Networking in the New ICT Curricula*

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Abstract

New guidelines for ICT curricula have recently appeared, both in Europe and the United States. New European guidelines are sponsored by the European Commission and are a consequence of the political mandate to implement the European Higher Education Area. In the U.S., new guidelines proposed by ACM/IEEE are an update of previous guidelines by those institutions, basically motivated by technological change. This paper analyzes and compares the role of networking in those new guidelines and proposes a synthesis of them.

Keywords: *Networking, Net-centric computing, ACM/IEEE Computing Curricula 2001, Career Space initiative.*

1 Introduction

New guidelines for Information and Communication Technology (ICT) curricula have appeared in the last year, both in Europe and the United States. The motivation for such a renewal is diverse:

- In Europe, the Bologna Declaration (1999) called for a harmonization of higher education and proposed the creation of a European Higher Education Area (EHEA) to promote the mobility of undergraduates and graduates across the European Union. To achieve that aim, a framework for a European Higher Education System (EHES) based on a common structure for university curricula has been defined, and recommended contents and profiles for every discipline are currently being identified and proposed under the sponsorship of the European Union. In particular, the effort being carried out in the ICT sector encompasses computing curricula.
- In the U.S., the definition of new curriculum guidelines is motivated by technological change and is driven by non-government institutions such as IEEE and ACM, rather than by the administration. The new ACM/IEEE Computing Curricula 2001 are essentially an update of the previous curriculum guidelines published by those two institutions in 1991.

In Section 2, the European initiatives are introduced, with a special focus on the ICT sector. In Section 3, the ACM/IEEE Computing Curricula 2001 are reviewed. Section 4 deals with the views on networking by European and American curriculum guidelines. Section 5 is an attempt at synthesizing those views to come up with a unified approach to presenting networking in the undergraduate and graduate ICT curricula. Some conclusions are listed in Section 6.

2 The EHES and the new ICT curricula in Europe

The aim of the European Union is to become a truly open and global society, and this requires free exchange of professionals within the Union. For such an exchange to possible, education must be multilingual, internationally-oriented and linking different cultures. A basic milestone is for regional education systems to be able to mutually recognize their levels, so as to facilitate mobility: a student should be able to pursue different stages of her education in different regional education systems, and this in a way as transparent as possible.

The transition to an integrated university system in Europe is far from trivial. Current university systems are not homogeneous across countries; in fact, differences start al-

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ready in secondary education. Roughly speaking, there are two types of university systems in Europe:

Continental This system is based on two types of university programmes:

- The long education programme, typically 5 years long and with a more theoretical emphasis.
- The short education programme, lasting about 3-4 years and with a more practical orientation.

Anglo-American This system consists of two consecutive university programmes:

- The undergraduate programme, typically 3-4 years long and leading to a Bachelor degree.
- The graduate programme, lasting about 1-2 years and leading to a Master's degree.

The Anglo-American system, with its consecutive degrees of Bachelor, Master and Ph. D. has become a worldwide *de facto* reference model. Those three degrees are recognized all over the world, which facilitates mobility of undergraduates and graduates across the global education system and labor market. Realizing such benefits, the ministers of science and education of the European Union undersigned in June 1999 the so-called Bologna Declaration, which mandates that a European Higher Education System should be in operation before 2010.

Similar to the Anglo-American system, EHES is based on two main cycles: undergraduate and graduate. Access to the second cycle is only possible after successful completion of the first cycle, which lasts at least 3 years. The degree obtained after the first cycle should constitute a proof of qualification and give access to the European labor market. The second cycle leads to the Master's or Ph. D. degrees. Note that completion of the first cycle allows doctoral studies to be directly started.

