The 2nd International School on Enabling Technologies, Applications, and Methods for Emerging 5G Systems

22 – 27 October 2018

IST, Lisbon, Portugal

Scope

The School features a program of lectures delivered by leading experts in the area of 5G networks. The objective of the School is to introduce key features of the emerging 5G technologies from the networking perspective. Attendees will have an opportunity to participate in stimulating discussions with researchers, present their own work, obtain useful feedback, and initiate new collaborations. Lectures will provide the background on 5G wireless communications concepts, with a particular emphasis on the IoT paradigm, broadcast and multicast convergence in 5G networks, as well as D2D/M2M communications in 5G systems. In the course of the lectures, connections will be made to network architectures and protocol design, including radio resource management issues, while also introducing the mathematics associated with analysis and optimisation of the emerging wireless communication systems.

The School will be co-located with the *12th International Workshop on Applied Problems in Theory of Probabilities and Mathematical Statistics*.

Targeted Audience

The School is aimed at Researchers, and Ph.D., M.Sc. and B.Sc. Students, who actively work on or are interested in future mobile networks.

Dates

The School will take place from Monday, Oct. 22nd, to Friday, Oct. 26th.

Programme

The programme is composed of the following lectures and lecturers (a detailed description is provided at the end of this document):

- "*Specifics of Radio Wave Propagation at mmWave Frequencies*", Vasilii Semkin (Tampere University of Technology, Tampere, Finland; Peoples' Friendship University of Russia (RUDN), Moscow, Russia)
- "*RF Convergence Applications for Autonomous Robots*", Alexander Pyattaev (Peoples' Friendship University of Russia (RUDN), Moscow, Russia)
- "*Mathematical Modelling Issues in the Future Multiservice Networks*", Konstantin Samouylov and Yuliya Gaidamaka (Peoples' Friendship University of Russia (RUDN), Moscow, Russia)

- "*Millimetre Wave-Based Wearable Networks: Design Challenges and Open Research Questions*", Olga Galinina (Tampere University of Technology, Tampere, Finland)
- "*Internet of Things*", Augusto Casaca (INESC-ID, Lisbon, Portugal)
- "*Statistical Detection of Internet Traffic Anomalies*", M. Rosário Oliveira (IST - University of Lisbon, Lisbon, Portugal)
- "*Blockchain Technologies that Solve Communication Challenges*", Yevgeni Koucheryavy (Tampere University of Technology, Tampere, Finland)
- "*Three Problems/Challenges in the Area of 5G: Modelling Ultra-Reliable Low Latency Communication (URLLC) Radio Services*", Luis Bernardo, "*Three Problems/Challenges in the Area of 5G: Network Orchestration in 5G/NFV/SDN Infrastructures*", Pedro Amaral, "*Three Problems/Challenges in the Area of 5G: Aggregate Interference Modelling in Future Wireless Networks*", Rodolfo Oliveira (FCT - New University of Lisbon, Lisbon, Portugal)
- "*System Modelling and Control Methods in Heterogeneous 5G Mobile Networks*", Sergey Andreev (Tampere University of Technology, Tampere, Finland)
- "*Increasing Power and Spectral Efficiencies in Wireless Communications - A 5G Challenge*", Rui Dinis (FCT - New University of Lisbon, Lisbon, Portugal)
- "*An Approach to Cloud and Virtual Radio Access Networks*", Luis M. Correia (IST - University of Lisbon, Lisbon, Portugal)

General Schedule

The following schedule will be held daily:

- 09h30 – 11h00: lecture
- 11h00 – 11h30: break
- 11h30 – 13h00: lecture
- 13h00 – 14h00: lunch
- 14h00 – 15h30: lecture

The Workshop will be held daily, on the time-slot after the School's last one (i.e., 16h00 – 18h00).

The last day will be dedicated to students' presentations and seminar.

