A Perspective on Graduate Studies in Telecommunications at IST Lisbon

Luis M. Correia

Abstract — **This paper describes graduate studies at IST Lisbon (Technical University of Lisbon) in the area of Telecommunications. It starts by describing the Ph.D. programme, with its curricular components where students need to enrol in 5 courses. It also addressed the thesis process of this programme, which usually lasts for 4 years. Then, a degree more devoted to industry training is presented, POSTIT. One presents the structure of the degree, which lasts one academic year, split into trimesters, with a total duration of 300 lecture hours and 36 ECTS credits. Courses are grouped into three areas (Basic Training, Specialised Technologies, and Management and Telecommunications Policy). The degree is composed of 12 courses. Lectures are held on Friday afternoon and Saturday morning. The degree is targeted to students who already have training in the area and wish to update, and to those who have not but possess a set of skills that allows them to do the upgrade.**

Keywords — Graduate Studies. Telecommunications. Ph.D. Programme. Professional Training.

I. INTRODUCTION

The importance that the sector of Telecommunications and Information Technologies has today in society is well known, hence, it does not require a special presentation of itself. The current world mobile phones penetration and the momentum achieved by the continuous introduction of new technologies and services, including the Internet, are examples of the role that the sector has in social and economic terms.

The telecommunications industry is one of the most dynamic and innovative of the Portuguese economic landscape. This sector:

- contributes to about 6% (10 B €) of the GDP (Gross Domestic Product);
- represents about 20% of the stock exchange index;
- employs about 24 000 people, i.e., about 0.5% of the active population;
- invests about 1 B € per year;
- encompasses a universe of over 500 companies;
- represents about 10% of turnover among the 500 largest companies, and has 3 in 15 companies with the highest turnover (about 5 B €);
- has 4 in the list of the 10 companies with the largest advertising investment (about 0.327 B €).

Furthermore, Telecommunications is a technologically intensive industry, which relies on the constant development of new technologies and on the demand for new processes for their implementation, contributing in a decisive way to the modernisation of business. The own nature of the industry requires the formation of human resources with sophisticated skills, capable of being active agents in the innovation process, while simultaneously possessing an overview of the area, enabling an easy adaptation to new environments, as well as new career pathways.

IMS, Web 2.0, all IP NGNs, multimedia communications, and convergence of networks and services, are buzzwords that currently mark the business models of operators, equipment manufacturers, and services providers. It is in this context that one must provide a modern educational offer in graduate studies, addressing both the Ph.D. level and continuous training. The ultimate goal has to be to give students the training that they need to develop the type of solutions required by the various companies in the sector. Strong and renewed skills in the area of new generation communication and information networks are key nowadays for business. This involves new skills and knowledge, which increasingly requires a cross-cutting and multi-disciplinary perspective, with an emphasis on technological development and engineering services. Telecommunications operators are increasingly abandoning their exclusive role of "carriers of information", rather assuming also the role of services providers, not in the traditional sense of telecommunications services, but in the perspective of those with an impact on the end user. Examples are IPTV, fixed and mobile digital TV broadcast, value-added services on mobile networks, and home networking, among others. Manufacturers are also following this view, developing products and equipment that ensure / support the development of such services, and even becoming service providers as well (not to end users, but to operators).

Therefore, it is key that a modern and advanced training in Telecommunications and Information Technologies presents the required broad view, providing a range of conceptual and technological knowledge that goes from modern transmission and transport technologies to the tools required to support the development of new services. This training should include advanced basic and specialised components, and encompass, in addition to technological expertise in networks and services engineering, aspects related to management, business strategies and regulation.

In this context, IST has its graduate studies (the so-called 3rd Cycle) in Telecommunications organised in two different programmes: the Ph.D. programme, PDEEC, and an advanced training one, POSTIT. In the European context, a 3rd Cycle programme means that students are required to have a Master (M.Sc.) level on admission. The Ph.D. programme, targeted at fresh M.Sc. graduates, is a general one, in Electrical and Computer Engineering (ECE), within which a specialisation in Telecommunications is offered. The advanced training programme aims at staff working in industry, wishing to get an update on technology, in a broad perspective.

