome but leverage molecular absorption; intelligent transmit, receive and reflecting surfaces able to engineer wavefronts in ways that in the past were only available to optical systems; and early hints to design a protocol stack for ultrabroadband ultradirectional networks, always with an eye towards experimental demonstrations with state-of-the-art testbeds.

Emanuela Raffinetti
Explainability of Artificial Intelligence methods: new perspectives.

When applied to high impact and regulated industries, such as energy, finance and health, Artificial Intelligence (AI) methods need to be validated by national regulators, in order to monitor the risks arising from their employment. Indeed, most AI methods rely on the application of highly complex machine learning models which, while reaching high predictive performance, lack explainability and then trustworthiness. To be trustworthy, AI methods have to fulfill a set of basic key-principles, specified in terms of accuracy, explainability, robustness, fairness and sustainability. The notion of "explainability" has become crucial in the recent years, following the increasing application of AI methods that impact the daily life of individuals and societies. Explainability means that an interested stakeholder is able to understand the main drivers of a model driven decision. In line with this requirement, a promising methodology, based on the combination between the Shapley-values and the Lorenz Zonoid tool, was proposed to fulfill both the requirements of accuracy and explainability. The Shapley-value theoretical framework ensures that the predictive output of the highly accurate machine learning models are explainable, while the Lorenz Zonoid tool provides a measure of the machine learning model accuracy together with the global evaluation of the associated explainability. The proposal is applied to the financial and credit scoring data: in the former case, to determine the main factors affecting the bitcoins' price prediction and, in the latter case, to detect the balance sheet variables leading the SMEs to default.

Vincenzo Sciancalepore
Openness: The new paradigm shift in 6G networks

6G networks are expected to provide flexible compute and connect technologies that will fully support innovative use-cases and unprecedented services by means of a concrete and sustainable transformation of all existing network designs into smart-connected telecommunication infrastructures. In this context, main business players have recently powered together a new network revolution related to the advent of the 6G era: Openness. Open environments and equipment are required to establish groundbreaking technologies able to bring advanced communication and sensing capabilities while keeping costs and the carbon footprint affordable. Therefore, it would require new architectural interfaces thereby opening the telecom industry's door to hardware and software providers according to the new Open-RAN (O-RAN) standard. In parallel, new nearly-passive sustainable network nodes, namely Reconfigurable Intelligent Surfaces (RIS), are expected to be deployed to programmatically control the surrounding propagation environment: RIS as man-made passive surfaces can be seamlessly integrated into the new programmable RAN vision to bring flexibility and innovation into the upcoming wireless network generation.

Michele Zorzi
Non-Terrestrial Networks in the 6G Era: Challenges, Opportunities, Technologies, and Trends.

Many organizations recognize non-terrestrial networks (NTNs) as a key component to provide cost-effective and high-capacity connectivity in future 6th generation (6G) wireless networks. Despite this premise, there are still many questions to be answered for proper network design, including those associated with latency and coverage constraints. In this talk, after reviewing research activities on NTNs, we present the characteristics and enabling technologies of NTNs in the 6G landscape (with a focus on architecture, spectrum, and antenna advancements in the air/space design), and shed light on the challenges in the field that are still open for future research. As a case study, we evaluate the potential of multi-layered hierarchical networks, i.e., the orchestration among different aerial/space platforms, including Unmanned Aerial Vehicles (UAVs), High Altitude Platforms (HAPs), and satellites co-operating at different altitudes, and provide guidelines on the optimal working point(s) for which it is possible to achieve a good compromise between improved system flexibility and network performance, with respect to a baseline standalone deployment. We also discuss the feasibility of configuring UAVs and satellites to operate in the millimeter wave (mmWave) bands, and the research challenges associated with this design.

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