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

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 7h</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Introduction to large-scale dynamic systems</td>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td>- Taxonomy, classification</td>
<td>Laboratory classes: 1h</td>
</tr>
<tr>
<td>- Complex systems. Dynamical systems. Models</td>
<td>Self study: 3h</td>
</tr>
<tr>
<td>- Graph theory and networks. Taxonomy, classification</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Related activities:</th>
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<tbody>
<tr>
<td>- Definition of the course project composed of three uses cases</td>
<td></td>
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<tr>
<td>- Graph exercises</td>
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<tr>
<td>- Complex systems: classification and tools</td>
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<tr>
<td>- Analysis and simulation tools. Set-up</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 17h</th>
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</thead>
<tbody>
<tr>
<td>- Complex systems introduction</td>
<td>Theory classes: 4h 30m</td>
</tr>
<tr>
<td>- Dynamical systems. Definitions and classification</td>
<td>Laboratory classes: 1h 30m</td>
</tr>
<tr>
<td>- Logistic function</td>
<td>Self study: 11h</td>
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<td>- Predator-Prey system</td>
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<td>- Chaotic systems</td>
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<td>- The logistic Map</td>
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<tr>
<td>- Dynamical systems with time delays. Hutchinson’s time-delay model</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Related activities:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Use Case 1:</td>
<td></td>
</tr>
<tr>
<td>- Facilities sharing and network competition. A predator-prey system approach</td>
<td></td>
</tr>
</tbody>
</table>
### Unit 3. Lecture 6, 7, 8. Title: Network models (1.5 weeks)

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

**Description:**  
- Large-scale and robustness  
- Small-world networks  
- Watts-Strogatz and Newman-Watts models  
- Phase transition  
- Scale-free networks  
- Power law distribution

**Specific objectives:**  
Use Case 2:  
- Analysis of an Internet Service Provider

### Unit 4. Lecture 9, 10, 11. Title: Growing networks models (1.5 weeks)

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

**Description:**  
- Models of network formation  
- Price’s model  
- Uniform attachment model  
- Preferential attachment. Barabási-Albert model  
- Non-linear preferential attachment  
- Fitness model

**Specific objectives:**  
Use Case 3:  
- Modelling temporal evolution of network and services provider: Formation, growth and evolution.
### Unit 5. Lecture 12. Title: Competitive and cooperative systems  (1 week)

**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

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

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

**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

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

Basic:

Complementary: