Course Description

Title: Fantastic Gs and Where to Find Them
Fields of activity: Computer Engineering, Electronic/Electrotechnical Engineering, Multimedia and Communication Design, Telecommunications/Electronics
Examination type: Written exam
Number of ECTS credits issued: 1 or 1.5 (it will be defined soon)
Learning Goals and Objective: After participating in the course, students should be able to compare the latest generation of mobile wireless technologies and explain how each generation differs one from another. Apart from that, each student should acknowledge the current state of the 5G technology and understand the importance of the security requirements for this mobile network. Finally, the students should be able to build perspectives on future technological advances in the field of mobile wireless communication.

BEST Skopje
FEIT, Ruger Boskovik, bb
Baraka 5
1000 Skopje, Macedonia

Tel/Fax: +389 30 66 029
E-mail: skopje@BEST.eu.org
www.BEST.eu.org/skopje

Syllabus

Name of activity	5G: Technology overview; Challenges and Innovative Solutions
Number of working hours	4 hours
Type of activity	Lectures + Demonstrative Exercises
Lecturer	Liljana Gavrilovska
Short summary of content	Compared to the previous generations of mobile networks, 5G will provide a significant paradigm shift by including beyond state of the art technical solutions. However, unlike the previous generations of mobile systems, it will also be highly integrative and backward compatible. Spectrum regulation will need to be rethought and significantly improved, whereas energy and cost efficiencies will become one of the key parameters that will steer the 5G design and development. This lecture will outline the 5G related topics, identifying the key challenges for future research and preliminary 5G standardization activities, and will provide a comprehensive survey of the current R&D activities.
Bibliography	1. C. L. I, S. Han, Z. Xu, S. Wang, Q. Sun and Y. Chen, "New Paradigm of 5G Wireless Internet," in IEEE Journal on Selected Areas in Communications, vol. 34, no. 3, pp. 474-482, March 2016. 2. L. Gavrilovska, V. Rakovic and V. Atanasovski, “Visions Towards 5G: Technical Requirements and Potential Enablers”, Wireless Personal Communications, pp. 731-757, 2015. 3. A. Gupta and R. K. Jha, "A Survey of 5G Network: Architecture and Emerging Technologies," in IEEE Access, vol. 3, no. , pp. 1206-1232, 2015. 4. B. A. A. Nunes, M. Mendonca, X. N. Nguyen, K. Obraczka and T. Turletti, "A Survey of Software-Defined Networking: Past, Present, and Future of Programmable Networks," in IEEE Communications Surveys & Tutorials, vol. 16, no. 3, pp. 1617-1634, 2015. 5. E. Hossain and M. Hasan, "5G cellular: key enabling technologies and research challenges," in IEEE Instrumentation & Measurement Magazine, vol. 18, no.

	3, pp. 11-21, June 2015. 6. W. Roh et al., "Millimeter-wave beamforming as an enabling technology for 5G cellular communications: theoretical feasibility and prototype results," in IEEE Communications Magazine, vol. 52, no. 2, pp. 106-113, February 2014. 7. A. Osseiran et al., "Scenarios for 5G mobile and wireless communications: the vision of the METIS project," in IEEE Communications Magazine, vol. 52, no. 5, pp. 26-35, May 2014.
Expected effect	The attendees will obtain basic knowledge about key concepts and fundamental principles of the 5G system operation.

Name of activity	Physical layer aspects in 5G
Number of working hours	2 hours and 30 minutes
Type of activity	Lecture
Lecturer	Slavche Pejoski
Short summary of content	Basics of the physical layer of the wireless communication systems. Basics of wireless channels and wireless channels used in 5G. Basics of signal waveforms and modulation and the candidates waveforms and associated modulations for 5G. Basics of MIMO and massive MIMO and their utilization if 5G.
Bibliography	8. Andrea Goldsmith, “Wireless Communications”, Cambridge University Press, 2005 9. P. Banelli, S. Buzzi, G. Colavolpe, A. Modenini, F. Rusek and A. Ugolini, "Modulation Formats and Waveforms for 5G Networks: Who Will Be the Heir of OFDM?: An overview of alternative modulation schemes for improved spectral efficiency," in *IEEE Signal Processing Magazine*, vol. 31, no. 6, pp. 80-93, Nov. 2014. 10. Zheng Ma, ZhengQuan Zhang, ZhiGuo Ding, PingZhi Fan and HengChao Li, “Key techniques for 5G wireless communications: network architecture, physical layer, and MAC layer perspectives”, Science China Information Sciences, 2015.

	11. Markku Renfors, Leonardo G. Baltar, Oriol Font-Bach, Nikolaos Bartzoudis, David Gregoratti, Elefterios Kofidis, Laurent Martinod, Andre Myrvoll, Slobodan Nedic, Dmitry Petrov, Dejan Rakic, Vidar Ringset, Hmaied Shaiek, "Flexible and Spectrally Localized Waveform Processing for Next Generation Wireless Communications", EMPhAtiC FP 7 Project 12. L. Gavrilovska, V. Rakovic and V. Atanasovski, "Visions Towards 5G: Technical Requirements and Potential Enablers", Wireless Personal Communications, pp. 731-757, 2015 13. ITU, "Technical feasibility of IMT in bands above 6 GHz" Tech. Rep. M.2376, ITU 14. Thorsten Wild, Gerhard Wunder, "Final 5GNOW Transceiver and frame structure concept", Tech. Rep. D3.3, 5GNOW FP7 project, 2015 15. P. Baracca, D. Aziz, "Final performance results and consolidated view on the most promising multi-node/multi-antenna transmission technologies", Tech. Rep. ICT-317669-METIS/D3.3, Mobile and wireless communications Enablers for the Twenty-twenty Information Society (METIS) FP 7 project, 2015 16. Malte Schellmann, "Proposed solutions for new radio access", Tech. Rep. ICT-317669-METIS/D2.4, Mobile and wireless communications Enablers for the Twenty-twenty Information Society (METIS) FP 7 project, 2015 17. Amer Baghdadi, "Test-bed/demonstration results", Tech. Rep. ICT-317669-METIS/D1.3, Mobile and wireless communications Enablers for the Twenty-twenty Information Society (METIS) FP 7 project, 2015 18. Fei Hu, "Opportunities in 5G Networks: A Research and Development Perspective" CRC Press, 2016 19. E. G. Larsson, O. Edfors, F. Tufvesson and T. L. Marzetta, "Massive MIMO for next generation wireless systems," in *IEEE Communications Magazine*, vol. 52, no. 2, pp. 186-195, February 2014.
Expected effect	The attendees will obtain basic knowledge about key concepts at physical layer in a communication system and the physical layer concepts needed to achieve the 5G goals.

Name of activity	Millimeter wave communications for 5G
Number of working hours	1 hour
Type of activity	Lecture
Lecturer	Aleksandar Ichkov
Short summary of content	Understanding of the main requirements for future 5G cellular networks and the need for new spectrum bands. Basics of the physical layer of millimeter wave wireless communications and their emergence as a candidate for 5G. Basics of wireless channels for 28, 38, 60 and 70 GHz as suitable candidates for future cellular communications.
Bibliography	[1] T.S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G.N. Wong, J. K. Schulz, M. Samimi and F. Gutierrez, “Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!”, IEEE Access, May 2013 [2] S. Rangan, T. S. Rappaport and E. Erkip, "Millimeter-Wave Cellular Wireless Networks: Potentials and Challenges," in *Proceedings of the IEEE*, vol. 102, no. 3, pp. 366-385, March 2014. [3] R. Baldemair *et al.*, "Ultra-dense networks in millimeter-wave frequencies," in *IEEE Communications Magazine*, vol. 53, no. 1, pp. 202-208, January 2015. [4] T. Bai and R. W. Heath, Jr., “Coverage and rate analysis for millimeter wave cellular networks“, IEEE Trans. Wireless Commun., vol.14, no. 2, pp. 1100-1114, Feb. 2015 [5] M. R. Akdeniz *et al.*, "Millimeter Wave Channel Modeling and Cellular Capacity Evaluation," in *IEEE Journal on Selected Areas in Communications*, vol. 32, no. 6, pp. 1164-1179, June 2014. [6] T. S. Rappaport, G. R. MacCartney, M. K. Samimi and S. Sun, "Wideband Millimeter-Wave Propagation Measurements and Channel Models for Future Wireless Communication System Design," in *IEEE Transactions on Communications*, vol. 63, no. 9, pp. 3029-3056, Sept. 2015. [7] A. I. Sulyman, A. T. Nassar, M. K. Samimi, G. R. Maccartney, T. S. Rappaport and A. Alsanie, "Radio propagation path loss models for 5G cellular networks in the 28 GHZ and 38 GHZ millimeter-wave bands," in *IEEE*