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This paper is structured into three more sections, besides this one. Section II presents the Ph.D. programme. Section III addresses POSTIT, describing the degree structure, the framework for the courses, the courses grouping into areas, among other aspects. Conclusions are presented in Section IV.

II. THE PH.D. PROGRAMME

The Ph.D. Programme in Electrical and Computer Engineering (PDEEC) [1] integrates the 3rd Cycle of higher education, according to the Bologna Agreement. It complements the basic formation of the 1st and 2nd Cycles (Bachelor, B.Sc., and Master, M.Sc.) in Electrical and Computer Engineering. The students that graduate from this programme obtain the Ph.D. degree.

Students are given a research intensive study of the fundamentals of electrical or computer engineering. Students will create and disseminate knowledge of electrical and computer systems during the course of obtaining the Doctoral degree. With the help of a faculty advisor, students define an education and research program that is consistent with their background, and is best suited to their own academic goals.

Students with a B.Sc. or an M.Sc. degrees in ECE (or equivalent/similar area) may apply to PDEEC. In general, students with a B.Sc. degree may have to take up to a maximum of 3 courses (at the M.Sc. level) to complete a bridging programme.

Completion of the Ph.D. degree usually takes about four years of study. In order to obtain the Ph.D. degree, the student must demonstrate technical breadth, steady progress in research, contribute to the body of knowledge in ECE, and disseminate this knowledge through oral and written forms. Each of these abilities is tested using a variety of requirements. There are two basic steps:

- to complete credits in Ph.D.-level courses;
- to write and successfully defend an original thesis.

Students demonstrate breadth by taking graduate courses. All incoming students are required to complete a minimum of 30 ECTS (European Credit Transfer and Accumulation System) credits, or 5 advanced (graduate/doctoral level) courses. Each student may choose his/her own courses and research schedule, with the approval of the advisor. Students who have completed Ph.D.-level courses at other programmes may be exempt of some or all of these courses in PDEEC.

Currently, the courses in Telecommunications offered to the students are:

- Advanced Wireless Communications;
- Inverse Problems in Signal and Image Processing;
- Modelling and Analysis of Optical Fibre Telecommunication;
- Satellite Communication Systems;
- Simulation Based Analysis and Methods;
- Statistical Learning.

Students may demonstrate their ability to disseminate knowledge through completing a Teaching Internship. Students may complete a one semester internship in university teaching. This teaching internship is equivalent to a graduate course (Teaching Assistance) and it contributes with 6 ECTS to the course requirements. It may be completed at any time during the student's enrolment in the programme.

The thesis must describe independent original research work, at the level that is adequate for publication in international scientific journals. Each student must prepare a thesis proposal within four semesters following his/her admission in the programme. The proposal is an informal written description of the problem to be investigated, and the expected accomplishments of the investigation. The proposal is presented (orally) in a public session to the Thesis Accompanying Committee (CAT) for its review and recommendations. This committee consists of at least three members, including the student's advisor.

Following the completion of the proposed research, a doctoral thesis documenting the research is required. The doctoral thesis should be a report of the work done, its relation to previous work in the area, and the conclusions drawn from the results. The thesis should include a section describing how the research has contributed to the body of knowledge in ECE.

The Thesis Committee is normally composed of six members: the Chairman, who is one of the members of the PDEEC Board, the CAT ones, and two outside the university; in many cases, one of these external members is even outside Portugal. After the thesis is written, the student submits a draft version to the Thesis Committee, which determines whether the thesis is acceptable for public defence, or if changes are required. Approval of the thesis is by majority decision of the Thesis Committee, leading to the stage in which the candidate prepares the final version of the manuscript, and its presentation and defence in a public examination.

