



## Telecommunications Systems Management

TELE 6510: Fundamentals of IoT (Internet of Things)

Fall 2023 Saturdays, 1:30 PM - 5:00 PM

Snell Library 005

Instructor: Rolando Herrero, PhD (e-mail: r.herrero@northeastern.edu)

**This syllabus is subject to change based on the needs of the class.**

**Course Description:** Explores the foundations and technologies involved in Internet of Things (IoT) from an industry perspective. Topics include Machine to Machine (M2M) communication and Wireless Sensor Networks (WSNs) and their relationship with IoT as well as their evolution. This involves all three main elements: (1) devices, (2) communications/networks and (3) analytics/applications. Specifically, it introduces technologies and interfaces associated with embedded devices and presents the fundamentals of IoT analytics including machine learning and rule-based AI. The bulk of the content presented in the class is focused on the industry led standardization of IoT networking mechanisms. In this context, it examines fundamental components of the IoT architecture and presents a large array of real life applications and case studies. Focuses on different LPWAN and WPAN wireless technologies that are relevant to meet requirements of IoT including WiFi, Bluetooth Low Energy, IEEE 802.15.4, ITU G.9903, ITU G.9959, LoRa and LTE-M/NB-IoT among others. Explores 6Lo adaptation mechanisms like 6LoWPAN. Discusses the most common IoT application technologies with special emphasis on MQTT, CoAP and AMQP. Introduces routing mechanisms like RPL and resource identification protocols like mDNS, SD-DNS and UPnP. Also explores special issues that affect IoT networks including security and privacy considerations as well as reliability mechanisms intended to overcome network impairments. It also presents new trends like the use of blockchain technologies to enable transactive IoT applications.

**Prerequisite(s):** None

**Credit Hours:** 4

**Text(s):** *No Required Text*

**Recommended Text(s):**

1. ***Fundamentals of IoT Communication Technologies***, Herrero, 1<sup>th</sup> Edition, Springer-Nature; 2021
2. ***From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence***, Holler et al, 1<sup>th</sup> Edition, Academic Press; 2014
3. ***Internet of Things: A Hands-On Approach***, Bahga, Madisetti, 1<sup>th</sup> Edition, VPT; 2014
4. ***Internet of Things***, Buyya, Dastjerdi, 1<sup>th</sup> Edition, Morgan Kaufmann Pub; 2016
5. ***Designing the Internet of Things***, McEwen, Cassimally, 1<sup>th</sup> Edition, Wiley; 2014
6. ***Learning Internet of Things***, Waher, 1<sup>st</sup> Edition, Packt Publishing; 2015

7. “*Rethinking the Internet of Things: A Scalable Approach to Connecting Everything*”, daCosta, 1<sup>th</sup> Edition, APress; 2014
8. “*Computer Networking*”, Kurose, Ross, 8<sup>th</sup> Edition, Pearson; 2019
9. “*Wireless Networking Technology*”, Rackley, Steve, 1<sup>th</sup> Edition, Newnes; 2007
10. “*6LoWPAN*”, Shelby, Zash, 1<sup>th</sup> Edition, Wiley; 2010
11. “*Wireless Sensor Networks*”, Sohraby, Kakeem, 1<sup>th</sup> Edition, Wiley; 2010

## Course Objectives:

At the completion of this course, students will be able to:

1. Understand the different components involved in IoT architectures.
2. Know the most common IoT protocols and standards.
3. Be familiar with state-of-the-art technologies associated with IoT like machine learning and blockchain.

## Grade Distribution:

|              |     |
|--------------|-----|
| Midterm Exam | 30% |
| Final Exam   | 30% |
| Quizzes      | 15% |
| Assignments  | 15% |
| Project      | 10% |

## Course Policies:

- **General**

- Exams are closed book, closed notes.
- **No makeup exams will be given.**

- **Assignments**

- Students are expected to work independently. **Offering and accepting** solutions from others is an act of **plagiarism**, which is a serious offense and **all involved parties will be penalized according to the Academic Integrity and Plagiarism Policies**. A student who is found cheating in any exam or test **will receive an automatic F for this course**. Discussion among students is encouraged, but when in doubt, direct your questions to the professor.
- **No late assignments will be accepted under any circumstances.**

## Academic Integrity:

A commitment to the principles of academic integrity is essential to the mission of Northeastern University. The promotion of independent and original scholarship ensures that students derive the most from their educational experience and their pursuit of knowledge. Academic dishonesty violates the most fundamental values of an intellectual community and undermines the achievements of the entire University.

As members of the academic community, students must become familiar with their rights and responsibilities. In each course, they are responsible for knowing the requirements and restrictions regarding research and writing, examinations of whatever kind, collaborative work, the use of study aids, the appropriateness of assistance, and other issues. Students are responsible for learning the conventions of documentation and acknowledgment of sources in their fields. Northeastern University expects students to complete all examinations, tests, papers, creative projects, and assignments of any kind according to the highest ethical standards, as set forth either explicitly or implicitly in this Code or by the direction of instructors. Go to <http://www.northeastern.edu/osccr/academic-integrity-policy> to access the full academic integrity policy.

### **Student Accommodations:**

Northeastern University and the *Disability Resource Center* (DRC) are committed to providing disability services that enable students who qualify under Section 504 of the Rehabilitation Act and the *Americans with Disabilities Act Amendments Act* (ADAAA) to participate fully in the activities of the university. To receive accommodations through the DRC, students must provide appropriate documentation that demonstrates a current substantially limiting disability. For more information, visit <http://www.northeastern.edu/drc/getting-started-with-the-drc>.

### **Diversity and Inclusion:**

Northeastern University is committed to equal opportunity, affirmative action, diversity and social justice while building a climate of inclusion on and beyond campus. In the classroom, members of the University community work to cultivate an inclusive environment that denounces discrimination through innovation, collaboration and an awareness of global perspectives on social justice. It is my intention that students from all backgrounds and perspectives will be well served by this course, and that the diversity that students bring to this class will be viewed as an asset. I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, socioeconomic background, family education level, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class. Your suggestions are encouraged and appreciated.

Please visit <http://www.northeastern.edu/oidi> for complete information on Diversity and Inclusion.

### **TITLE IX:**

Title IX of the Education Amendments of 1972 protects individuals from sex or gender-based discrimination, including discrimination based on gender-identity, in educational programs and activities that receive federal financial assistance. Northeastern's Title IX Policy prohibits Prohibited Offenses, which are defined as sexual harassment, sexual assault, relationship or domestic violence, and stalking. The Title IX Policy applies to the entire community, including male, female, transgender students, faculty and staff. In case of an emergency, please call 911. Please visit [www.northeastern.edu/titleix](http://www.northeastern.edu/titleix) for a complete list of reporting options and resources both on-

