300475 - NETSCI - Network Science

Coordinating unit: 300 - EETAC - Castelldefels School of Telecommunications and Aerospace Engineering
Teaching unit: 744 - ENTEL - Department of Network Engineering
Academic year: 2019
Degree: MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019).
(Teaching unit Optional)
ECTS credits: 5
Teaching languages: English

Teaching staff
Coordinator: Sallent Ribes, Sebastià

Opening hours
Timetable: Monday between noon and 2 P.M.

Prior skills
Be graduated in engineering or sciences having completed the corresponding credits

Requirements
There are non requirements

Teaching methodology
The methodology is essentially based on learning by doing, developing a project based on master classes, exercises and group project development.

The units consist essentially of presentations made by the teacher (encouraging the active participation of students), but also it ask for students to work certain parts of the course on their own (self-learning) from materials provided by the teacher (slides, documents on use cases / products, book chapters, etc.).

The theoretical concepts are reinforced with exercises, which in many cases will be the tools to find the solution of the use cases, which allows a self-assessment of the learning achieved in each unit and activity.

The practical sessions and the project (use cases) are carried out in groups and use simulation tools and planning software.

Learning objectives of the subject
Provide a set of tools to analyze, model and design large-scale networks, services and complex IT systems governed by dynamic, deterministic or random processes managed in concentrated or distributed mode
# Content

## Unit 1. Lecture 1, 2. Title: Introduction to large-scale dynamic systems (1 week)

**Learning time:** 7h  
Theory classes: 3h  
Laboratory classes: 1h  
Self study: 3h

### Description:
- Introduction to large-scale dynamic systems  
- Taxonomy, classification  
- Complex systems. Dynamical systems. Models  
- Graph theory and networks. Taxonomy, classification

### Related activities:
- Definition of the course project composed of three uses cases  
- Graph exercises  
- Complex systems: classification and tools  
- Analysis and simulation tools. Set-up

## Unit 2. Lecture 3, 4, 5. Title: Complex systems (1,5 weeks)

**Learning time:** 17h  
Theory classes: 4h 30m  
Laboratory classes: 1h 30m  
Self study: 11h

### Description:
- Complex systems introduction  
- Dynamical systems. Definitions and classification  
- Logistic function  
- Predator-Prey system  
- Chaotic systems  
- The logistic Map  
- Dynamical systems with time delays. Hutchinson’s time-delay model

### Related activities:
Use Case 1:  
- Facilities sharing and network competition. A predator-prey system approach
<table>
<thead>
<tr>
<th><strong>Unit 3. Lecture 6, 7, 8. Title: Network models (1.5 weeks)</strong></th>
<th><strong>Learning time:</strong> 17h</th>
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<tbody>
<tr>
<td><strong>Description:</strong></td>
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<tr>
<td>• Large-scale and robustness</td>
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<td>• Small-world networks</td>
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<td>• Watts-Strogatz and Newman-Watts models</td>
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<td>• Phase transition</td>
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<td>• Scale-free networks</td>
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<td>• Power law distribution</td>
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<td><strong>Specific objectives:</strong></td>
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<td>Use Case 2:</td>
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<td>• Analysis of an Internet Service Provider</td>
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<th><strong>Unit 4. Lecture 9, 10, 11. Title: Growing networks models (1.5 weeks)</strong></th>
<th><strong>Learning time:</strong> 17h</th>
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<td><strong>Description:</strong></td>
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<tr>
<td>• Models of network formation</td>
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<td>• Price’s model</td>
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<td>• Uniform attachment model</td>
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<td>• Preferential attachment. Barabási-Albert model</td>
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<td>• Non-linear preferential attachment</td>
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<td>• Fitness model</td>
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<td><strong>Specific objectives:</strong></td>
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<td>Use Case 3:</td>
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<td>• Modelling temporal evolution of network and services provider: Formation, growth and evolution.</td>
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### Unit 5. Lecture 12. Title: Competitive and cooperative systems (1 week)

**Learning time:** 12h  
Theory classes: 1h 30m  
Laboratory classes: 0h 30m  
Self study: 10h

**Description:**  
- Game Theory. Inverse Game Theory  
- Static (finite and continuous) games  
- Finite Games. Decisions. Utility maximization  
- Dominant strategies. Cooperative outcomes: Prisoner’s dilemma.  
- Nash equilibrium: pure and mixed strategies  
- Dynamic games. Cournot competition  

**Related activities:**  
Use Case 3 (cont.):  
- Profit maximization. Internet service provider

### Unit 6. Lecture 13, 14. Title: Game Theory for resource sharing: Auctions (2 weeks)

**Learning time:** 17h  
Theory classes: 3h  
Laboratory classes: 2h  
Self study: 12h

**Description:**  
- Utility functions. Fairness. Proportional fairness  
- Ascending and descending price auction.  
- Auctions as a game. Single-item and multiple-item auction  
- Vickrey auction  
- Vickrey-Clarke-Groves (VCG) mechanism  
- Examples: Search ads and sell ad spaces (Google, eBay)

**Related activities:**  
Use Case 4  
- Spectrum auction
Unit 7. Lectures 15, 16 Title: Viralization: viral mechanisms in networks and services (2 weeks)

Description:
- Viral effects. Population base models and topology dependent influence models
- Information cascades. Tipping
- Synchronization
- Examples YouTube, Facebook and Twitter

Related activities:
Use Case 4 (cont)
- Spectrum auction

Learning time: 17h
- Theory classes: 3h
- Laboratory classes: 2h
- Self study: 12h

Unit 8. Lectures 17, 18. Title: Network utility maximization (NUM) (2 weeks)

Description:
- Network utility. Congestion Control
- Distributed model. Delay inference (RTT). Feedback delay and stability
- Dual congestion control algorithm
- TCP Feedback control loop model
- Reverse engineering
- Example: Power control for wireless

Related activities:
Use Case 5
- TCP Reno and TCP Vegas evaluation

Learning time: 15h
- Theory classes: 3h
- Laboratory classes: 2h
- Self study: 10h

Qualification system
- Class participation: 10%
- Uses cases and final presentation project: 40%
- Midterm exam: 20%
- Quizzes: 10%
- Final exam: 20%
Bibliography

Basic:


Complementary:
