Introduction to 5G Networks Yaakov (J) Stein

The first generation of cellular networks was being designed to connect people via basic analog voice telephony, and 2G did the same in digital fashion, adding only short text messaging and a very low rate data service. 3G increased the voice quality and provided 10 Mbps packet data, while the present 4G supports always-on high-rate Internet access, video, and location-based services. The fifth generation is being designed to be the ultimate network, connecting not only people but the Internet of Things, via wireline or wireless, providing data rates exceeding 10Gbps, dense connectivity, high reliability, ultra-low delay, coverage at high velocities, security, and privacy. The first 5G version (release 15) is to be finalized by June 2018 for trials during 2019, while the full standard is planned for March 2020.

The course will describe all aspects of 5G, starting with the innovations of the New Radio air interface at conventional RF and millimeter waves; massive MIMO and personal cells; the gNodeB base station; methods of sharing of network resources between mobile operators; the Radio Access Network; Cloud RAN and virtualized RAN; backhauling, fronthauling and intermediate functional splits; Time Sensitive Networking; the Next Generation core; the new SDN-based concept of network slicing; use of NFV and MEC; methods for achieving 5G's stringent timing requirements; and 5G's application to eMBB, WTTP, massive IoT, V2X, and VR/AR.

Students are expected to have taken basic courses in digital communications (e.g., course 512.4161) and packet switched networking (e.g., course 512.4462).

Knowledge of legacy cellular networks is not essential, as the basics will be reviewed.

Lecture Schedule

1. Introduction to cellular communications – generations 1 - 4
2. Limitations of 4G and 5G design goals (based on ITU-R M.2083)
   Initial deployments
3. Overall 5G architecture (gNb, NR, RAN, NGCN) and co-existence options
   3GPP standardization
4. 4G Air Interface and basic improvements (framing, CA, channel coding)
5. MIMO and massive MIMO
   New spectral bands and millimeter waves
   Innovative coverage strategies (OneWeb, Aquila)
6. 5G Radio Access Network and functional splits
7. Transport options (XGS-PON, 802.3by/cd/bs), FlexE, eCPRI, TSN, DetNet)
8. Cloud RAN (cRAN) and virtual RAN (vRAN)
   HetNets
   MOCN and MORAN
9. Network slicing
10. 5G core network (NGCN), standalone and non-standalone modes
11. Use case – eMBB (enhanced Mobile BroadBand) and fixed wireless
12. Use case – URLLC (Ultra Reliable Low Latency Communications)
    Use case – IoT, CI, and smart city
    Use cases – V2X, AR/VR

Mandatory Bibliography

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Akhil Gupta et al, IEEE Access, July 2015, 1206-1232

Additional Bibliography (expected to be updated)

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METIS-II Project Deliverables, https://metis-ii.5g-ppp.eu/documents/deliverables/

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NGMN, March 2015, https://www.ngmn.org/5g-white-paper/

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Shanzhi Chen and Jian Zhao, IEEE Communications Magazine, May 2014, 36-43

Cellular Architecture and Key Technologies for 5G Wireless Communication Networks
Cheng-Xiang Wang et al, IEEE Communications Magazine, February 2014, 122-130

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NGMN, February 2018, https://www.ngmn.org/publications/technical-deliverables.html

5G Air Interface System Design Principles
Naga Bhushan et al, IEEE Wireless Communications, October 2017, 6-8

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5G Radio Network Design for Ultra-Reliable Low-Latency Communication
Joachim Sachs et al, IEEE Network, March/April 2018, 24-31

5G Backhaul Challenges and Emerging Research Directions: A Survey
Mona Jaber et al, IEEE Access vol 4, April 2016

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NGMN, February 2018, https://www.ngmn.org/publications/technical-deliverables.html

Network Slicing for 5G with SDN/NFV: Concepts, Architectures, and Challenges
Jose Ordonez-Lucena et al, IEEE Communications Magazine, May 2017, 80-87

5G-Crosshaul Network Slicing: Enabling Multi-Tenancy in Mobile Transport Networks
Xi Li et al, IEEE Communications Magazine, August 2017, 128-137

5G Security Landscape, 5G-PPP, June 2017, https://5g-ppp.eu/white-papers/