and off-campus

**Tentative Course Outline:** The weekly coverage might change as it depends on the progress of the class.

| Week           | Content   |
|----------------|---|
| Week 1 (9/9)   | <ul style="list-style-type: none"> <li>• IoT Preview [1][2]:               <ul style="list-style-type: none"> <li>– M2M and the evolution of IoT</li> <li>– Components and use case examples</li> <li>– Functional Layers of IoT</li> <li>– The Data → Information → Knowledge Transformation</li> </ul> </li> </ul>  |
| Week 2 (9/16)  | <ul style="list-style-type: none"> <li>• Overview of Data Network Concepts [8]:               <ul style="list-style-type: none"> <li>– Computer Networking Concepts (Internet, ISPs, Delay, Loss)</li> <li>– Session/App Layer: HTTP, HTTPS</li> </ul> </li> </ul>  |
| Week 3 (9/23)  | <ul style="list-style-type: none"> <li>• Overview of Data Network Concepts [8]:               <ul style="list-style-type: none"> <li>– Transport UDP/TCP</li> <li>– IPv4/IPv6/NAT</li> <li>– Basics of Routing</li> <li>– Security: Encryption/Authentication/Integrity, Intro to Blockchains</li> </ul> </li> </ul>  |
| Week 4 (9/30)  | <ul style="list-style-type: none"> <li>• Device Side of IoT [1][2]:               <ul style="list-style-type: none"> <li>– Devices and Gateways. Architectures. Interfaces</li> <li>– IoT Data Management. Purpose and Considerations</li> <li>– Sensors and Actuators</li> <li>– Accelerometers. Position and Velocity. Rotation. Leds. Motor Control</li> </ul> </li> </ul> |
| Week 5 (10/7)  | <ul style="list-style-type: none"> <li>• Application Side of IoT [1][2]:               <ul style="list-style-type: none"> <li>– Everything as a service (XaaS)</li> <li>– IoT Analytics</li> <li>– Intro to Machine Learning</li> <li>– State of Art: ETSI, ITU and IETF standardization efforts</li> <li>– Architecture Reference Model</li> </ul> </li> </ul>               |
| Week 6 (10/14) | <ul style="list-style-type: none"> <li>• Wireless Technologies for IoT [1][2][9][12]:               <ul style="list-style-type: none"> <li>– IEEE 802.11 and IoT (IEEE 802.11p, IEEE 802.11ah and IEEE 802.11ba)</li> <li>– IEEE 802.15.4</li> <li>– BLE and IoT (Bluetooth 5.2)</li> </ul> </li> </ul>   |
| Week 7 (10/20) | <ul style="list-style-type: none"> <li>• 6LoWPAN [9]:               <ul style="list-style-type: none"> <li>– IPv6 to 6LoWPAN</li> <li>– Header Compression</li> <li>– Mesh Routing</li> <li>– Fragmentation</li> </ul> </li> </ul>  |

| Week            | Content   |
|-----------------|---|
| Week 8 (10/27)  | <ul style="list-style-type: none"> <li>• Application Technologies for IoT [1][2][6][12]:               <ul style="list-style-type: none"> <li>– WoT. REST Architectures.</li> <li>– EDA Architectures.</li> <li>– HTTP</li> <li>– MQTT</li> </ul> </li> </ul>   |
| Week 9 (11/2)   | <ul style="list-style-type: none"> <li>• Pre-midterm Exam Review</li> <li>• Pre-midterm Assessment Quiz (Not for Grade)</li> <li>• Wireless Sensor Networks [1][11]:               <ul style="list-style-type: none"> <li>– Applications</li> <li>– Scalability and adaptability</li> <li>– Power Considerations</li> <li>– Communication Patterns. Routing</li> </ul> </li> </ul>  |
| Week 10 (11/10) | <ul style="list-style-type: none"> <li>• Catch UP!</li> </ul>   |
| Week 11 (11/17) | <ul style="list-style-type: none"> <li>• Midterm Exam (classes 1 to 8)</li> </ul>   |
| Week 12 (11/24) | <ul style="list-style-type: none"> <li>• NO CLASS (Thanksgiving/Fall Break Recess)</li> </ul>   |
| Week 13 (12/1)  | <ul style="list-style-type: none"> <li>• Wireless Sensor Networks [1][11]:               <ul style="list-style-type: none"> <li>– Routing: Flooding, Gossiping, SPIN, LEACH, PEGASIS, Directed Diffusion</li> </ul> </li> <li>• RPL [RFC6550][11]:               <ul style="list-style-type: none"> <li>– DODAG creation</li> <li>– Storing/Non-storing modes</li> </ul> </li> </ul>  |
| Week 14 (12/8)  | <ul style="list-style-type: none"> <li>• Identification Mechanisms; mDNS [1][RFC6762][12]:               <ul style="list-style-type: none"> <li>– Querying/Responses</li> <li>– Negative Responses</li> <li>– Answer/Question Suppression</li> </ul> </li> <li>• Identification Mechanisms; SD-DNS [1][RFC6763][12]               <ul style="list-style-type: none"> <li>– Service/Instance Names</li> <li>– Records</li> </ul> </li> </ul> |