D10.3: Description of Internet Science Curriculum

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1. Introduction

This document presents a proposition for a reference Internet Science curriculum that can be adapted and implemented jointly or in collaboration, by different Universities.

The construction of the curriculum represents a challenge and an opportunity for the NoE, as it represents the essence of Internet Science. What are the main aspects to be taught? What is the kernel? These questions are answered by the curriculum.

The curriculum is a reference document and a guideline for the different universities wishing to implement it. It has to allow for adaptation to the heterogeneous national and institutional contexts. Nonetheless, our goal is to have the curriculum provide a definitive basis for a universally-recognised degree, considering the related constraints in order to ensure compatibility. In this way, the curriculum presented here is the root of a range of curricula; it may lead to a degree within an existing Departmental course, an autonomous and dedicated degree or a component of new joint degrees.

This document presents the process that leads to the construction of the curriculum, followed by the main goal, the scientific content and issues related to possible implementation.

The version presented here is a preliminary version. This is due to several reasons; most noticeable being that the choice of the implementation schema is currently under study (deliverable due for end of 2014) and its input might influence the form or content of the curriculum. On the other hand, we will start collecting feedback, which will might as well trigger changes.

The curricula in its current form it's been subject to a communication at WebSci Education Workshop, held in con-junction with the Web Science 2014 Conference, in Bloomington, Indiana, June 2014. We had positive feedback during the conference from the web-science community. The 6 theme balanced structure was particularly appreciated.

2. Process

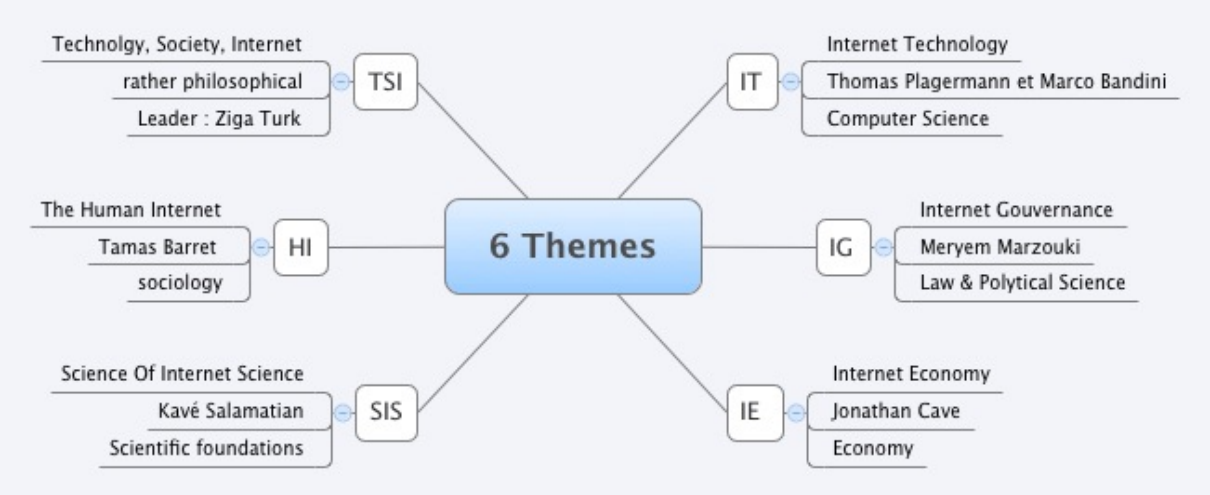
The NoE involves more than 35 partners in Europe, so it came as obvious that the Curricula construction will be made by a committee delegated by the different partners. A call for interest has been made, to which several persons responded. Fortunately the committee was interdisciplinary and covered all the internet science areas. The final composition of the committee is the following:

Name	Main areas of expertise	Affiliation
Thomas Plagemann	Computer Science	University of Oslo
Žiga Turk	information technology	Univ. of Ljubljana
Meryem Marzouki	internet governance	UPMC
Panayotis Antoniadis	interdisciplinary researches	ETH Zurich
Jonathan Cave	Economics, game theory	University of Warwick
Tamas David - Barrett	social science, economics	Oxford
Marco Prandini	computer science	Unibo
Huang Nguyen	computer science	EPFL
Kavé Salamatian	computer science	UoS
Sorana Cimpan	computer science, pedagogy	UoS

The committee had one constructive face-to-face meeting, which was preceded by 2 preparation on-line meetings. Individual production as well was several on-line coordination meetings followed.