The overall schedule is given below:

Time	Day					
	Monday, Oct. 22nd	Tuesday, Oct. 23rd	Wednesday, Oct. 24th	Thursday, Oct. 25th	Friday, Oct. 26th	Saturday, Oct. 27th
09:30 - 10:30	*School Registration*	Konstantin Samouylov, Yuliya Gaidamaka	M. Rosário Oliveira	Sergey Andreev	*School Student Seminar*	Social Programme
10:30 - 11:00	*School Opening*					
11:00 - 11:30	Break	Break	Break	Break	Break	
11:30 - 13:00	Vasilii Semkin	Olga Galinina	Yevgeni Koucheryavy	Rui Dinis	*School Student Seminar*	
13:00 - 14:00	Lunch	Lunch	Lunch	Lunch	Lunch	
14:00 - 15:30	Alexander Pyattaev	Augusto Casaca	Luis Bernardo, Pedro Amaral, Rodolfo Oliveira	Luis M. Correia	*School Student Seminar*	
15:30 - 16:00	Break	Break	Break	Break	Break	
16:00 - 18:00	Workshop APTP+MS Registration & Opening	Workshop APTP+MS Session 1	Workshop APTP+MS Session 2	Workshop APTP+MS Session 3	Workshop APTP+MS Round Table	
20:00 - 22:00			Dinner			

Duration and Credits

The School, together with the associated Workshop, will have a total duration of 30 hours.

The students completing the evaluation component will get 2 ECTS credits.

Evaluation

The students wishing to get ECTS credits will have to take the evaluation component of the School.

The evaluation will be a paper to be written by the students, bridging one of the School's lectures with their own thesis, to be delivered by Nov. 30th, 2018.

Supporting Texts

Attendees will get an electronic version of all presentations, during the School.

Language

The School will be entirely held in English.

Location

The venue is "Centro de Congressos" at the Alameda Lisbon campus of IST (Instituto Superior Técnico), in room 02.1 at the ground floor.

A map of the campus is available at http://grow.tecnico.ulisboa.pt/wp-content/uploads/2017/01/IST_Campus_6.pdf, "Centro de Congressos" being located at the ground floor of "Pavilhão de Civil" (building #2 in the map).

General information on the location of the campus can be found at http://grow.tecnico.ulisboa.pt/local-info/address.

Accommodation

There is a wide choice of hotels nearby the campus. Take a look into http://grow.tecnico.ulisboa.pt/local-info/accommodation.

Registration

You can register by contacting Vera Almeida, until Wednesday, Oct. 17th, 2018.

The registration fee is 200 € just for the School, and 300 € for both the School and the Workshop.

Social Event

A dinner will be offered to participants and lecturers on Wednesday, Oct. 24th.

Contacts

If you need any information or help, contact:
Ms. Vera Almeida
Email: vera.almeida@inesc-id.pt
Tel.: +351 213 100 432

Organisation and Programme Committee

The School is organised jointly by:

- Luis M. Correia, IST - University of Lisbon, Lisbon, Portugal
- Konstantin Samouylov, Peoples' Friendship University of Russia (RUDN), Moscow, Russia
- Yevgeni Koucheryavy and Sergey Andreev, Tampere University of Technology, Tampere, Finland

The School is organised with the support of the "RUDN University Program 5-100"

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Detailed Programme

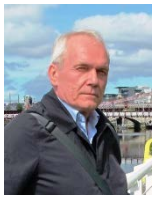
Alexander Pyattaev (Peoples' Friendship University of Russia (RUDN), Moscow, Russia): Dr. Alexander Pyattaev is a graduate of Tampere University of Technology, Finland. He has vast experience in both academic and industrial work with top ICT companies such as Intel and Ericsson. An expert in radio access technologies, his expertise includes such topics as WiFi optimization for both AP and D2D modes, cellular client relay and WiFi offloading, cellular and ad-hoc mmWave, and most recently autonomous robot radio. Academically, Alexander has authored over 25 scientific articles, and has supervised the defence of 4 students. He is also lecturing the course on computer networking at Tampere University of Technology. Currently, he is the CTO of an R&D company YL-Verkot in Tampere, Finland. YL-Verkot is a privately held enterprise developing industry-leading software for radio channel modelling and network system level simulation, as well as algorithms for network control.

RF Convergence Applications for Autonomous Robots: The mobile robots are taking many shapes – drones surveying the skies, cars driving us to work, diggers mining for minerals. All of them, however, are facing the same problem as automobiles 100 years ago – the need for effective and reliable means of signalling their movement plans to each other, as to avoid collisions and coordinate their work. While turn signals have served us well for almost 100 years now, our robots are not equipped to interpret them effectively, especially in extreme conditions where we expect them to work rather often. Through application of advanced RF technologies, however, we can enable our robots to "see" in almost any spectrum, resulting in a variety of solutions: RADAR, LIDAR, TOF cameras, and more. However, while these systems allow robots to see each other, they are not intended to carry data like the turn signals are. In this talk, we will discuss how RADAR and, in extension, almost any MIMO radio, can be expanded to support robot coordination on unprecedented scale. The lecture will cover in detail the specifics of the hardware capabilities required, as well as the signal processing needed to mix information with RADAR sounding signals. Further, the MAC techniques required to enable such systems on a practical scale will be discussed. Finally, the extension to arbitrary MIMO receiver will be presented.

Augusto Casaca (INESC-ID, Lisbon, Portugal): Prof. Augusto Casaca got the Ph.D. in Computer Science at the University of Manchester, UK, and the degree of Aggregate in Electrical and Computer Engineering at the University of Lisbon, Portugal. Full Professor at Instituto Superior Técnico (IST), Lisbon, Portugal, presently he is a researcher at INESC-ID and at INOV, Lisbon, Portugal. At the scientific management level, he has been President of the Electrical and Computer Engineering Department at IST, President of the Scientific Council of INESC-ID, Leader of the Communication Networks and Mobility Group at INESC-ID, and Chairman of the IFIP Technical Committee 6 (Communication Systems). After the Ph.D., his scientific activity was in the area of Digital Systems Design. In this context, he was Research Associate at CERN, Geneva, Switzerland, for one year and Visiting Research Associate for four years. Afterwards, his scientific activity was directed into the area of Communication Networks. He has participated in many projects of the European Research Programs in Telecommunications and he has also participated in several research projects at Eurescom, Heidelberg, Germany. He has actively participated in standardization activities in the area of Networking at ITU-T and ETSI. He has consulted with the main Portuguese companies in telecommunications and with the European Commission. He has more than 150 scientific publications and has co-chaired five international conferences on Networking. He is a Life Senior Member of IEEE. His present research interests are in network architecture, Internet of Things (IoT) communications, and IoT vertical applications for smart grids and smart water infrastructures.

Internet of Things: The Internet of Things (IoT) is a global infrastructure, enabling advanced services by interconnecting physical and virtual things based on interoperable information and communication technologies. The lecture starts by giving an overview of the IoT concept and of the main reasons that are driving its fast implementation. A short analysis of the main types of sensors and actuators, which are the best examples for the instantiation of things, will be made and will be followed by a detailed study of the IoT network architecture and its relation to the Internet protocol modelling. A key part of the IoT network

architecture is related to the link and physical layer communication protocols to be used, therefore a state of the art review of the most important protocols to be considered will be made. The second part of the lecture is focused into the service platforms required to run the IoT applications. For some near real- time applications, the latency is a relevant parameter, which invalidates to rely only on the cloud infrastructure processing of the data collected by the IoT platform. The new concept of fog computing, which runs between the cloud and the local IoT platform, permits reducing the latency of the IoT operations and will be analysed. Then, the IoT vertical markets for the applications will be discussed and some deployed IoT application examples will be presented. The lecture ends with a review of the open issues in IoT, namely security, privacy and standardization.



Konstantin Samouylov (Peoples' Friendship University of Russia (RUDN), Moscow, Russia): Konstantin Samouylov received his PhD degree from the Moscow State University and Doctor of Sciences degree from the Moscow Technical University of Communications and Informatics. During 1985–1996, he held several positions at the Faculty of Sciences of the Peoples' Friendship University of Russia (now RUDN University) where he became the head of the Telecommunication Systems Department in 1996. Since 2014, he has been the head of the Applied Probability and Informatics Department of RUDN University. During last two decades, Konstantin Samouylov has been conducting research projects for the Helsinki and Lappeenranta Universities of Technology, Moscow Central Science Research Telecommunication Institute, several Institutes of Russian Academy of Sciences and a number of Russian network operators. His current research interests are performance analysis of 4G/5G networks and business process modelling. He has written more than 150 scientific and technical papers and three books.

Yuliya Gaidamaka (Peoples' Friendship University of Russia (RUDN), Moscow, Russia): Yuliya Gaidamaka received the PhD in 2001 and Doctor of Sciences degree in 2017 in Mathematics from the Peoples' Friendship University of Russia (RUDN University). Since 2001, she has been an associate professor and currently a professor in the university's Applied Probability and Informatics Department. She is the author of more than 50 scientific and conference papers, co-author of the monograph on multiplicative solutions of finite Markov chains. Her current research focuses on performance analysis of 4G/5G networks, queuing theory, and mathematical modelling of communication networks.

Mathematical Modelling Issues in the Future Multiservice Networks: Over the past few years, there has been an increasing level of research activities worldwide to design and performance analysis for the future multiservice networks, namely M2M and D2D communications over the LTE networks. Our course outlines how mathematical models are being used to address current issues concerning quality of service and performance parameters of the modern and future networks. We shall first show models based on the tele-traffic and queuing theory and reflecting key features of admission control mechanisms in the LTE network. We also show some stochastic geometry problems of the interference analysis in D2D wireless networks.

Luis Bernardo (FCT - New University of Lisbon, Lisbon, Portugal): Luis Bernardo received the Ph.D. degree from the Instituto Superior Técnico, Technical University of Lisbon, Portugal, in 2002, and the Habilitation degree in telecommunications from the Faculdade de Ciências e Tecnologia (FCT), Universidade Nova de Lisboa (UNL), in 2013. Since 1999, he has been an Assistant Professor with the FCT, UNL. Since 2000, he has been a Researcher with the Instituto de Desenvolvimento de Novas Tecnologias, Departamento de Engenharia Electrotécnica, FCT, UNL. Since 2013, he has been a Researcher with the Instituto de Telecomunicações, Lisbon. His research interests include medium access control protocols for wireless communications, cross-layer optimization of wireless systems, routing protocols, and network modelling.

Three Problems/Challenges in the Area of 5G: Modelling Ultra-Reliable Low Latency Communication (URLLC) Radio Services: Ultra-Reliable Low Latency Communication (URLLC) Radio Services have strict requirements in terms of delay and reliability, which cannot be verified using traditional stochastic models, based on average behaviour. New modelling approaches are needed, that provide rare event probabilities. Some modelling challenges are presented based on some possible implementation approaches foreseen for the URLLC services.

Pedro Amaral (FCT - New University of Lisbon, Lisbon, Portugal): Pedro Amaral Received the PhD. in Electric and Computer Engineering in 2013 and the M.Sc. in Computer Engineering in 2006 from Faculdade de Ciências e Tecnologia (FCT), NOVA University of Lisbon (UNL). He Is an Assistant Professor at the Department of Electrical Engineering, NOVA University of Lisbon and a researcher at Instituto de Telecomunicações (IT), Lisbon. Research interests include routing modelling, low delay networks and intelligent network management in SDN and NFV environments.

Three Problems/Challenges in the Area of 5G: Network Orchestration in 5G/NFV/SDN Infrastructures: The 5G network architecture is emerging with a technological convergence between computing and communication systems. 5G networks have service platforms deployed as micro-clouds at the edge of the 5G infrastructure. These services are composed by generalized Virtual Functions (VFs) providing both applications and network services. These VFs have to be dynamically composed in what is called Service Function Chaining (SFC). SFC is a resource allocation problem where QoS metrics like end-to-end latency are important. Modelling challenges to this problem are presented focusing on challenges such as accommodating elastic resource demands or accurately modelling VNF latency.

