



**Summer School on  
5G: ENABLING TECHNOLOGIES, OPPORTUNITIES AND RESEARCH CHALLENGES AHEAD  
4 – 8 July 2022**

**Outline of Lectures – 6 ECTS**

**1. 5G and the Ever-Lasting Quest for Efficient Communications**

Prof. M. Luise

- Communications: a Person's Fundamental Right
- Mobile/Wireless Communications and the Internet
- Generations of Mobile Networks: From 2G to 3G to 4G to 5G
- Searching For Efficiency: the 5G 10 x 10 x 10 Equation
- Challenges in 5G Deployment: where are we now?

**2. PHY-layer Technologies for 5G**

Prof. L. Sanguinetti, Prof. M. Moretti

- Multiple antenna technologies (MIMO, massive MIMO).
- mmWave Communications.
- Dense networks (small cells,...)
- Ultra-reliable low-latency communications
- Massive connectivity (NOMA,...)

**3. Methodologies for electromagnetic propagation in 5G**

Prof. A. Monorchio

- E.M. Propagation Phenomenology at 5G bands
- Short introduction to high-frequency techniques
- Ray Tracing procedure
- Applications and validation

- Limitations and efficiency improvement
- Comparison with empirical propagation models
- Phased Array Antenna modelling
- Decoupling of antennas
- E.M. field level evaluation

#### **4. Cloud/Edge Computing for 5G Networks and Applications**

Carlo Vallati

- Cloud computing: general introduction to Cloud Computing and basic concepts.  
Virtualization as enabling technology for cloud computing.
- Mobile Edge Computing: general introduction to MEC as extension that moves computing and storage at the edge of the network.
- The role of MEC in 5G networks.

#### **5. Security and privacy in 5G systems**

Prof. Gianluca Dini

- Security and privacy evolution in cellular networks.
- Privacy and security issues in 5G standard: main approaches, threats and challenges
- Reference to the security-by-design approach, authentication and subscriber's privacy.
- Open security issues and risks in the 5G echo-system.

#### **6. SDN and NFV in the 5G era**

Prof. A. Virdis

- SDN Principles: Control- and data-plane Separation, SDN general architecture and components, Northbound and Southbound interfaces.
- Open-SDN: the classical SDN view, flowtables, openflow, the role of the SDN controller
- The evolution of SDN: from network management to SDN, alternative SDN views
- Network softwarization and slicing: SDN architecture for 5G
- NFV: virtual network functions and orchestration, architecture overview, relation with SDN

#### **7. System-level simulation and real-time emulation of 5G networks**

Prof. Giovanni Stea, Giovanni Nardini

- Introduction to discrete-event simulation
- Open-source tools to simulate 5G: link-level vs. application-level
- Introduction to the OMNeT++ framework
- Modelling the 5G protocol stack and network components

- o Overview of the Simu5G simulator
- o Simulating 5G network scenarios
- Fast prototyping of 5G applications
  - o Configuring Simu5G as a real-time network emulator
  - o Running real-time applications in emulated 5G networks

## **8. Artificial Intelligence for 5G Networks and Applications**

Prof. Pietro Ducange

- A brief introduction to Artificial Intelligence
- Artificial Intelligence in 5G technology
- Artificial intelligence applications supported by 5G technology
- Future trends

## **9. The role of Beyond 5G on Industrial IoT**

Prof. Rosario Garroppo

- Classifications, Requirements and Performance Indicators of IIoT services.
- Technologies and architectures for supporting IIoT URLL and Massive IoT Services.
- Support for Time Sensitive Communications.
- 5G Non-Public Networks and support for a 5G-LAN type service.
- Technical Challenges for B5G-based IIoT services.

## **10. 5G and UAV applications**

Prof. Stefano Giordano

- Space-based networks, Air-based Networks, Ground-based Networks
- UAV-assisted communications
- Cellular-connected UAVs
- Flying Ad Hoc Networks (FANETs)
- Aerial Hetnets; Combined UAV and D2D Communications
- Dynamic Deployment Ability
- UAV-Based Swarm Networks
- Low- and high-altitude platforms
- Energy harvesting in UAV Networks
- Computing Communication and Caching/Storage in the sky
- Network Softwarization and Virtualization in UAV Communications

- Networks in a box

### **11. Non-terrestrial networks for 5G**

Prof. Filippo Giannetti

- Basics of radio wave propagation through the atmosphere
- Non-Terrestrial Communication Systems
- The Role of NTN Communications in 5G Ecosystem
- Radio Layer Issues
- Radio protocol issues
- Open Issues and Future Directions

### **12. End-to-end network programmability: from core switches to end hosts**

G. Procissi, G. Lettieri

- From original SDN to programmable network data-plane
- In-network computing: programmable switches and the the P4 language
- P4 in practice: running a programmable software switch in an emulated network environment
- End-host computing: in-kernel networking with extended Berkeley Packet Filter
- (eBPF)eBPF in practice: programming simple applications on a Linux machine

### **13. Vehicle-to-Everything (V2X) Services in 5G and Beyond**

Prof. Rosario Garroppo

- Classification and requirements of V2X services.
- V2X use-cases.
- IEEE and 3GPP Technologies for basic V2X services.
- 5G and B5G Architecture and technologies for supporting advanced V2X services.
- Technical Challenges of Advanced V2X.

### **14. Electromagnetic Systems for 5G Automotive Applications**

A. Michel

- Sensors and Wireless Systems integrated on vehicles: applications and requirements
- Key performance parameters of Electromagnetic Systems for vehicular application
- Evolution of Electromagnetic Systems for Cellular Communication: from GSM to 5G and beyond
- Effect of vehicle on Electromagnetic System performance

- Challenges and future trends on Automotive Electromagnetic Systems for Cellular Communications

### **15. Electronic circuits and systems for 5G Automotive V2X scenarios**

Prof. Sergio Saponara

- Introduction about HW enabling technologies for 5G
- RF/mmW transceiver circuits for 5G
- 5G digital baseband processors
- Safety and HW security for on-board 5G vehicle connectivity
- Circuit solutions for 802.11p WLAN and 5G C-V2X vehicle to everything connections
- Analysis of devices and application examples to autonomous and connected vehicles