3. The curriculum content

The curriculum is structured around 6 main themes, or knowledge areas (cf. figure below). The different courses are equally distributed among these 6 areas, which are meant to have the same importance.



The curriculum is conceived for 2 years of study, and thus 120 ECTS.

The two years will be organised by half-yearly semesters: S1, S2 and S3 will be devoted to courses and S4 is reserved for preparing a master's thesis.

Given that the 6 knowledge areas have equivalent importance, the starting point is to allocate to each area the equivalent of 5 ECTS for each of the 3 coursework semesters. That makes a total of 15 ECTS of courses to be provided for each theme. Nevertheless, in order to facilitate implementation and exchange we encourage courses corresponding to 3 or 6 ECTS. There will be thus 5 (components of) modules of 3 ECTS to be proposed in 3 different semesters.

The individual themes will be presented hereafter. It will be noted that, in keeping with the essential interdisciplinarity of Internet Science, many topics are treated in more than one theme. Faculty should co-ordinate in developing these topics; for the most important ones (e.g. privacy or net neutrality) consideration should be given to guest or joint lectures, multidisciplinary debates and interdisciplinary theses that either analyse the topics from a cross-thematic perspective or focus on 'translational' research from one theme to another. For such theses, advisors with multiple thematic backgrounds should be involved, and supervisions conducted with hybrid groups of students.

1.1. KA1 : TSI- Technology, Society and Internet

Leader, main contributor: Žiga Turk

Overall description: This module investigates the relation between technology and society from a rather philosophical perspective.

TSI1 – Technology, Society and Internet : Historical perspective and interplay	***6 ECTS***	
TSI4– Technology and politics	***3 ECTS***	
TSI3 – Individual research		***6 ECTS***

TSI1 – Technology, Society and Internet: historical perspective and interplay

- *Historical perspective*
  - History form a technological perspective
  - Communication revolutions
  - From narratives to theory: Structure of scientific revolutions
- *Theories related to interplay between technology and society*
  - Philosophy of science and technology
  - Organisational theory
  - Institutional theory
- *Human society and the Internet*
  - Impact on individuals
  - Impact on lightly regulated institutions
  - Impact on heavily regulated institutions

TSI2 – Technology, policies and politics

- Values in society
- Ethical dimensions of technology
- Moral foundations theory
- Political economy of technology in general
- Political economy of the internet
- Internet policies
- Designing technology for positive societal impact
- Designing policies for positive technological impact

TSI 3- Individual research

- Scientific method
- Interpretive inquiry and rational analysis as scientific methods
- Scientific communication

1.2. KA2: IG- Internet Governance

Leader: Meryem Marzouki, UPMC

Overall description:

Internet technical governance cannot anymore be dissociated from its political governing and the regulation of the network usages. Internet governance deals with institutions, regimes, policies, human actors and technical artefacts governing the Internet infrastructure, its applications and services, as well as content and activities deployed via the network.

The aim of this course is to acquire the fundamentals and the analytical and methodological keys related to technical, economical, legal, ethical and political stakes in the governance of the Internet and of its usages, as well as to the wide range of involved public and private interests. The National, European and Global contexts will be introduced and analysed.

The objective is to understand how the Internet is governed, who sets its norms, rules and protocols, how and for which objectives, and how its technical, legal, political, economical and social norms are implemented, articulated and enforced.