Rodolfo Oliveira (FCT - New University of Lisbon, Lisbon, Portugal): Rodolfo Oliveira received the Licenciatura degree in electrical engineering from the Faculdade de Ciências e Tecnologia (FCT), Nova University of Lisbon (UNL), in 2000, the M.Sc. degree in electrical and computer engineering from the Instituto Superior Técnico, Technical University of Lisbon, in 2003, and the Ph.D. degree in electrical engineering from FCT, UNL, in 2009. From 2007 to 2008, he was a Visiting Researcher at the University of Thessaly, and from 2011 to 2012 he was a Visiting Scholar at Carnegie Mellon University. He is currently with the Department of Electrical Engineering, NOVA University of Lisbon, and is also affiliated as a Researcher with the Instituto de Telecomunicações, where he researches in the areas of wireless communications and networking.

Three Problems/Challenges in the Area of 5G: Aggregate Interference Modelling in Future Wireless Networks: Due to different techniques of orthogonalization envisioned for the future wireless networks multiple transmitters may be simultaneously active at the same time and in the same frequency band. From the point of view of a single receiver the multiple transmitters act as interferers. The sum of the signals originated by the interferers, aka aggregate interference, impact on the receiver's performance and is a major cause of underperformance. The knowledge of the aggregate interference through its stochastic characterization is thus a prime tool to predict the performance of future wireless networks. However, the stochastic modelling of the aggregate interference is a hard task due to the multiple sources of randomness that are often non-identically distributed and the lack of closed-form solutions. This lecture introduces the assumptions usually adopted in aggregate interference modelling, identifies the limitations of the current approaches, and presents new challenges that need to be addressed to achieve more realistic models

Luis M. Correia (IST - University of Lisbon, Lisbon, Portugal): Luis M. Correia was born in Portugal, in 1958. He received the Ph.D. in Electrical and Computer Engineering from IST (University of Lisbon) in 1991, where he is currently a Professor in Telecommunications, with his work focused in Wireless/Mobile Communications in the areas of propagation, channel characterisation, radio networks, traffic, and applications, with the research activities developed in the INESC-ID institute. He has acted as a consultant for Portuguese communications operators

and the telecommunications regulator, besides other public and private entities, and has been in the Board of Directors of a telecommunications company. Besides being responsible for research projects at the national level, he has participated in 31 projects within European frameworks, having coordinated 5 of them and taken leadership responsibilities at various levels in many others. He has supervised more than 200 M.Sc./Ph.D. students, having edited 6 books, contribute to European strategic documents, and authored more than 450 papers in international and national journals and conferences, for which served also as a reviewer, editor, and board member. Internationally, he was part of 33 Ph.D. juries, and 52 research projects and institutions evaluation committees for funding agencies in 10 countries and the European Commission. He has been the Chairman of Conference, of the Technical Programme Committee and of the Steering Committee of several major conferences, besides other several duties. He was a National Delegate to the COST Domain Committee on ICT. He was active in the European Net!Works platform, by being an elected member of its Expert Advisory Group and of its Steering Board, and the Chairman of its Working Group on Applications, and was also elected to the European 5G PPP Association.

An Approach to Cloud and Virtual Radio Access Networks: The talk addresses the concept of cloudification and virtualisation of Radio Access Networks (RANs). One starts by giving the motivation for the virtualisation of networks, from the services' and users' viewpoint. Then, the concepts of Cloud-RAN and Virtual-RAN are presented. Network architectures are presented for Cloud-RAN and Virtual-RAN, enabling operators to have multiple roles compared to today's reality, and to serve as multiple Virtual Network Operators by sharing the resources among them, and to split the functionalities with Infrastructure Providers. The split of Base Stations into Remote Radio Heads and Baseband Processing Units is presented. An overview of some models and algorithms for managing virtual radio resources and for deploying cloud architectures are presented, aiming at the optimisation of the usage of resources, depending on the services offered by users, on the radio channels experiences by users, and on the Service Level Agreements existing in between Virtual Network Operators and Infrastructure Providers, among others. Constraints like physical capacity, maximum latency, multiple access technique, are also taken into consideration. It is also shown that allocation of resources should be done according to the type services, and their classes on quality of service. Some reference scenarios are put forward, together with some application examples, upon which some results are presented. Conclusions are presented at the end.

Olga Galinina (Tampere University of Technology, Tampere, Finland): Olga Galinina is a Finnish Academy Postdoctoral Researcher in the Laboratory of Electronics and Communications Engineering at Tampere University of Technology (TUT). She received her B.Sc. and M.Sc. degrees in Applied Mathematics and Computer Programming from the Department of Applied Mathematics, St. Petersburg State Polytechnic University of Peter the First, Russia as well as the Ph.D. degree from TUT. In the period from Sept. 2015 to Aug. 2018, she has been working as a postdoctoral researcher at TUT with the support of Finnish Cultural Foundation central and regional funds. She started her Finnish Academy Postdoctoral position in Sept. 2018. Her research interests include applied mathematics and statistics, queueing theory and its applications; wireless networking and energy efficient systems, machine-to-machine and device-to-device communication.

Millimetre Wave-Based Wearable Networks: Design Challenges and Open Research Questions: The next step in the evolution of consumer electronics after the era of smartphones is high-end wearable devices, which will eventually rid of wires and replace traditional flat screen displays. The only viable solution, in this case, is millimetre wave (mmWave) connectivity that is able to support high data rates (e.g., for streaming 4K VR or full-parallax hologram video) and low end-to-end latencies (at least less than 20ms, to prevent user vertigo). In contrast to the mainstream cellular mmWave, high-end wearable networks need to have reasonable battery lifetime, support standalone mmWave operation, and be scalable in very dense environments, without having to fall back onto lower frequencies. Moreover, tighter constraints on size and

heat dissipation impose limitations on the number of antennas that can be supported and the multi-antenna processing capabilities. Targeted at system-level analysts and theoreticians, this talk outlines key challenges associated with massive, ultra-dense, and highly dynamic deployments inherent for the anticipated mobile high-end wearable use cases. Starting with the properties of mmWave propagation and basic principles of large-scale modelling of mmWave systems, we will follow the road towards an understanding of the latest and most exciting research directions related to mmWave-based wearable networks.

M. Rosário Oliveira (IST - University of Lisbon, Lisbon, Portugal): M. Rosário Oliveira graduated in applied mathematics and computer science at Instituto Superior Técnico, in 1992, received the M.Sc. degree in Applied Mathematics from Technical University of Lisbon in 1995, and obtained the Ph.D. degree also in Mathematics at the Technical University of Lisbon in 2002. She has been working at Instituto Superior Técnico (IST) since 1990, where she is Assistant Professor at the Mathematics Department, and has been a full member of the Center for Mathematics and its Applications from IST since 2002. She has been involved in teaching, research and consulting in the areas of data science and statistics, and in national and international projects/consortiums, including European Networks of Excellence Euro-NGI, Euro-FGI, and TEMPUS project Applied Computing in Engineering and Science. Her current research interests include data science, robust statistics, multivariate analysis, and biostatistics.