III. THE ADVANCED TRAINING PROGRAMME

A. Degree Structure

POSTIT (Post-Graduate studies in Telecommunications and Information Technologies) [2] aims at staff working in industry, wishing to get an update in technology, in a broad perspective. The students that graduate from POSTIT obtain a diploma of graduate studies, but which is not equivalent to degree. More specifically, the goals are to:

- provide updated training, consolidating and structuring knowledge in the area of telecommunications and information technologies;
- provide training related to management, business strategies and policies in telecommunications, in addition to the technological components;
- respond to the needs of people without specialised training in this specific area.

POSTIT is structured into three trimesters; each trimester has a lecture period of 10 weeks, plus 4 weeks for evaluations. The whole duration of the degree is one academic year.

The existence of three trimesters facilitates individualisation / segmentation of the topics to be taught in the degree. A high individualisation is more appropriate when it is necessary to hire experts for teaching certain topics; it enables also that more specific topics are taught. In addition, it is also more advantageous in terms of marketing, since it allows one to give more detailed information about the course structure when advertising it. In pedagogical terms, the evaluation on a trimester basis is closer to a system of continuous evaluation, compared to a semester one; this aspect is of value as well, since students are not full time ones, i.e., an increased segmentation of courses improves the conditions for success. Moreover, there is the possibility that each course can also be attended by students not enrolled in the full programme; in this case, people are interested in specialised and well defined topics, which is more difficult to structure into semesters rather than trimesters.

Each trimester has four courses. The weekly lecture load is 2.5 hours per course, in a total of 10 hours. Lectures are evenly split into two days: Friday afternoon, and Saturday morning.

The degree has a total lecture load of 300 hours, corresponding to 36 ECTS credits. For the calculation of ECTS credits, one considers that each student has a study time at home of 2 hours in addition to each hour of lecturing; the conversion of study and lecture time to ECTS credits is made under rule "1 ECTS credit = 28 hours (lecture and study)". The full account of the credits per course considers also the study period for the exams (or other evaluation components). Overall, each course has 3 ECTS credits.

The 4-weeks period for evaluation is taken in such a way that at its end, all courses exams and other evaluation components (papers, projects, etc.) are completely finalised, on a scheme of one week per course.

B. *Courses Structure*

The structure of the courses is such that in the first trimester one gives a more general training, followed by the more advanced topics in the following ones.

Courses are grouped into three areas, according to their contents:

- Basic Training (B)
  These courses aim at providing the necessary foundations, and allow a harmonisation of skills among participants.
- Specialised Technologies (T)
  The courses in this area give an updated overview of the dominant technologies in the telecommunications industry, services, and perspectives of future trends in technology.
- Management and Telecommunications Policy (M)
  The area of Management and Telecommunications Policy includes aspects related to economy and regulation in telecommunications, as well as the definition of strategies and business views.

The structure of the courses per trimester is the one shown in Table 1. The B courses are all located in the first trimester, so that in fact they serve their purpose, and the M courses are spread between the first and second trimester. The T courses occupy basically the second and third trimesters.

TABLE I. *TRIMESTER COURSE STRUCTURE*.

Trimester	Course Area			
1º	B	B	B	M
2º	T	T	T	M
3º	T	T	T	T

The corresponding percentage of each area is presented in Table II. More than 50% of the degree is devoted to advanced technological courses (T), while less than 20% concerns the courses on management and policy (M).

TABLE II. *WEIGHT OF COURSE AREAS*.

Area	Number of courses	Lectures Time [h]	ECTS Credits	Relative Weight [%]
B	3	75	9	25.
T	7	175	21	58.
M	2	50	6	17.
Total	12	300	36	100

It should be noted that the general structure of the degree, the overall weight of the areas, and the general content of the courses was discussed with industry in Portugal. Prior to the launching of the first edition of the degree, a series of interviews was held with key people in several companies: these conversations were taken with people at the director level, from both the technical and the human resources areas. The targeted companies were operators, vendors, service providers, and consultancy, as well as the regulator.