	Core 1	Core 2	Elective
IG1 - Internet Governance definition and ecosystem components	***6 ECTS***		
IG2 - Internet Governance: issues and processes	***3 ECTS***		
IG3 - Internet Governance Issues in detail		***6 ECTS***	
IG4 - Internet Governance Individual Research			***3 ECTS***

IG1 - Internet Governance: definition and ecosystem components

• Introduction – Main Internet stakes – Impact on human rights, democracy, rule of law, and sovereignty

• Internet Regimes, domains and mechanisms

• Sources and actors of Internet governance (States, IOs, Private sector, NGOs and Civil Society, Technical Fora…)

• WSIS, IGF, and other networked governance fora

IG2 - Internet Governance: issues and processes

• Infrastructure and critical resources: issues, management modes and stakes: generic, geographic and sponsored top level domains, internationalisation, DNS, backbone infrastructure, ICANN and registries, Tariffication and competition…

• Privacy, Personal data protection, security and cybersecurity

• Access to information, transparency and open governance

• Intellectual property: concepts, issues and controversies (author rights, copyright, trademarks, patents…)

• Net neutrality: issues and controversies. Censorship and technical neutrality in practice (DPI, DNS blocking, BGP, tunnelling…) ; Traffic management and Net neutrality : good and bad practices, gateways regulation

• Cloud computing, web2.0 and social networks: specificities with regards to the issues introduced in previous courses

IG3 - Internet Governance: issues in detail

• Internet content regulation

• Technical intermediaries liability : role of various gatekeepers

• Technical intermediaries liability and internet content regulation : French, European and Global legislation ; Towards a privatised governance ?

• Privacy and personal data protection and commercial use : economics of personal data, behavioural advertising

• Privacy and personal data protection and security policies : police databases, biometric ID, data retention, communication surveillance

• Intellectual property : French, European and Global legislation (DADVSI, HADOPI, SOPA, PIPA, ACTA, etc.)

• Economics of Intellectual property and alternative models (FLOSS, legal license/global license, creative commons…)

• Net neutrality : legislation and regulation in France, Europe and other parts of the world

IG4 - Internet Governance Individual Research

• Case studies related to previous topics: students make presentations of their own researches on these cases or present and discuss academic publications.

1.3. KA3: IT- Internet Technology

Leader, main contributor: Marco Prandini, Thomas Plagemann

Overall description:

"The Internet and computer networks are now ubiquitous and a growing number of computing activities strongly depend on the correct operation of the underlying network. Networks, both fixed and mobile, are a key part of the computing environment of today and tomorrow. Many computing applications that are used today would not be possible without networks. This dependency on the underlying network is likely to increase in the future. The high-level learning objective of this module can be summarised as follows:

- Thinking in a networked world. The world is more and more interconnected and the use of networks will continue to increase. Students must understand how the networks behave and the key principles behind the organisation and operation of the networks.
- Continued study. The networking domain is rapidly evolving and a first networking course should be a starting point to other more advanced courses on network design, network management, sensor networks, etc.
- Principles and practice interact. Networking is real and many of the design choices that involve networks also depend on practical constraints. Students should be exposed to these practical constraints by experimenting with networking, using tools, and writing networked software."

[ACM Computer Science Curriculum 2013]

	Core 1	Core 2	Elective
IT1 - Operating systems and network programming	***3 ECTS (IT1.1)***		
IT2 - Network technology and protocols	***3 ECTS (IT2.1)***		***3 ECTS (IT2.2)***
IT3 - Resources, services and user interfaces	***3 ECTS (IT3.1)***	***3 ECTS (IT3.2)***	***Note IT3 - Elective***
IT4 - Information Security		***3 ECTS (IT4.2)***	***Note IT4 - Elective***

IT1.1 - Operating systems and network programming

This course introduces the fundamental programming abstractions and tools for communication between processes and covers the following topics:

- Processes and threads
- Inter Process Communication (shared memory, pipes, socks, critical sections, mutex, locks)
- Network programming with the socket API
- Introduction to implement networked applications on Android

IT2.2 - Network infrastructures

- Switching models; Fragmentation; Sequence control; Congestion
- Multiple access to shared media; IEEE 802.3 (Ethernet); IEEE 802.11 (Wireless LAN); protocols and devices for the physical/data-link layers; Access through the cellular phone infrastructure;
- Static and dynamic routing; routing protocols
- Automated configuration (DHCP) and monitoring (SNMP)

IT3.1 - Resources, services and user interfaces (needs more detail?)