	Communications Magazine, vol. 52, no. 9, pp. 78-86, September 2014. [8] S. Sun, T. S. Rappaport, R. W. Heath, A. Nix and S. Rangan, "Mimo for millimeter-wave wireless communications: beamforming, spatial multiplexing, or both?," in IEEE Communications Magazine, vol. 52, no. 12, pp. 110-121, December 2014. [9] A. L. Swindlehurst, E. Ayanoglu, P. Heydari and F. Capolino, "Millimeter-wave massive MIMO: the next wireless revolution?," in *IEEE Communications Magazine*, vol. 52, no. 9, pp. 56-62, September 2014.
Expected effect	The attendees will obtain basic knowledge about the physical layer concepts needed to achieve the 5G goals and the possibility of using millimeter wave spectrum in 5G cellular networks.

Name of activity	Quality of Service in 5G
Number of working hours	2 hours and 30 minutes
Type of activity	Lecture
Lecturer	Tomislav Shuminoski, M.Sc.
Short summary of content	The students are going to learn the QoS fundaments, algorithms and mechanisms for present and future (5G) mobile wireless technologies. Moreover, they will learn the differences between the existing and future QoS mechanisms, and the current state of the QoS in 5G technologies. Finally, they will understand the importance of the QoS provisioning for the 5G mobile and wireless networks and multimedia services.
Bibliography	[1] Cheng-Xiang Wang et al.. "Cellular Architecture and Key Technologies for 5G Wireless Communication Networks." IEEE Communications Magazine. Vol. 52, No. 2, February (2014): 122-130. [2] Janevski, Toni. 5G Mobile Phone Concept. Science Paper, Las Vegas, USA: CCNC conference, January 2009. [3] Federico Boccardi et al.. "Five Disruptive Technology Directions for 5G." IEEE Communications Magazine. Vol. 52, No. 2, February (2014): 74-80.

	[4] Boyd Bangerter, Shilpa Talwar, Reza Arefi, and Ken Stewart. “Networks and Devices for the 5G Era." IEEE Communications Magazine. Vol. 52, No. 2, February (2014): 90-96. [5] Lu, W. Willie. “An Open Baseband Processing Architecture for Future Mobile Terminals Design.” IEEE Wireless Communications. Volume: 15 , Issue: 2, April (2008): 110 - 119. [6] Aleksandar Tudzarov and Toni Janevski. "Design for 5G Mobile Network Architecture.” International Journal of Communication Networks and Information Security (IJCNIS). Vol. 3, No. 2, August (2011): 112-123. [7] Aleksandar Tudzarov and Toni Janevski, "Protocols and Algorithms for the Next Generation 5G Mobile Systems", Network Protocols and Algorithms, ISSN 1943-3581, Vol. 3, No. 1, pp.94-114, April 20, 2011. [8] Josef Noll, Mohammad. M.R Chowdhury. “5G – Service Continuity in Heterogeneous Environments.” Wireless Personal Communications - DOI: 10.1007/s11277-010-0077-6, Published online: 31 July 2010. [9] Toni Janevski, "NGN Architectures, Protocols, and Services", John Wiley and Sons, April 2014. [10] Toni Janevski, "Internet Technologies for Fixed and Mobile Networks", Artech House, USA, November 2015. [11] Recommendation ITU-T Y.2052 (02/2008): Framework of multi-homing in IPv6-based NGN. [12] Jonathan Rodriguez, "Fundamentals of 5G Mobile Networks", John Wiley & Sons, Ltd., 2015. [13]Mohammed Atiquzzaman (2004). SCTP: State of the Art in Research, Products, and Technical Challenges. IEEE C ommunications Magazine, pp.: 64-76. [14] Patrick Kwadwo Agyapong, et al. "Design Considerations for a 5G Network Architecture." IEEE Communications Magazine. Vol. 52, No. 11, November (2014): 65-75. [15] Alper Yegin, et al. "Terminal-Centric Distribution and Orchestration of IP Mobility for 5G Networks." IEEE Communications Magazine. Vol. 52, No. 11, November (2014): 86-92.
Expected effect	The expected result of this activity is achieving fundamental knowledge for the QoS in 5G mobile and wireless networks,

	understanding the QoS mechanisms and how each different QoS mechanism differs one from another. And finally, understand the importance of the QoS provisioning in the 5G mobile and wireless networks and multimedia services. At the end of the session, the students should be able to build perspectives on future QoS provisioning and challenges in the field of mobile and wireless networks and services.

Name of activity	Localization techniques in wireless networks
Number of working hours	2 hours and 30 minutes
Type of activity	Lecture
Lecturer	Assoc. prof. Vladimir Atanasovski
Short summary of content	Fundamental techniques for localization of transmitters in wireless networks such as Angle-of-Arrival (AoA), Time-Difference-of-Arrival (TDoA) and RSS-based with an emphasis on practical applicability for provisioning location-based services in future 5G scenarios.
Bibliography	[1] Grambozov, V. Atanasovski and L. Gavrilovska, "Practical evaluation of TDoA, AoA and hybrid methods for geolocation of wireless transmitters," IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Ghent, Belgium, June 17-19, 2015. [2] D. Denkovski, M. Angjelicinoski, V. Atanasovski and L. Gavrilovska, "RSS-Based Self-Localization Framework for Future Wireless Networks," Springer Wireless Personal Communications, Volume 78, Issue 3, October 2014, DOI: 10.1007/s11277-014-1903-z. [3] M. Angjelichinoski, D. Denkovski, V. Atanasovski and L. Gavrilovska, "SPEAR: Source Position Estimation for Anchor Position Uncertainty Reduction," IEEE Communications Letters, Vol. 18, No. 4, April 2014, pp. 560-563.
Expected effect	Deeper understanding of the fundamental mechanisms behind various localization techniques used in wireless networks.

Name of activity	Security issues in 5G networks
Number of working hours	3 hours
Type of activity	Lecture
Lecturer	Prof. dr. Aleksandar Risteski
Short summary of content	Students will learn about basics of secure communications; security mechanisms in 2G, 3G and 4G networks; summary of current open issues towards 5G security.
Bibliography	-
Expected effect	Broadening the knowledge of students towards understanding basic principles and mechanisms implemented for providing security and privacy in mobile networks.

Name of activity	Internet of Things towards 5G
Number of working hours	2 hours
Type of activity	Lectures
Lecturer	Valentin Rakovic
Short summary of content	The Internet of Things (IoT) paradigm is set to revolutionize the way we live and work by means of a wealth of new services, based on seamless interactions between a large amount of heterogeneous devices. In recent years a large variety of communication technologies have emerged, reflecting a large diversity of application domains and of communication requirements. The heterogeneity and fragmentation of the connectivity landscape is currently hampering the full realization of the IoT vision, by posing many complex integration challenges. In this context, the introduction of 5G systems, with the availability of a connectivity technology which provide truly ubiquitous, reliable, scalable, and cost-efficient services, is considered as the key driver for the globally emerging IoT. The lecture will, analyze the potential of 5G technologies for IoT, by considering both the technological and standardization aspects. It will review the present-day IoT connectivity landscape and will

	illustrate the massive business shifts as a result of the link between IoT and 5G.
Bibliography	1. M. R. Palattella et al., "Internet of Things in the 5G Era: Enablers, Architecture, and Business Models," in IEEE Journal on Selected Areas in Communications, vol. 34, no. 3, pp. 510-527, March 2016. 2. M. Condoluci, G. Araniti, T. Mahmoodi, Mischa Dohler, “Enabling the IoT Machine Age with 5G: Machine-Type Multicast Services for Innovative Real-Time Applications,” IEEE Access (transactions), Special Issue on IoT, in press, 2016. 3. Alexander Hellemans, Why IoT Needs 5G, IEEE Spectrum, 2015. 4. L. Gavrilovska, V. Rakovic, “Human Bond Communications: Generic Classification and Technology Enablers’”, Springer Journal on Wireless Personal Communications, 2016. 5. A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," in IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2347-2376, 2015. 6. B. B. Sánchez, Á Sánchez-Picot and D. S. D. Rivera, "Using 5G Technologies in the Internet of Things Handovers, Problems and Challenges," Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2015 9th International Conference on, Blumenau, 2015, pp. 364-369.
Expected effect	The attendees will obtain basic knowledge with respect to the IoT concept and its relation to the 5G systems.

Name of activity	Optimal broadband wireless technology deployment in conjunction with traffic trends in the network of Makedonski Telekom (Macedonian Telekom)
Number of working hours	2 hours
Type of activity	Lecture
Lecturer	Lazar Dinov and Goran Jordanovski – company representatives
Short summary of content	Mobile broadband nowadays represents the leading edge in

	innovation and development for networking, software, computing and Internet technology. The major developments in the mobile broadband market include rapid deployment of 4th Generation (4G) networks, which provides a better understanding of what our industry needs to do to address data demands, which are growing exponentially. Over this past year, the need for additional spectrum has become particularly urgent, resulting in a number of new initiatives by industry and government.
Bibliography	1. J. Scott Marcus, Werner Neu, "Study on Impact of traffic off-loading and related technological trends on the demand for wireless broadband spectrum."
Expected effect	The students will know how is traffic off-loading evolving over time, in terms of technical and of market developments. They should be able to explain how does this evolution influence the need for spectrum.

Name of activity	Visit to "Makedonski Telekom AD" – telecommunication company
Number of working hours	2 hours and 30 minutes
Type of activity	Company Visit
Lecturer	Company representative from Makedonski Telekom
Short summary of content	During the visit of "Makedonski Telekom" the respective engineers will present: **1**. Packet Core equipment: a. SGSN/MME MKVIII from ERICSSON b. GGSN/SGW/PGW (SSR 8020 platform) from ERICSSON c. IPWorks DNS servers from ERICSSON d. RADIUS servers (Free radius) e. CGNAT from HUAWEI (Eudemon 8000 – X3) **2**. Mobile Soft Switch & User Database Equipment a. MGW - GMP v3.0, BC 3024 from ERICSSON b. MSC-BC APZ 214 03/APZ 212 60 (IS 2.1) from ERICSSON c. HLR/STP APZ 212/50 from ERICSSON d. HSS NSP 6.1 from ERICSSON

	3. Prepaid Charging system and PCRF from ERICSSON a. CCN NSP6.1 b. SDP c. MBC part of CCN for Gx/Gy d. SAPC (PCRF) on NSP 6.1 **4**. SMSC from COMVERSE **5**. MMSC from ERICSSON **6.** Radio Access Network Nodes a. RNC - 6900 from HUAWEI b. BSC - 6900 from HUAWEI c. mBTS - 3900 (2G/3G/LTE) from HUAWEI **7.** Voice Mail from COMVERSE
Bibliography	-
Expected effect	The students will get an overview about mobile telecommunications, broadband and fixed-line internet services, and IT and network services in Macedonia.

Name of activity	NEOTEL: Next Generation Network
Number of working hours	2 hours and 30 minutes
Type of activity	Company Visit
Lecturer	Company representative from Neotel Macedonia
Short summary of content	The students will be introduced with the LTE – Advanced System and the WDM Optical Network. They will be provided with an introduction and description about each of these systems and will get to know the functional solutions which this company offers.
Bibliography	-
Expected effect	Broadening the knowledge base about the transition from Mobile WiMAX to LTE-Advanced and will enrich their knowledge on the WDM Optical Network.

Name of activity	Visit to one of the base stations of VIP – Mobile Telecommunication Operator in Macedonia
Number of working hours	2 hours and 30 minutes
Type of activity	Company Visit
Lecturer	Company representative
Short summary of content	The network is distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. This base station provides the cell with the network coverage which can be used for transmission of voice, data and others. A cell might use a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed service quality within each cell. The Base Station only functions as a transmitter and a receiver and radio resources are being controlled by using Spectrum which is a magnetic air base to aid communication without a wire.
Bibliography	-
Expected effect	Students will gain valuable insight into the mechanism behind mobile network communication and learn more about the process involved in the transmission of signals.

Name of activity	Visit to Ericsson Telecommunications Macedonia LTD
Number of working hours	2 hours
Type of activity	Company Visit
Lecturer	Company representative from Ericsson Telecommunications Macedonia
Bibliography	-
Short summary of content	Laying the foundation of the Networked Society by developing appropriate and efficient wireless connectivity solutions is essential to support the diverse needs of people, businesses, industries and society. With using LTE, 5G and other radio technologies, the telecommunication companies are taking the

	Wireless Access Networks to the next level.
Bibliography	-
Expected effect	Students will learn about the most advanced 5G trial systems to the field to test real-world applications and support global standardization

Name of activity	Final exam
Number of working hours	2 hours
Type of activity	Revision + Written exam
Lecturer	The test will have several questions from every lecturer
Short summary of content	The participants will summarize what they learned in the past week and solve a test made up of questions on the topic of lectures and discussions
Bibliography	-
Expected effect	The students will get back to and work on the key points of the topic of the course that will be included in the test, thus hopefully taking some solid knowledge back with them ☺

BEST Skopje
FEIT, Ruger Boskovik, bb
Baraka 5
1000 Skopje, Macedonia

Tel/Fax: +389 30 66 029
E-mail: skopje@BEST.eu.org
www.BEST.eu.org/skopje