

## **Tutorial T-15: Emerging Concepts and Technologies towards 5G+ Wireless Networks**

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### **Tutorial Overview**

Since the development of 4G LTE standards around 2010, the research communities both in academia and industry have been brainstorming to predict the use cases and scenarios around 2020, to determine the corresponding technical requirements, and to develop the enabling technologies, protocols, and network architectures towards the next-generation (5G) wireless standardization.

This exploratory phase is winding down as the 5G standardization phase approaches. The first wave of 5G standards are expected to be developed during the 2017-18 timeframe, to be approved by ITU during the 2019-2020 timeframe, and to become operational in the early 2020s. As such, it is time to reinitiate a similar brainstorming endeavour towards the beyond-5G wireless networks; we refer to such networks as 5G+ in order to include the evolution of the 5G standards in 2020s and to perform the groundwork for those to be developed towards 2030.

Despite the recent advances in wireless technologies, the wireless community faces the challenge of enabling a further traffic increase of around 1,000 times, latency reduction of around 100 times, device increase of around 100 times in the next 15 years or so, while no customer is willing to pay more for the wireless pipe itself: the so called “traffic-revenue decoupling”. Moreover, many experts warn that the low-hanging fruits in wireless research (especially in information theory, communications theory, and signal processing) have already been collected. While the research community is full of ideas (as usual), many of these ideas are either not-too-relevant (i.e., not in the bottleneck areas) or they are in areas in which progress toward a tangible implementation is too slow.

The overall goal of the tutorial is to identify

- the emerging concepts and technologies, and
- the necessary analytical tools to study them (such as optimization, game theory, dynamic feedback control, and artificial intelligence).

Towards that end, a number of important components will be presented in the single coherent framework of 5G cellular networks with a “systems” scope and approach.

In the first part of this tutorial (1.5 hours), the following topics will be covered:

- Fundamental dynamics of cellular and wireless communications
- 3GPP operation
- Key technologies in LTE-Advanced (R10)
- Highlights of 3GPP Releases 11, 12, 13, and 14
- Challenges and opportunities as we move forward
- Revisiting the theoretical basics: What we know and what we don’t know
- Enabling technologies in layer-1 and layer-2 as well in the network architecture
- Bottleneck problems in the beyond-2020 wireless networks

In the second part of the tutorial (1.5 hours), the potential research directions towards coping with the bottleneck problems, especially in the context of radio access network (RAN), resource allocation, layers 1, 2, and 3, will be discussed; the underlying mathematical tools will also be highlighted:

- Cognitive radio & spectrum usage
- Advances in PHY
- Noncoherent communications
- HetHetNets (heterogeneous traffic in heterogeneous networks) o 5G+ traffic models
  - o Intercell load coordination (ICLC)
  - o Layer 8: User-in-the-Loop (demand shaping in space and time)
  - o Drone-based communications
- New frontiers in resource allocation
- Interdisciplinary approaches in decision making
- Robust algorithms and protocols

In the absence of a clear technology roadmap for the 2020-2030 timeframe, the tutorial has, to a certain extent, an exploratory view point to stimulate further thinking and creativity. We are certainly at the dawn of a new era in wireless research and innovation; the next twenty years will be very interesting.

### **Presenter Biography**

Halim Yanikomeroglu was born in Giresun, Turkey, in 1968. He received the B.Sc. degree in electrical and electronics engineering from the Middle East Technical University, Ankara, Turkey, in 1990, and the M.A.Sc. degree in electrical engineering (now ECE) and the Ph.D. degree in electrical and computer engineering from the University of Toronto, Canada, in 1992 and 1998, respectively.

During 1993–1994, he was with the R&D Group of Marconi Kominikasyon A.S., Ankara, Turkey. Since 1998 he has been with the Department of Systems and Computer Engineering at Carleton University, Ottawa, Canada, where he is now a Full Professor. His research interests cover many aspects of wireless technologies with a special emphasis on cellular networks. He coauthored about 80 IEEE journal papers, and has given a high number of tutorials and invited talks on wireless technologies in the leading international conferences. In recent years, his research has been funded by Huawei, Blackberry, Samsung, Telus, DragonWave, Communications Research Centre of Canada (CRC), and Nortel. This collaborative research resulted in about 25 patents (granted and applied). Dr. Yanikomeroglu has been involved in the organization of the IEEE Wireless Communications and Networking Conference (WCNC) from its inception, including serving as Steering Committee Member as well as the Technical Program Chair or Co-Chair of WCNC 2004 (Atlanta), WCNC 2008 (Las Vegas), and WCNC 2014 (Istanbul). He was the General Co-Chair of the IEEE Vehicular Technology Conference Fall 2010 held in Ottawa. He has served in the editorial boards of the IEEE TRANSACTIONS ON COMMUNICATIONS, IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, and IEEE COMMUNICATIONS SURVEYS & TUTORIALS. He was the Chair of the IEEE's Technical Committee on Personal Communications (now called Wireless Technical Committee). He is a Distinguished Lecturer for the IEEE Communications Society as well as the IEEE Vehicular Technology Society.

Dr. Yanikomeroglu is a recipient of the IEEE Ottawa Section Outstanding Educator Award in 2014, Carleton University Faculty Graduate Mentoring Award in 2010, the Carleton University Graduate Students Association Excellence Award in Graduate Teaching in 2010, and the Carleton University Research Achievement Award in 2009. Dr. Yanikomeroglu spent the 2011–2012 academic year at TOBB University of Economics and Technology, Ankara, Turkey, as a Visiting Professor. He is a registered Professional Engineer in the province of Ontario, Canada