- the World Wide Web; address and content: URL and HTML; the HTTP protocol; browsers, servers and proxies; search engines;
- peer-to-peer networks;
- from e-mail to instant messaging to social networks;
- mobile apps;

IT3.2 - Web Platforms

- Web programming languages (e.g., HTML5, Java Script, PHP, CSS)
- Web platform constraints
- Software as a Service (SaaS)
- Web standards

IT3.3 - Mobile Platforms

- Mobile programming languages
- Challenges with mobility and wireless communication
- Location-aware applications

- Performance / power tradeoffs
- Mobile platform constraints
- Emerging technologies

Note IT3-Elective

A list of possible elective modules on the "Resources, services and user interfaces" topic is presented here; the titles are taken from the IEEE/ACM Curricula for CS (2013 edition), where detailed description for each can be found.

- CN/Interactive Visualisation
- CN/Data, Information, and Knowledge
- HCI/Foundations
- HCI/New Interactive Technologies
- IM/Information Management Concepts (maybe core 2)
- IM/Data Modeling
- IM/Information Storage and Retrieval
- IS/Fundamental Issues (maybe core 2)
- IS/Basic Knowledge Representation and Reasoning
- IS/Advanced Representation and Reasoning
- IS/Agents
- IS/Natural Language Processing
- IS/Perception and Computer Vision
- PD/Cloud Computing

IT4.1 - Security essentials

- CIA (Confidentiality, Integrity, Availability); Basic cryptography; Symmetric and asymmetric ciphers; main weaknesses; keys and their characteristics; Public Key Infrastructures;
- Authentication and authorisation, access control (mandatory vs. discretionary)
- Concepts of risk, threats, vulnerabilities, and attack vectors; Examples of malware (e.g., viruses, worms, spyware, botnets, Trojan horses or rootkits); Denial of Service (DoS) and Distributed Denial of Service (DDoS); Social engineering (e.g., phishing)

IT4.2 - Human Factors and Security

- Applied psychology and security policies
- Security economics; Regulatory environments – responsibility, liability and self-determination; Examples of computer crimes and legal redress for computer criminals; Crime prevention strategies
- Organisational vulnerabilities and threats; Issues surrounding the misuse of access and breaches in security; Security policies;
- Usability design and security
- Pretext, impersonation and fraud, e.g., phishing and spear phishing
- Identity management; Trust, privacy and deception; Social engineering, identity theft and recovery; Biometric authentication (camera, voice)
- Motivations and ramifications of cyber terrorism and criminal hacking, "cracking"; Attacker goals, capabilities, and motivations (such as underground economy, digital espionage, cyberwarfare, insider threats, hacktivism, advanced persistent threats); Effects of malware, such as viruses, worms and Trojan horses.

Note IT4-Elective

A list of possible elective modules on the "Information Security" topic is presented here; the titles are taken from the IEEE/ACM Curricula for CS (2013 edition), where detailed description for each can be found.

- IAS/Principles of Secure Design
- IAS/Defensive Programming
- IAS/Network Security
- IAS/Cryptography
- IAS/Web Security
- IAS/Platform Security
- IAS/Security Policy and Governance

1.4. KA4: HI-Human Internet

Leader, main contributor: Tamas David-Barret

Overall description: Human social behaviour is at the same time shaping the way the Internet is developing, and being altered by the increasing digitalisation of our social existence. This module will focus on both of these phenomena. First, the module introduces the different human sociality features, and compares their off-line and on-line manifestations. In particular, the module will discuss individual-level dyadic sociality as opposed to group-level structural factors. Second, the module will introduce different theoretical approaches to analysing human coordination of collective action and decision making on networks, and discuss their implications for Internet-based group behaviour. The module will also introduce a range of new and emerging applications of social coordination on the Internet, such as predictive markets, crowdsourcing, collective intelligence, collective innovation, etc. Third, the module will focus on topics addressed by the emergent disciplines of Internet sociology and the anthropology of the Internet.