Statistical Detection of Internet Traffic Anomalies: For computers and communication networks, security has become a major concern. The cost of committing errors in Internet anomaly detection is higher than in other areas of application. Indeed, an attack not early identified and/or blocked can cause severe damage to users and organizations. Conversely, licit traffic wrongly captured by computer security, even if occurring at a low rate, can decrease the quality of service of the Internet service provider. Internet anomaly detection can be formulated as a classification problem. Mainly, we want to assign a new instance to one of a given set of classes, based on a training set of data containing observations whose class membership may be, or not, known. A set of quantifiable characteristics, known usually as features, is chosen to characterize the objects to be classified, and an algorithm that implements the classification procedure is constructed. In this course, we will discuss how principal component analysis can be used to detect anomalies and the importance of using robust estimation methods, capable of dealing with potential mislabelled observations, a strong advantage from the operational point of view. To illustrate these methodologies, we will use examples based on several network scenarios, which were designed to be capable of producing measurements under real (but controlled) traffic conditions without label mistakes. The measurements obtained allow a trustful assessment of the accuracy of the statistical methods. The results show that a pre-processing step to finding the relevant features to discriminate between licit and illicit traffic is of major importance.

Rui Dinis (FCT - New University of Lisbon, Lisbon, Portugal): Rui Dinis received the Ph.D. degree from Instituto Superior Técnico (IST), Technical University of Lisbon, Portugal, in 2001 and the Habilitation in Telecommunications from Faculdade de Ciências e Tecnologia (FCT), Universidade Nova de Lisboa (UNL), in 2010. He is an associated professor at FCT-UNL and a researcher at IT (Instituto de Telecomunicações). During 2003 he was an invited professor at Carleton University. Rui Dinis is or was editor at IEEE Transactions on Communications (2012-2017), IEEE Transactions on Vehicular Technology (since 2015), IEEE Transactions on Wireless Communications (since 2017) and Elsevier Physical Communication. (since 2013) He and is or was TPC member for some of the major IEEE conferences, and was involved in the organization of several IEEE conferences such as ICT'2014, VTC'2018-Spring and ISWCS'2018. Rui Dinis has been involved in several international and national research projects in the broadband wireless communications area. He published 5 books, over 100 journal papers and over 300 conference papers, and has 14 patents. His main research activities are on modulation and

transmitter and receiver (nonlinear effects, detection, equalization, channel estimation and carrier synchronization), with emphasis on frequency-domain implementations for MIMO systems and/or OFDM and SC-FDE modulations. He is also working on cross-layer design and optimization, as well as positioning techniques.

Increasing Power and Spectral Efficiencies in Wireless Communications - A 5G Challenge: The evolution from 4G (4th Generation) to 5G (5th Generation) wireless systems is driven by the expected huge growth in user bit rates (a 10 to 100 times increase) and overall required bit rates (about 1000 increase). This means a substantial spectral efficiency increase, which must be achieved while maintaining or even improving the power efficiency. To accomplish this one needs to employ new transmission techniques, with the most promising ones being the use of mm-Wave (millimetre Wave) bands and massive MIMO (Multiple-Input and Multiple-Output) schemes. The adoption of mm-Wave transmission is mainly due to the huge bands available. Moreover, the small wavelength means small antennas, allowing small-sized transmitter and receivers with very high number antenna elements and, therefore, enabling massive MIMO implementations. However, these frequencies present considerable challenges both in terms of propagation (high propagation free-space path losses, small diffraction effects and almost total absorption losses due to obstacles) and implementation (namely at the power amplification level). Therefore the design of mm-Wave communications with high power and spectral efficiencies presents a considerable challenge. In this tutorial we start by making an overview on the constraints on power and spectral efficiencies, as well as techniques to improve them. Then we present an a massive MIMO architecture for broadband mm-Wave communications that is compatible with highly-efficient, low-cost saturated amplifiers, even for large quadrature amplitude modulation (QAM) constellations or other dense constellations with high spectral efficiency.

Sergey Andreev (Tampere University of Technology, Tampere, Finland): Sergey Andreev received his Specialist and Cand.Sc. degrees from the Saint Petersburg State University of Aerospace Instrumentation, Saint Petersburg, Russia, in 2006 and 2009, respectively, and the Ph.D. degree from the Tampere University of Technology, Finland, in 2012. He is currently a Senior Research Scientist with the Laboratory of Electronics and Communications Engineering, Tampere University of Technology. Since 2018, he has also been a Visiting Senior Research Fellow with the Centre for Telecommunications Research, King's College London, UK. He has authored or co-authored over 150 published research works on wireless communications, energy efficiency, heterogeneous networking, cooperative communications, and machine-to-machine applications.