C. *Courses*

The courses included in each of the areas of the degree are as follows (the trimester is indicated in parenthesis)

- Basic Training (B)
  - Aspects of Telecommunication Systems (Tr1)
  - Databases (Tr1)
  - IP Networks (Tr1)
- Specialised Technologies (T)
  - Content Processing (Tr3)
  - Integrated Networks (Tr3)
  - Middleware (Tr2)
  - Mobile and Wireless Communication Systems (Tr2)
  - Network and Systems Security (Tr3)
  - Network Planning (Tr3)
  - New Generation Telecommunication Networks (Tr2)
- Management and Telecommunications Policy (M)
  - Policies and Regulation (Tr1)
  - Models of Engineering and Management (Tr2)

A brief description of the contents of each course is given in Appendix I.

The evaluation of the students is specific of each course. Still, in general, each course has two components:

- exam, with a weight ranging between 50% and 60%;
- research paper/project, with a weight in between 40% and 50%.

Exams follow the usual model in a university. The papers/projects are done as much as possible in the area of interest for the student, intending that his/her professional working area is brought into the courses; this way there is a bridging in between the working activity of the students and the areas of study in which they are enrolled.

This model of evaluation proves to be successful. Obviously, the working load for the students is high. On the other hand, they are closer to their reality, and it increases the success ratio. Around 80 % to 90% of the students complete the full programme.

D. *Students*

POSTIT being a graduate studies degree, it is intended for students with a university degree, with a minimum of 5 years of study. Target students include senior managers active in the area telecommunications, and professionals from other fields of engineering with adequate knowledge in telecommunications and information technologies.

The degree is oriented both to people who already have training in the area and wish to update, and to those who have not but possess a set of skills that allows to do the upgrade.

For the former, the degree allows a consolidation and systematisation of the knowledge, broadening their skills to other areas of technology or business, getting acquainted with new planning tools systems and networks, and acquiring a

perspective of evolutionary trends in the short and medium terms. In this case, most likely, the added value for these students is to get an update that will allow them to evolve in their working area, or even to move to other areas in the company where they work (or even to another company), through the enrichment of their professional curriculum.

Regarding the latter, the course enables them to acquire training in a new area with great potential for professional development. It certainly opens employment opportunities in in telecommunications and information technologies, which hardly would be the case with the basic training they had.

By positioning itself as essentially a degree for people who already develop a professional activity, therefore not enrolling full time, the degree is structured to meet these constraints (described above).

Candidates apply by submitting: a form, curriculum vitae, and reference letters. The selection of candidates is done by the Board of the Degree, through the assessment of the written documentation and interviews. There is numerus clausus of 30 students.

It is also allowed that students apply to attend isolated courses, and not necessarily the entire degree. The conditions for admission are the same as those of the other candidates, subject to the capacity of the courses.

IV. CONCLUSIONS

This paper describes graduate studies at IST Lisbon (Technical University of Lisbon) in the area of Telecommunications. There are two graduate programmes: the Ph.D. programme, with a curricular component and a thesis, and a degree more devoted to industry training, POSTIT.

Completion of the Ph.D. degree usually takes about four to five years of study. Students are required to complete a minimum of 30 ECTS credits, or 5 advanced (graduate/doctoral level) courses. Each student may choose his/her own courses and research schedule, with the approval of the advisor. Students may complete a one semester internship in university teaching, which is equivalent to a graduate course (Teaching Assistance) and it contributes with 6 ECTS to the course requirements.

The thesis must describe independent original research work, at the level that is adequate for publication in international scientific journals. Each student must prepare a thesis proposal within four semesters following his/her admission in the programme. The proposal is an informal written description of the problem to be investigated, and the expected accomplishments of the investigation. The proposal is presented in a public session to the Thesis Accompanying Committee (CAT) for its review and recommendations.