2.1 The Career Space guidelines

After the approval of the Bologna Declaration, the European Commission started sponsoring several initiatives aiming at producing guidelines to implementing EHES in several sectors. In the ICT sector, the Commission promoted a consortium called *Career Space* (`www.career-space.com`), formed by large European or Europe-based ICT companies —Britisch Telecom, Cisco Systems, IBM Europe, Microsoft Europe, Nokia, Nortel Networks, Philips Semiconductors, Siemens AG, Telefónica S.A. and Thales— and EICTA —European Information and Communication Technologies Association, an association of European ICT industries—. Career Space works in close cooperation with the European Commission to fill the currently existing gap in ICT capabilities, a gap which is seen by the Consortium as a threat to European prosperity. The two first steps taken in this direction by Career Space have been the following:

- Develop generic capability profiles needed to fill key ICT positions. Thirteen profiles were described in Report [1] which are: Radio frequency (RF) engineering, Digital design, Data communications engineering, Digital signal processing applications design, Communications network design, Software and applications development, Software architecture and design, Multimedia design, IT business consultancy, Technical support, Product design, Integration and test/implementation and test engineering, Systems specialist.
- Work in collaboration with more than twenty European universities and higher education institutions to develop new guidelines for ICT curricula, using the curriculum framework sketched by the Bologna Declaration. These guidelines have been published in Report [2].

According to [2], the European ICT sector is very satisfied with the Bologna Declaration and is requesting urgent implementation of EHES to public administrations and universities. From the ICT point of view, the new EHES should enable students to:

1. Pursue the undergraduate and the graduate cycles in different countries and acquire international experience in different cultures during their study period.
2. Enter the labor market after completion of the undergraduate cycle and, when they feel it appropriate, resume the second cycle as part-time or full-time students in order to improve or update their knowledge. This concept of second cycle (as either improvement, update or both) is especially relevant in a rapidly changing fields such as ICT.

Specifically, Document [2] recommends universities to move towards offering a new variety of ICT programmes for first-cycle degrees (FCD) and for second cycle degrees (SCD). The following programme groups are identified:

- ICT programmes leading to a first cycle degree (FCD, 3-4 years) aiming at educating ICT specialists for several groups of profiles. These are new programmes for basic ICT education.
- Consecutive ICT programmes leading to a second cycle degree (SCD, 1-2 years), designed for students holding an ICT FCD who wish a higher specialization enabling them to tackle R+D activities in specialized ICT sectors.

- MBA conversion programmes as second cycle degrees (SCD), designed for students holding an ICT FCD who wish a qualification enabling them to tackle a variety of corporate business activities which require solid backgrounds both in ICT and business administration.
- ICT conversion programmes as second cycle degrees (SCD), designed for students holding an FCD in a non-ICT discipline who wish to become involved in one or several ICT application areas.

As to the contents, Career Space suggests that 30% of an ICT programme should be devoted to scientific aspects, 30% to technological aspects, 25% to applications and system thinking and 15% to personal and business skills.

3 The ACM/IEEE Computing Curricula 2001

While Career Space guidelines stay quite general and leave to universities the actual task of defining detailed programme contents, ACM and IEEE have a long-standing tradition in providing detailed models for computing curricula. In December 15, 2001, the *Computer Science* volume of *ACM/IEEE Computing Curricula* was published (from now on referred to as CS2001, [3]); the *Computer Engineering* (referred to as CE2001, [4]) is still under development. Two additional volumes on software engineering and information systems are also under development. Unlike Career Space, the ACM/IEEE documents focus on the Bachelor degree and are not concerned with graduate programmes.

3.1 The CS2001 computer science volume

According to CS2001, the following curriculum topics have gained importance over the ten years elapsed since publication of the previous guidelines ACM/IEEE *Computing Curricula 1991* [5]: WWW and its applications, Network technologies (esp. TCP/IP), Graphics and multimedia, Embedded systems, Relational databases, Interoperability, Object-oriented programming, Use of sophisticated APIs, Human-computer interaction, Software reliability, Security and cryptography, Application domains.

To accomodate technological change, CS2001 defines a body of knowledge consisting of 14 areas: Discrete structures, Programming fundamentals, Algorithms and complexity, Architecture and organization, Operating systems, Net-centric computing, Programming languages, Human-computer interaction, Graphics and visual computing, Intelligent systems, Information management, Social and professional issues, Software engineering, Computational science and numerical methods.

CS2001 then proposes several alternative course models that cover the body of knowledge at the undergraduate level.