System Modelling and Control Methods in Heterogeneous 5G Mobile Networks: Heterogeneous wireless networks are becoming the fabric of the emerging fifth generation (5G) mobile systems and beyond. They comprise a hierarchical deployment of small cells operating at different frequencies and under various radio access technologies. This complex environment requires an innovative modelling approach that will combine the spatial distribution of nodes with their temporal traffic dynamics. In this talk, a novel modelling methodology is outlined that captures the space-time properties of heterogeneous 5G mobile networks and helps develop efficient control algorithms for flow-level traffic steering and offloading.

Vasilii Semkin (Tampere University of Technology, Tampere, Finland; Peoples' Friendship University of Russia (RUDN), Moscow, Russia): Vasilii Semkin is a Postdoctoral Researcher in the Department of Electronics and Communications Engineering at Tampere University of Technology, Finland. He received B.Sc. degree from Saint-Petersburg State University of Aerospace Instrumentation, Russia, in 2009 and M.Sc. degree in 2011. He received Lic. Sc. (Tech.) in 2014 and D.Sc. (Tech.) in 2016 from Aalto University, School of Electrical Engineering. Over the

recent years, he has actively pursued collaborative research on developing reconfigurable antennas and radio wave propagation characterization for 5G and beyond communication systems.

Specifics of Radio Wave Propagation at mmWave Frequencies: The millimetre wave (mmWave) bands and other high frequencies above 6 GHz have emerged as a central component of Fifth Generation (5G) cellular standards to deliver high data rates and ultra-low latency. In order to effectively deploy high data rate millimetre-wave communication systems in urban environments, accurate information about the radio-wave propagation channel is essential. Radio-wave propagation in urban scenarios strongly depends on the topography of the immediate surroundings. Different physical effects take place and should be considered.

Yevgeni Koucheryavy (Tampere University of Technology, Tampere, Finland): Yevgeni Koucheryavy is a Full Professor (tenured) at the Faculty of Computing and Electrical Engineering of Tampere University of Technology (TUT), Finland. He received his PhD degree (2004) from the TUT. Yevgeni has been teaching from 1996 for different target groups, students and professionals in Austria, Brazil, China, Czech Republic, Finland, Ireland, Russia, Kazakhstan, Sweden, Spain, UK and USA. He has acted as a PhD evaluation committee member or examiner in >10 countries. He graduated 8 PhD students and over 60 MSc students. He has worked in a number of research and development projects within different frameworks, e.g., FP7, H2020, and companies including Nokia, Intel, Alcatel-Lucent, Ericsson, Cisco, etc. He acts as an external reviewer for state funding agencies of several European countries and H2020. Yevgeni has authored or co-authored over 250 papers in the field of advanced wired and wireless networking and communications. His Scopus h-index is 26. He holds two US patent and two pending. His current research interests include various aspects in heterogeneous wireless communication networks and systems, network and services performance evaluation, the Internet of Things, and nano-scale communications. Yevgeni is an Associate Technical Editor of IEEE Communications Magazine and Editor of IEEE Communications Surveys and Tutorials. Yevgeni is a Senior IEEE member. Yevgeni is a chairman of the board of YL-Verkot Oy and co-founder of Battery Intelligence Oy.

Blockchain Technologies that Solve Communication Challenges: Blockchain-based technologies already provide a significant impact on a plethora of industries such as banking, digital identity, real estate etc. It is anticipated that blockchain will contribute significantly to communication services by becoming a tool to solve many existing challenges in different domains such as security, spectrum management, resource sharing etc. This lecture will provide a big picture of blockchain role in communication challenges and reveal the existing developments in this area. Special attention will be given to the opportunities blockchain opens in Internet of Things, VANETS, SDNs, etc.