	Core 1	*Core 2*	*Elective*
HI1 - Human sociality off-line vs. on-line	***3 ECTS***		
HI2 - Decision making and collective action on networks	***3 ECTS (Theory)***	***3 ECTS (application)***	***3 ECTS (application case studies)***
HI3 - Internet Sociology and Anthropology of the Internet	***3 ECTS***		***3 ECTS***
HI4 - Human behaviour on the Internet		***3 ECTS***	

HI1. Human sociality off-line vs on-line

- Dyadic relationships off-line vs on-line (friendship, kinship, romantic relationship, the meaning of an acquaintance)
- The characteristics of communities off-line vs on-line: the concept of location. Case study: a comparison between an off line cul-de-sac community and an internet community
- Constraints for evolving relationship maintenance technologies

HI2. Decision making and coordination of collective action on networks

- Evolution of society: non-human network models, and their adaptations / Non-human coordination on networks
- Coordination games on networks
- Wisdom-of- -crowds models on networks/ the foundations for crowd sourcing
- Behavioural synchrony models
- Empirics (herd behaviour, collaboration cultures on the Internet)
- Applications (predictive markets, crowds, collective intelligence, collective innovation, …)

HI3. Internet Sociology and Anthropology of the Internet

- Social network analysis (methodology, basic properties)
- Micro structure of social networks (human, non-human)
- Macro structure (stratification, inequality, xenophobia, group markers, network cleavages)
- Global social network

HI4. Human behaviour on the Internet

- Dunbar's number, multi-layered ego networks
- Traits facilitating social network formation
- Mate-choice on the Internet
- Linguistics
- Evolutionary consequences
- Internet altering the fundamental properties of human sociality? / Social network structure

1.5. KA5: IE - Internet Economics

Leader, main contributor: Jonathan Cave

Overall description: Economics serves a number of complementary roles in relation to the development of Internet Science. It provides the systems of incentives and mechanisms for action and engagement that motivate and direct the actions of many key stakeholders (people and institutions), at least at some stages of their development and in respect of some of their activities. This applies not only to individual profit-maximising or rent-seeking behaviour, but also tho the creation and use of mechanisms (e.g. auctions, artificial markets, etc.) used to address Internet technological, governance and implementation problems. Moreover, it provides a 'substrate' on which many of the impacts of the Internet itself (e.g. machine-trading, cryptocurrencies) are played out. Finally, it generates a wide range of measurable data (revenues, employment, profits, etc.) and analytic tools (e.g. econometrics) useful in understanding the structure, conduct and performance of the Internet and the socioeconomic institutions that evolve along its linkages. In order to equip students of Internet Science with a common toolkit, this theme provides a review of the basics of (especially micro) economics (IE1), emphasising those aspects of most relevance to Internet-hosted economic activity. It helps students to understand the economic importance and linkages among key Internet resources (IE2). Then the theme develops two complementary perspectives; a positive analysis (IE3) based on understanding the (not necessarily commercial) objectives, capabilities and relationships of different parties and a normative analysis (IE4) based on the concept of mechanism design – the use of novel forms of property rights (which enable market activity) and other 'games' to enable heterogeneous actors to tackle collective problems. Then, to bring these tools to the real world, the tools will be applied (in IE5) to the analysis of how organisations function individually (business models) and collectively (market organisations).

	Core 1	Core 2	Elective
IE1 - Internet Economics Basics (review)	***3 ECTS***		
IE2 - Internet Economics Resources	***3 ECTS***		
IE3 - Internet Economics Objectives	***3 ECTS***		
IE4 - Property Rights		***3 ECTS***	
IE5 - Business Models and Market Organisations		***3 ECTS***	
IE6 Project work (group)			***3 ECTS***

IE1 - Internet Economics Basics (review)

The purpose of this module is to give students common grounding in basic economic concepts, tools and results. It is anticipated that many of the students will have some familiarity with many of these elements, so there will be a high degree of modularisation, with opportunities for self-study and periodic targeted tests allowing students to assess and demonstrate their mastery of key topics. To ensure a close focus on those aspects of economics most relevant to the Internet Science perspective, the module will cover five main topics.

First we shall review the basics of microeconomics, to give students an understanding of how market players operate and how their collective actions come together to produce observed behaviour. This will consider individuals acting as consumers (maxmising utility subject to budget constraints) and as producers (maximizing profit through the use of tangible inputs in conjunction with technologies and knowledge). We will then consider the basis of exchange and production market competitive equilibrium, and the simplest forms of market linkage (the vertical relation of suppliers to demanders and the associated notions of two-sided 'platform markets' .

Of course, the purely competitive paradigm is of limited utility, especially in relation to markets with network and interoperability 'externalities' where market power tends to concentrate. To lay the basics for understanding this tendency of Internet-enhanced markets and their governance, we shall review the essentials of imperfect competition, especially. monopoly, price and quality discrimination (which play key roles in understanding e.g. net neutrality), oligopoly and oligopsony and collusive behaviour. In developing this theme, we will consider the most relevant sources of market failure in the Internet, including information asymmetry and control of key assets (e.g. IPR, networks)

As mentioned, the costs and benefits arising from the actions of individual consumers and firms in specific sectors are not limited to those sectoprs – especially not in networked environments. To understand how these linkages can distort the function of markets the third component will deal explicitly with externalities and public goods, especially network externalities.

We shall also develop some of the 'Internet-specific recent developments in economics, notably 2-sided or n-sided ('platform') markets and network goods (where the utility of consuming or producing a good or service is affected by the number of other consumers or producers with whom an entity interacts).

Finally, because the behavioural assumptions of conventional market economics, based as they are on the rational behaviour of individuals powerlessly confronting an unreacting 'system', are so remote from the realities of Internet contexts, and because different situations can give rise oto a bewildering plethora of models, we shall study the basic elements of noncooperative game theory (Nash equilibrium) and bargaining.

IE2 - Internet Economics Resources

To develop an appropriate understanding of the specifics of Internet-involved economic systems and to analyse specific economic aspects bearing on the growth and performance of the Internet, it is

necessary to study the special features and particular institutions that have grown up around particular resources (both shared and exclusive) used to produce the Internet in its full scientific sense. The specific resources to be studied include:

Electromagnetic Spectrum, in particular the property rights (spectrum licenses, shared spectrum, etc.) allocation mechanisms (auctions, administrative allocation) and charging mechanisms (e.g. licensing);

Bandwidth, which in this case refers specifically to broadband and the economics of bandwidth provision and pricing. In addition to the amount of transport and the speed with which it takes place, this will review quality of service and experience and and arrangements for termination and carriage (e.g. peering, paid peering and transit).

Another type of resource – in many ways the one that differentiates the Internet from other networked sectors, is information. While this is an enormous and complex topics, we shall get the students started in understanding the specific economics of information goods, in particular the distinct characters of data, information, knowledge and belief and attention. Finally, the students will be given the chance to study (through independent reading) other inputs and outputs including energy, as the economics of electric power is important to understanding the reliance, sustainability implications and critical vulnerabilities off the Internet, especially in conjunction with such developments as power line communications and data centre rationalisation.

IE3 - Internet Economics Objectives

Although this theme is concerned with economics, it is not limited to an analysis of monetary costs and benefits; markets may not exist to elicit and combine information about individual values and trade-offs, let alone to price activities and risks. Moreover, many of the key stakeholders may be motivated by non-pecuniary or even anti-pecuniary concerns, or may be motivated by abstract or indirect drivers such as power or moral and ethical values. Economics has long sought to work with the full range of human motivation; this component will examine how this has been accomplished and how the existing models and results can be adapted.

We begin with an examination of the fundamental modelling assumption made to build aggregatable models of directed or intentional human behaviour; consequential rationality, and the neoclassical decision framework to which it gives rise. We shall also consider the key assumptions and the consequences of weakening them.

One key assumption is selfishness – properly understood, this does not necessarily mean that individual care only about what they themselves consume or obtain, but rather that they are motivated entirely by subjective assessments of the consequences of their choices and behaviour. One extension of this concept involves different forms of altruism, which may be particularly important when creating software for (unknown) others to use, or when creating institutions that will affect the welfare (and behaviour) of people in other places now and in the future. In addition to analysing altruism, we will examine the ‘evolution of conventions’ literature, which looks at how altruistic preferences and

behaviour may evolve in networked environments and especially at the relation between network structures and the emergence of selfish or unselfish preferences.

Other 'moral preferences' have also been studied in economics, and may be particularly important when actions (e.g. of Internet standardisation or design) affect individual who are far away; those of whom the actors are aware, but whom they do not know. Such preferences may include notions of procedural fairness such as inequity aversion. Others may directly consider the individual as part of a complex network of linked individuals and linked groups. In this context, objectives relating to (Pareto) efficiency (not being able to make everyone better off) and notions of consequential as well as procedural fairness become important and will be reviewed using mainly Internet market applications from the literature.

IE4 - Property Rights

Market work on the basis of exchanges; market failures can be seen as the consequence of being unable to exchange – for example, by having no medium of exchange, or no store of value that one can use to accomplish complex trades. The solution to market failures caused by incomplete markets is to complete them; this means creating property rights, sometimes where none existed before. Examples of such artificial rights include rights to electromagnetic spectrum and to personal information. They form a continuum running from exclusive/tradable rights up to inclusive/commons. We shall examine both theoretical and empirical forms of property right for the resources covered, and the mechanisms that use them (e.g. auctions, bargaining/Shapley value, rules, regulation).

Finally, this module shall look at a particular form of property right of direct relevance to the Internet itself, bound up in the concepts of critical infrastructures and associated rights of common carriage.

IE5 - Business Models and Market Organisation

The final coursework module within this theme will discuss the 'biology' of Internet-based economic entities and structures.

One distinguishing characteristic of the Internet ecosystem (as it has become fashionable to call it) is the range and rapid dynamics of organisational structures and functions. These are generally summed up in the form of business models (how entities seek to create and capture 'value') and value propositions (how value is defined for those involved in decision making and for those whose efforts, resources, money or information they seek to obtain and use). Some business models seem to be original to Internet economic systems (e.g. cloud computing's SaaS, IaaS, etc. configurations, freemium pricing arrangements and servitisation); others are reinventions, reinvigorations or recombinant forms of prior business models. We will review the main forms (using standard classification schemes) and consider case studies of their development and competition.

The ecosystem that links these business models (or the firms that adopt them) can be considered either as a modification of an idealised market (or, more generally, auction) or as a value network (originally value chain, but the non-linearity, complexity and dynamism of Internet economic

interactions called for a more general framework). We shall review the applied economic literature on market structures, including: value chains and value networks; networked markets; and (drawing on the tools developed in IE1 and IE2), platform and facilities-based competition.

Finally, we shall survey, as a prolegomena to potential projects during the 4th semester, generalisations beyond the classical notion of the firm, especially networked and virtual enterprises and their implications for e.g. finance, labour markets and innovation.

1.6. KA6: SIS - Science of Internet Science

Leader, main contributor: Kavé Salamatian

Overall description: Internet Science is an emerging science at the confluence of several scientific domain. For this reason future Internet Scientists need a scientific basis that combines strong philosophical and epistemological underpinnings with rigorous and effective mathematical and analytic methodologies. KA6 is the place where this intersection happens and where these two bases are provided. For this reason Core 1 of Key Area 6 contains a course on scientific methodology and an interdisciplinary project that will give students the tools needed to put in perspective their basic disciplines with other disciplines and push them to develop a « lingua franca ». In addition to this KA6 is providing a set of fundamental analytic courses that are needed by all Internet Scientist from whatever background they come. Indeed based on the interest and background the student can also take some of the more advanced electives proposed.

	Core 1	Core 2	Elective
SIS1 Science Methodology: Axiology, ontology, epistemology and interdisciplinary project	***3 ECTS***		
SIS2 Statistics, Inference and modelling	***3 ECTS***		
SIS3- Information theory	***3 ECTS***		
SIS4 Complex and large scale systems		***3 ECTS***	
SIS5 Cooperation and optimisation		***3 ECTS***	
SIS6- Network Information Theory			***3 ECTS***
SIS7- Message passing techniques			***3 ECTS***
SIS8- Advanced Statistics and graph mining			***3 ECTS***
SIS9- Risk Analysis and Anti-fragile systems			***3 ECTS***

SIS1 Science Methodology: Axiology, ontology, methodology, epistemology

An introduction to the field of epistemology. Topics include the analysis of knowledge, a priori knowledge, immediate perceptual justification, foundational vs. coherence views, internalism vs. externalism, naturalised epistemology, and scepticism. Methodology: Scientific and Socratic method

The course will be the occasion of a project to confront student to interdisciplinary research by providing an interdisciplinary project topic that will force students to go beyond their basic topic of study and to interact with other disciplines in order to build a « lingua franca ». The project will build on concrete case studies like censorship and freedom of speech in Internet, Net Neutrality, cyberwar, cyber-geography, etc…

SIS2 Statistics, Inference and Modeling

This course gives the basis in statistics needed by all Internet scientists. It will focus in particular on inference methods used in data mining and behavioural analysis. It will introduce graphs as modelling tools to describe relationship and describe as case studies some graph mining and graph inference problems.

SIS3 Information Theory

The aim of this course is to introduce concepts of information theory like entropy, compression, side information, and define ultimate capacities communication networks. The course differ from a classical « information theory » course involving a full description of error correcting codes by putting more emphasis on entropic approaches in machine learning and other application areas more relevant to Internet Science.

SIS4 Complex and Large Scale Systems

This course provides fundamental basis in understanding large scale complex systems. It will in particular describe the scaling of microscopic interaction to macroscopic states through mesoscopic dynamics. For this purpose the course will build on approaches inherited from statistical physics and ultimately show some simple cases of mean-field approaches.

SIS5 Cooperation and optimisation

The course has two goals: to provide the fundamental Operational research tools in optimizing systems like Lagrangian and Hamiltonian methods, Simplex algorithms, relaxation, etc.. It will also illustrate the optimisations needed in applied problems like energy optimisation, network management, game theoretical behavioural optimisation, cooperation for information transfer, etc…

SIS6 Network Information Theory

The course will capitalise on the Information theory course in Core 1, to introduce concepts of multi-user information theory. In particular Slepian-Wolf coding as well as information geometry will be introduced to enable the extension of information theoretical methods to more complex multi-source/multi-destination scenarios.

SIS7 Message Passing Methods

Large Scale physical systems are generally robust in the sense that they can auto-configure when confronted with environmental changes in order to remain in optimal configurations. Recent years have seen the development of statistical physics approaches to the study of autonomous systems. The

course aim is to describe message passing techniques that have a large spectrum of application in network synchronisation and auto-configuration.

SIS8 Advanced Statistics and Graph Mining techniques

The course will be a follow up of the Statistics, Inference and modelling course taught in core 1. It will describe more advanced inference-like EM, MCMC and Monte Carlo approaches and present some more advanced topics on Graph mining like community detection. For this purpose it will include and build on an introduction to spectral theory of graphs.

SIS9 Risk Analysis and Anti-fragile systems

The course will begin with an introduction to random and systemic risk and will describe their importance. It will thereafter elaborate on the assessment of these two types of risks and their impact on system design and operation. The course will also develop some probabilistic tools for risk analysis like heavy-tailed distributions, large deviations, cascades and avalanche effects. The course will finally describe the Anti-fragile paradigm and illustrate it into some case studies relevant to Internet Science (like Market Stability, safety, etc…)

4. Implementation

The curriculum is intended as a reference curriculum, and different implementations can be envisaged.

Several implementation possibilities are under study, and will be presented in the deliverable D10.4.

4. Conclusions

The curriculum proposed is balanced over 6 knowledge areas. The following figure resumes the core courses in each of the theme.