3.2 The CE2001 computer engineering volume

Completion of CE2001 is scheduled for mid-2003, according to [6]. At the moment of this writing, what can be found on it is a draft report containing its design principles and a draft body of knowledge for public comment [4]. The draft body of knowledge consists of the following preliminary list of areas: *Discrete structures*, *Programming fundamentals*, *Algorithms and complexity*, *Computer architecture and organization*, *Operating systems*, *Networks*, Computer systems engineering, Embedded systems, Circuits and systems, Electronics, Digital logic, *Social and professional issues*, *Software engineering*, Digital image processing, VLSI and ASIC design, Design automation, Alternative computing paradigms, Testing and fault tolerance.

We have written in italics those areas in CE2001 which have their equivalent in CS2001 (the "Networks" CE2001 area corresponds to "Net-centric computing" in CS2001).

4 Networking across curriculum guidelines

4.1 Career Space and networking

Career Space does not deal with specific areas or subjects, but is limited to the definition of the 13 aforementioned professional profiles. The profile related to networking is "Communications network design". According to the consortium, coverage of this profile by current university programmes is rather weak: 29% of programmes give total coverage, 45% give partial coverage and 26% do not cover this profile at all.

In [1], the role of a communications network designer is described as designing networks using products from several suppliers. The designer should analyze and interpret the needs of customers and offer them detailed solutions. Teamworking and keeping the pace with the latest technologies are essential. Example solutions provided by professionals of this profile are: an internet network (TCP/IP); a mobile network integrating fax, voice and data; enhancements to existing networks using recent technologies, etc.

Technologies related to the design of communication networks can be summarized as: mobile networks, wireless data networks, IP technologies, SDH (Synchronous Digital Hierarchy) and PDH (plesiochronous digital hierarchy), microwave radio links, switching and intelligent networks, backbone architectures, high-speed optical transmission systems, cryptography, firewalls.

Technical capacities required by this profile include: information flow analysis, network systems, network modeling, network protocols, network-level telecom technology, cost modeling, statistics, design methods, security.

4.2 Networking in ACM/IEEE Computing Curricula

In the CS2001 computer science volume, networking corresponds to one area of the body of knowledge, namely "Net-Centric Computing" (NC for short). This area is divided in the following units, where core units are marked with a framebox and labeled with a minimum recommended time:

NC1. Introduction to net-centric computing (time: 2 hours)

NC2. Communications and networks (time: 7 hours)

NC3. Network security (time: 3 hours)

NC4. The web as an example of client-server computing (time: 3 hours)

NC5. Building web applications

NC6. Network management

NC7. Compression and decompression

NC8. Multimedia data technologies

NC9. Mobile and wireless computing

In the CE2001 computer engineering volume, networking corresponds to one area in the body of knowledge named "Networks" (NWK for short). This area is divided in the following units, where core units are marked with a framework and minimum recommended time is specified for all units:

NWK0. History and overview of networks (time: 1 hour)

NWK1. Communications network architecture (time: 4 hours)

NWK2. Communications network protocols (time: 6 hours)

NWK3. Local and wide area networks (time: 10 hours)

NWK4. The web as an example of client-server computing (time: 3 hours)

NWK5. Data security and integrity (time: 9 hours)

NWK6. Performance evaluation (time: 12 hours)

NWK7. Data communications (time: 12 hours)

NWK8. Wireless and mobile computing (time: 6 hours)

5 A synthetic proposal for networking in ICT curricula

The basic idea behind our proposal is:

- At the undergraduate level (First Cycle Degree), use a synthesis of ACM/IEEE CS2001 and CE2001 guidelines to determine the networking contents of a general ICT Bachelor's degree. See Subsection 5.1 below for details.

- At the graduate level (Second Cycle Degree), map each of the 13 Career Space generic professional profiles into a Master's degree; for networking, this yields a Master's degree on "Communications network design". We give no further details in this paper because the Master's contents we propose exactly match the profile description in [1] (an overview was given in Subsection 4.1).