POSTIT aims at staff working in industry, wishing to get an update on technology, in a broad perspective. More specifically, the goals are to: provide updated training, consolidating and structuring knowledge in the area of telecommunications and information technologies; provide training related to management, business strategies and policies in telecommunications, in addition to the technological components; respond to the needs of people without specialised training in this specific area. POSTIT is structured into three trimesters; each trimester has a lecture period of 10 weeks, plus 4 weeks for evaluations. The whole duration of the degree is one academic year. The degree has a total lecture load of 300 hours, corresponding to 36 ECTS credits.

Courses are grouped into three areas (Basic Training, Specialised Technologies, and Management and Telecommunications Policy). More than 50% of the degree is devoted to advanced technological courses, while less than 20% concerns the courses on management and policy. The degree is composed of 12 courses. Lectures are held on Friday afternoon and Saturday morning. The degree is targeted to students who already have training in the area and wish to update, and to those who do not but possess a set of skills that allows them to do the upgrade. Around 80 % to 90% of the students complete the full programme.

REFERENCES

[1] PDEEC, Ph.D. Programme at DEEC/IST, https://fenix.ist.utl.pt/cursos/deec?locale=en_EN, May 2013.

[2] POSTIT, Post-Graduate studies in Telecommunications and Information Technologies, http://postit.ist.utl.pt (in Portuguese), May 2913.

APPENDIX I – COURSES CONTENT

In what follows, one gives a brief description of the contents of each course of the POSTIT programme:

- Aspects of Telecommunication Systems

  Introduction to Telecommunications Systems. Radio Channels: characterisation in time and frequency, propagation models; capacity. Digital Modulations: signals, noise and interference; performance; modulations. Channel Coding: codes, performance, adaptive modulation. Multiple Access: duplexing; access techniques. Antennas for base stations and portable terminals. Structure of systems for optical fibre communications. Generation, modulation, detection and multiplexing of optical signals. Limitations in optical fibres transmission. Systems with regenerators. Systems with optical amplification. WDM Transmission Systems.

- Content Processing

  Introduction. Multimedia Information: Text, Audio, Image Bitmap, Vector Image, Colour, Video. Processing and Visualisation: Audio, Image, Video, Applications. Principles of Graphic Design: Alignment, Proximity, Contrast, Repetition, Blank; Typography; Colour. Multimedia Presentations: Creating high-impact multimedia presentations. Copyright and DRM: copyright laws; implications and alternatives. Structuring of Multimedia Information: hypermedia systems and applications. MPEG: MPEG standards; MPEG-1, MPEG-2, MPEG-4; Applications. MPEG-7: Multimedia Databases; description of multimedia content, MPEG-7 standards, recovery of multimedia content. Author Systems: metaphors; authoring systems for various types of multimedia information (commercial and alternative free and open-source). Data Recovery based media content. MPEG21: Distribution of multimedia content, MPEG-21.

- Databases

  Introduction to Databases. Characteristics of databases. Relational model. Modelling of databases. Conversion to the relational model. Design and construction of a database. Introduction to the SQL language. Exercises with SQL. Access database in

Java. Development of applications with databases. Advanced database themes.

- Integrated Networks

  Classic Networks: evolution of network signalling (associated channel, common channel, TUP). The first integration of networks (DSS1, ISUP, etc.); integration of cellular networks. The integration of new services by the use of signalling (Intelligent Networks, MAP). New modes of access network (DOCSIS, xDSL). ◦ The integration of packet networks (basic protocols, Quality of Service). Architectures for integration of new services (VoIP), streaming over IP, SIP, Megaco/H.248. IMS. New services enabled by IMS (OSA's XDM Service, Presence, Instant Messaging service, push-to-talk, etc.). IPTV and Mobile TV.

- IP Networks

  Concepts and networking technologies for access and transport. LAN devices. Wi-Fi, and WiMAX networks and mobility. IP Protocol. Addressing and Routing. Version 6 of the IP protocol. Quality of service in IP networks. TCP and UDP Transport protocols. MPLS technology as the basis for modern communication networks. SNMP protocol for managing IP networks. Evolution to next generation networks.

- Middleware

  Introduction and Fundamentals - Introduction to large-scale distributed systems, presenting problems / challenges, nonfunctional requirements, and theoretical foundations. Requirements, Models and Solutions - models (applicational objects, communication, synchronisation, naming, fault and security) and architectures (client-server, publish-subscribe, P2P and Grid) taking into account non-functional requirements. Architectures - study of each of the aforementioned architectures in greater detail (client-server, publish-subscribe, P2P and Grid) with emphasis on the client-server under which specifically address file systems, distributed object systems, replication and clustering. Case Study - presentation of current systems most representative example of the matters referred to above.

- Mobile and Wireless Communication Systems

  Services and Applications: classification of services, quality requirements, models of traffic. Cellular systems – UMTS / LTE: network architecture, radio interface, radio resource management; evolution. LANs and metropolitan wireless: architecture of 802.11 and 802.16; main access protocols; standardisation; mobility, transport and network protocols in mobile environments, self-organised structures.

- Models of Engineering and Management

  Models structuring, corporate structures. Value Chain. Motivation, leadership and delegation, training and development groups, business communication. Business processes, BPM, quality processes, Demming cycle and TQM, mind maps and flow charts, network models, decision making, project management.

- Network and Systems Security

  Security architecture of an organisation. Vulnerabilities in networks. Vulnerabilities in systems. Periphery control systems. Application of cryptographic mechanisms. DNSSEC and PKI. Secure communication protocols. Practical Applications: analysis of protocols for wireless networks (GSM, UMTS, WiFi, Bluetooth); analysis of VPNs (IPSec, TLS, PPTP, OpenVPN).

- Network Planning

  Introduction to planning of telecommunication networks: standardisation in telecommunications, network architectures, process, steps and planning tools. Modelling and Algorithms: evolution and traffic characterisation, modelling networks, physical and logical topologies; optimisation models; topological algorithms for planning, routing algorithms and metrics. Aspects of network survival: reliability and network availability, reliability requirements imposed by the services; mechanisms and disaster recovery strategies, strategies for protection and restoration; methods for resilient network planning. Planning transport networks: planning SDH and OTN; planning Ethernet networks. Planning fixed access networks: planning ADSL networks; planning physical layer logic and passive optical networks.

- New Generation Telecommunication Networks

  Introduction to telecommunication networks: evolution and standardisation; fundamental concepts and topologies, network architectures. Services and service networks: current and emerging applications, network services (public telephone, IP phones, and CATV). Ethernet Networks: introduction to Ethernet, Gigabit Ethernet, Ethernet-class operator. SDH transport networks: plesiochronous technologies; synchronous digital hierarchy, next generation SDH, network planning and performance analysis. Optical transport networks: based technologies (optical fibres and optical components); principles division multiplexing wavelength (WDM), types and structure of the network elements; optical transport hierarchy (OTN). Access networks: infrastructure of the fixed access network, broadband solutions over copper pairs (xDSL); access networks of next generation optical (GPON, EPON, P2P networks and open), hybrid fibre-coaxial networks (DOCSIS). Survival networks: basic concepts, protection and restoration in SDH networks, protection in optical networks; protection on Ethernet networks. Topics on switching: basic concepts; digital switching circuits; packet switching.

- Policies and Regulation

  Objectives and instruments of regulation in the European Union. The European regulatory framework. Price regulation. Regulation of access pricing and interconnection. New Generation Networks. Vertical integration and structural separation. Assignment of radio frequencies. Policy Objectives. Universal Service. Market and country. Protection of competition: fundamental principles; concentrations; dominance, predatory pricing and margin squeeze; coalitions.