UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA ELÉTRICA

Wireless Communication Protocols for IoT Applications

Syllabus

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Course Objectives: Give the student a practical feel of the basic functionalities of wireless communication systems commonly deployed in Internet-of-Things (IoT) connectivity solutions for application in Smart Healthcare, Smart Homes, Industry 4.0, Smart Agriculture, Intelligent Transportation, among others. Thus, experimentally demonstrate concepts learned in theoretical classes is an important goal. The studend should also examine basic building blocks of communications systems using actual signals, (de)coding, (de)modulators, channel models, detectors, etc. Through numerical simulations the student should be able to determine the effect of varying parameters on the performance of the simulated systems, as well as on their spectral and energy efficiencies.

Lab Experiments: Practical experiments using nRF Connect SDK's and/or numerical simulations should be performed weekly, and the results presented after their conclusion. Students will form groups in order to implement an IoT solution of project subjects suggested by or discussed with the Instructors. Each group will write a report and present the main results of the implemented project. The Instructors will grade the reports and the presentations at the end of the course.

Learning Outcomes (LO's): At the end of this module the student is able to:

- Systematically design wireless communication protocols for smart systems based on critical performance analysis, leading to a proof-of-concepts based on technical requirements.
- Methodically realize a smart system application based proof-of-concept design, so that it leads to the specific solution.
- Critically validate the answer to the research question with subquestions through a logical line of reasoning from the specified research question to the specific solution.
- Critically reflect on the systematical investigation and results, recognizing strengths and weaknesses and indicating possible improvements to obtain a specific solution.
- Communicate the new insights, obtained by critically performing research, in a logical line of reasoning to a public of experts by writing a report and making a presentation.

Grading Policy and Assignments Types: 25% hands on activities (pratical and numerical simulations), 50% practical project, 25% report and presentation. These subjects are closely related to the rubric criteria described in Table II presented in Appendice I.

Bulletin Description: IoT basics, IEEE 802.15.4 PHY Layer basics, channel modelling, additive white Gaussian noise (AWGN), design of low rate and Low Power (LP) wireless systems (attenuation and link budget), Essentials of nRF Connect SDK firmware development, Zephyr project, Bluetooth Low Energy (BLE) and Zigbee fundamentals, Thread protocol implementation, Wireless-fidelity (Wi-Fi) and Wi-Fi 6 concepts, Matter Concept, LoRa and Sigfox as main Low-Power Wide Area Networks (LP-WANs), LTE, LTE-M and NB-IoT cellular technologies.

Topics in Lecture Notes		**Activities**	**Week**
Unit I	**IoT Basics**		
I.a	Introduction, network models and technologies, IEEE 802.15.4 PHY Layer	Theory and simulations	1
I.b	Channel modelling, design of low rate and LP wireless systems	Theory and simulations	2
Unit II	**Essentials of nRF Connect SDK firmware development**		
II.a	Embedded systems and Zephyr	Practical hands on	3
II.b	BLE fundamentals	Practical hands on	4
II.c	Thread fundamentals	Practical hands on	5 and 6
Unit III	**Personal Area Network (PAN) Wireless Protocols**		
III.a	BLE and Zigbee	Theory and simulations	7
III.b	Thread mesh network	Theory and hands on	8
Unit IV	**Local Area Network (LAN) Wireless Protocols**		
IV.a	Wi-Fi and Wi-Fi 6	Theory	9
IV.b	OFDMA	Theory and simulations	10
Unit V	**Matter Concept**		
V.a	Hybrid network implementation	Hands on	11
V.b	Project discussions	-	12
Unit VI	**LP-WAN Protocols and Cellular Technologies**		
VI.a	LoRa and Sigfox	Theory and simulations	13
VI.b	LTE and LTE-M	Theory and simulations	14
VI.c	NB-IoT	Theory and hands on	15

Required Text: There is no required text because the lecture notes are supposing to be self-contained. Nevertheless, the students are refered to the book titled "Connecting the Internet of Things: IoT Connectivity Standards and Solutions" (Kumar, Anil, Jafer Hussain, Anthony Chun; Apress; 2023)

Supplemental Texts

1. Nordic Semiconductors, *nRF Connect SDK Fundamentals*. Available online at https://academy.nordicsemi.com/courses/nrf-connect-sdk-fundamentals/
2. Nordic Semiconductors, *Bluetooth Low Energy Fundamentals*. Available online at https://academy.nordicsemi.com/courses/bluetooth-low-energy-fundamentals/
3. Nordic Semiconductors, *Cellular IoT Fundamentals*. Available online at https://academy.nordicsemi.com/courses/cellular-iot-fundamentals/
4. J. M. Cioffi, class notes for EE 379A *Digital Communication: Signal Processing.* Available online at: http://www.stanford.edu/group/cioffi/ee379a/
5. Cho, Yong Soo, et al., *MIMO-OFDM wireless communications with MATLAB*. John Wiley & Sons, 2010.
6. David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Rob Barton and Jerome Henry, *IoT Fundamentals: Networking Technologies, Protocols and Use Cases for Internet of Things*, Cisco Press, 2017
7. Arshdeep Bahga, Vijay Madisetti, *Internet of Things – A hands-on approach*, Universities Press, 2015
8. Rajkamal, *Internet of Things: Architecture, Design Principles and Applications*, McGraw Hill HigherEducation
9. Olivier Hersent, David Boswarthick, Omar Elloumi, *The Internet of Things – Key applications and Protocols*, Wiley, 2012