The above strategy takes advantage of the strengths of each curriculum initiative: ACM/IEEE is focused toward general ICT undergraduate programmes (*i.e.* Bachelor), while Career Space looks at specialized profiles needed by the industry (these can be more appropriately taught as Master's degrees).

5.1 Networking synthesis of CS2001 and CE2001 for undergraduates

By analyzing the contents proposed for units of CE2001 area "Networks" with CS2001 area "Net-centric computing", a correspondence can be established between both areas as follows. The introduction NWK0 is included in NC1. Units NWK1 and NWK2, devoted to architectures and protocols, are covered by NC2 and, regarding the concept of network architecture, by NC1. Unit NWK4 on the web as client-server computing exactly matches NC4. Unit NWK5 lies somewhere in between NC3 (network security) —in what regards cryptography— and NC6 (network management) —in what regards access control mechanisms and firewalls—. Unit NWK6 (performance evaluation) has some points in common with NC6 (network management). Unit NWK8 exactly matches NC9.

From the previous correspondence, some differences are evident in the way CS2001 and CE2001 treat networking:

Core units CS2001 considers security, and more specifically cryptography, as a core unit (NC3), while CE2001 considers it as an elective unit (NWK5). On the other hand, CE2001 considers local and wide area networks as a core unit (NWK3), while CS2001 does not even mention them.

Table 1. Distribution of units of NC-CS2001 and NWK-CE2001 in four undergraduate courses: "Computer Networks I" (CNI), "Computer Networks II" (CNII), "Cryptology" (CR) and "E-Commerce" (EC). Elective units written in italics. Notes: (1) CNI covers the part of NWK5 not included in NC3, while CR covers NC3; (2) partially covered unit.

CS2001	CE2001	CNI	CNII	CR	EC
NC1	NWK0	X			
NC2	NWK1, NWK2	X			
NC3	*NWK5*	$X^{(1)}$		$X^{(1)}$	
NC4	NWK4	X			
NC5					X
NC6		X			
NC7				$X^{(2)}$	$X^{(2)}$
NC8					
NC9	*NWK8*		X		
	NWK3		X		
	NWK6		X		
	NWK7				

Elective units CS2001 specifies elective units for web applications building (NC5), network management (NC6), compression and decompression (NC7) and multimedia data technologies (NC8). As mentioned before, network management described in NC6 has some points in common with performance evaluation proposed by CE2001 in NWK6. Topics treated in NC5, NC7 and NC8 are not mentioned by CE2001 which, in exchange, specifies elective units closer to telecommunications: data communications (from a signal processing viewpoint) and performance evaluation.

We propose to structure the networking materials covered by the "Net-centric computing" (NC-CS2001) and "Networks" (NWK-CE2001) units around four undergraduate courses: "Computer Networks I", "Computer Networks II", "Cryptology" and "Electronic Commerce". Distribution of materials between courses is specified by Table 1.

Even it the content distribution sketched by Table 1 gives some emphasis to computer security and e-commerce (two issues which have gained much importance in networking over the last years), it must be noted that it covers all core units in either CS2001 or CE2001. Regarding elective units, only NC8 and NWK7 are left aside. We propose to cover NC8 (Multimedia data technologies) through some specific subject, probably also linked to peripheral devices. Regarding NWK7 (Data communications), its physical approach makes it suitable to be partly covered by a physics or electronics course.

For each undergraduate course, an evaluation scheme is proposed giving 60% weight to an individual exam; 20% weight to work consisting of problems, critical readings and presentations carried out by groups of 3-4 students; 20% weight to practical implementation projects carried out by groups of 3-4 students.

6 Conclusion

Networking has become essential to ICT curricula over the last decade. However, its coverage by current computer science, computer engineering or telecom engineering degrees is not always satisfactory, precisely because networking lies in the middle of them. In this paper, we have reviewed recent ICT curriculum initiatives both in the U.S. and Europe. Based on them, we have proposed ways to accomodate networking contents in the undergraduate and the graduate curricula. ACM/IEEE Computing Curricula provide a good guidance in the undergraduate case, while the Career Space professional profile on Communications Network Design can be directly used as a description of a specialized Master's degree.

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