Module Code	**EEU45C09 / EEP55C09**
Module Name	Self Organising Technological Networks
ECTS Weighting[1]	**5 ECTS**
Semester taught	Semester 1
Module Coordinator/s	Prof. Nicola Marchetti Prof. Harun Siljak
Module Learning Outcomes with reference to the Graduate Attributes and how they are developed in discipline	On completion of this module the student will be able to: 1. Understand the limitations and applicability of self-organising systems' principles, in particular with respect to communication and other technological networks. 2. Model communication and other technological networks using information theory, network science, dynamical systems theory, and game theory. 3. Identify and describe the performance of self-organising networks and components by using agent-based modelling techniques. 4. Conduct simulations to analyse and interpret data, and draw valid conclusions on relevant self-organising network engineering problems. 5. Show an understanding of the potential impacts on the environment of sustainability-aware analysis and design in the context of self-organising technological networks. 6. Demonstrate knowledge and understanding of the social implications of self-organising technological networks. 7. Working in diverse and inclusive project teams, demonstrating knowledge and understanding of group dynamics and related leadership aspects. 8. Present the relevant technical aspects in a written form, showing the ability to synthesise one's own work and that of others in traditional and digital media. **Graduate Attributes: levels of attainment** To act responsibly - Enhanced To think independently - Enhanced To develop continuously - Enhanced To communicate effectively - Enhanced

[1] TEP Glossary

Module Content	Large networks are a dominant mode of organisation in the world we live in. In this module, we use the modern telecommunications systems as the main teaching paradigm, and proceed to unveil common patterns that extend further into other networked systems in technology and its application to science and society. Modern communications research is tending towards a dynamical description of networks; examples include 5G networks, Internet of Things (IoT), drone-based systems, and Industry 4.0. These dynamics, which include movement, growth, competition and adaptation, add complexity to the networks. All of this drives the requirement for self-organising functionality within the network transmitters and receivers as central planning becomes increasingly infeasible. The module introduces the students to the emerging scientific field of self-organisation. In particular, this module discusses the emergent properties of self-organising and highly dynamic networks, offering new insights that can be used in their design and deployment. The module will focus on different aspects of relevance to self-organising systems, including: local behaviour & global properties paradigm, implicit system coordination, self-synchronisation in nature and engineering systems, and adaptivity to changes. Information theoretical aspects of complex systems will be considered, in terms of specific quantities that characterize to what degree and in what sense a system can be defined as complex, and the relation to other aspects such as regularity and randomness in network abstractions. The module will also cover computing aspects, such as cellular automata, agent-based modelling and bio-inspired algorithms, using such approaches and related software tools to model and study modern communication networks such as 5G networks, Internet of Things, unmanned vehicle-based systems, Industry 4.0. In their own project work in the module, students divided in small groups will apply these concepts to other domains of science and engineering, such as traffic management of future cities, molecular communications, and hypothesis testing in social sciences. The module will then introduce students to network science aspects such as the classification of networks into random, small world, scale free, and regular, and how this relates to the analysis and design of modern communication networks. The time evolution of complex networks, encompassing dynamical systems, chaos theory and fractal geometry aspects, will then be studied. The module will finally discuss how game theory can be applied to model self-organisation in a communication network. Fundamental concepts in cooperative and non-cooperative game theory will be introduced, illustrating how they can be applied to model resource management in current and future networks.

	Module syllabus: 1. Introduction to self-organising systems; local behaviour & global properties paradigm, implicit system coordination, self-synchronisation in nature and engineering systems, adaptivity to changes. 2. Information theoretical aspects; measures of entropy and complexity, and application to e.g. self-organizing cellular and IoT networks. 3. Computing aspects; cellular automata and agent-based modelling for e.g. 5G - and beyond - moving networks (including drone-based networks) and IoT (e.g., traffic lights control, industry 4.0). 4. Network primers (mini projects): e.g., molecular communication, population dynamics, uncrewed aerial vehicles. 5. Application of bio-inspired algorithms to communication networks (e.g., genetic algorithms, simulated annealing). 6. Network science aspects; small world and scale free networks and application to e.g. 5G and beyond networks, IoT and social networks. 7. Dynamical systems, chaos theory and fractal geometry aspects; application to e.g. telecom traffic modelling, circuit and antenna design. 8. Modelling of wireless communications and networking problems using game theory.
Teaching and Learning Methods	The module is taught using a combination of lectures and tutorials. Every week one lecture is allocated to tutorials. Three software-based lab sessions will demonstrate some of the concepts covered in class and give students the basic tools for their mini projects which are to be done in groups (4 weeks for each project). Part of the lectures will take the form of flipped classroom.

Assessment Details[2]
Please include the following:

- **Assessment Component**
- **Assessment description**
- **Learning Outcome(s) addressed**
- **% of total**
- **Assessment due date**

Assessment Component	Assessment Description	LO Addressed	% of total	Week due
Group Projects	3 reports on mini-projects	LO3, LO4, LO5, LO6, LO7, LO8	40%	4, 8, 12
In class quiz	50 minutes written examination	LO1, LO2, LO3, LO8	20%	5
In class quiz	50 minutes written examination	LO1, LO2, LO8	20%	11
Pre class activities	Weekly activity on BlackBoard	LO1, LO5, LO6, LO8	10%	Every week

[2] TEP Guidelines on Workload and Assessment

	Lab project	Written report based on three 2 hours lab sessions	LO3, LO4, LO7, LO8	10%	2-6-10

Reassessment Requirements	Failure is defined as a module grade of less than 40% for year 4 (or 50% for year 5). Students who fail to achieve a minimum of 40% for year 4 overall (or 50% for year 5) may resubmit a comprehensive supplemental assignment covering aspects of the module.
Contact Hours and Indicative Student Workload[2]	**Contact hours:** 52 **Independent Study (preparation for course and review of materials):** 61 **Independent Study (preparation for assessment, incl. completion of assessment):** 12
Recommended Reading List	• *Elements of Information Theory, 2nd edition, T.M. Cover & J.A. Thomas, Wiley, 2006.* • *Agent-based modeling for archaeology: Simulating the complexity of societies*, I. Romanowska, C.D. Wren, S.A. Crabtree, SFI Press, 2021. • *Networks – An Introduction*, M.E.J. Newman, Oxford University Press, 2010. • *Game Theory for Wireless Engineers*, A. MacKenzie, L. DaSilva, Morgan & Claypool Publishers, 2006.
Module Pre-requisite	Mathematics (JS), Physics, Signal Processing (preferably JS), Basic knowledge of Linear Algebra, Probability and Statistics.
Module Co-requisite	n/a
Module Website	Material available on BlackBoard
Are other Schools/Departments involved in the delivery of this module? If yes, please provide details.	No
Module Approval Date	
Approved by	
Academic Start Year	September 2023
Academic Year of Date	2023/2024