Wireless Communications and Mobile Computing

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A. Programme

1. Theme, justification and comparable subjects

The main objective of this course is to provide the students with the competences required for understanding and using the communications component of an universal communications environment. Students will be provided, in particular, with the knowledge required to understand (a) emerging communications networks, (b) their computational demands, (c) the classes of distributed services and applications enabled by these networks, and (d) the computational means required to create the new networks and the new applications.

Emerging communications networks can be classified in 3 types: integrated access networks, ad-hoc networks, and peer-to-peer networks. Integrated access networks evolve from current telecom networks, and they aim at offering telecom services through multiple access technologies such as, Ethernet, WLAN, WMAN, UMTS, and DVB. As a result, the user becomes always connected to his operator and to the Internet, most of the times through a high bit rate connection. The access flexibility demands a unified management system which, for instance, enables a single bill to be issued. Ad-hoc networks refer to a new class of communications networks where radio access points or terminals, randomly and gradually displaced at home, in a building, in vehicles, or in a city, owned by one or multiple entities, are able to automatically detect each-other, to self-configure, and to collaborate in providing better networks. Peer-to-peer networks are virtual networks, offered over existing communications infrastructure, usually dedicated to a set of applications and having switching points which can be located at the user premises.

The emerging communications networks can be seen as distributed systems where some of their components move. They are mostly implemented in software and demand advanced computational and programming techniques for terminals, user servers, network elements, and telecom operator servers. These networks demand, for instance, functionality for authorizing the access to the network, to provide secure communications, to manage the mobility and the quality of the service, to discover services and redirect data, to account traffic, to adapt voice and video contents, and to support localisation procedures.

The communications services used by such universal communications environments will rely on these new functions. Aspects such as bandwidth availability and QoS assurances, permanent service access (*always-best-connected*), and mobility independence, all will strongly impact on the definition of future services. Moreover, the increasing availability of custom equipment containing also communications devices such as game consoles or digital cameras, combined with their multifeature capabilities demand new software capabilities at the network and service levels. Moreover, the new terminals will use different networking technologies, and the user expects seamless service support. This intelligent communication support enables the provisioning of increased functionalities to the user such as localization awareness.

The characteristics of the new communication devices, the availability of high bit rate connections, the support of mobility, and the localization services, all lead to new applications. These applications help supporting personal communications services, and professional, social and amusement activities. Common objects will become increasingly inter-connected and lead to intelligent ambient; when, for instance, deployed at home the object can obtain information from other objects, and collaborate on the provisioning of personalised ambient. Communications, the technologies, the protocols, and their limitations and potentialities, will play an essential part in the deployment of this pervasive, intelligent ambient.

The scientific areas addressed by this course are computer and mobile communications, with a strong emphasis on service engineering. Graduate level courses with similar objectives are offered at several universities. Below we present Carnegie Mellon (US), Berkeley (US), Carlos III de Madrid (SP), and Greenwich (UK), Many other universities offer similar courses.

Carnegie Mellon University:

CMU has several courses on the overall area of coverage of this subject: Mobile and Pervasive Computing, Wireless and Mobile Communications, and Wireless Networks, assuming students mostly with a computer science background. A summarized version of the courses is given below.

> *Mobile and Pervasive Computing*: This is a course exploring research issues in the newly emerging field of mobile computing. Many traditional areas of computer science and computer engineering are impacted by the constraints and demands of mobility. Examples include network protocols, power management, user interfaces, file access, ergonomics, and security. This will be an "advanced" course in the truest sense--most, if not all, the topics discussed will be ones where there is little consensus in the research community on the best approaches.
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> *Wireless Communications:* Wireless networks and wireless communications technology have the potential to make universal Internet use a reality, which will clearly lead to global connectivity, roaming, and ubiquitous communications. Given the astonishing increase in the number of Internet users (doubling every 90 days), this course aims to examine the relationship between the Internet and wireless networks. To that end, the emerging third generation (3G) wireless standards and how they accommodate data communications in addition to voice will be highlighted. While the emphasis will be on the networking issues and aspects of wireless communication networks, the relevant physical issues will briefly be reviewed as well. In addition, this year we will cover two hot topics as well: ad hoc wireless networks and ultra-wideband radio technology.
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> *Wireless and Mobile Communications:* Mobile computing devices such as laptop and palmtop computers are becoming widely available at very affordable prices, and many new wireless networking products and services are becoming available based on technologies such as spread-spectrum radio, infrared, cellular, and satellite. Mobile computers today often are as capable as many home or office desktop computers and workstations, featuring powerful CPUs, large main memories, hundreds of megabytes of disk space, multimedia sound capabilities, and color displays. However, wireless networks have fundamentally different properties than typical wired networks, including higher error rates, lower bandwidths, nonuniform transmission characteristics, increased usage costs, increased susceptibility to interference and eavesdropping, and higher variability of performance. Similarly, mobile nodes behave differently and have fundamentally different limitations than stationary nodes. For example, mobile nodes generally operate on limited battery power and may move and change their point of connection to the network. This course will examine the emerging area of mobile and wireless communications, through readings, lectures, class discussions, and a course project.

Carlos III de Madrid:

UC3M has a Ph.D. on Telematics, where several courses can be linked to our proposal, but the nearest one is Mobile Systems Communications. Target students profile is somewhat in a middle ground between computer science and electrical engineering.

COMUNICACIONES DE SISTEMAS MOVILES: Profundizar en los aspectos diferenciadores de las comunicaciones móviles y portables respecto a los sistemas terrenos, analizando aspectos de arquitectura, protocolos, servicios y señalización. Se ilustrará con sistemas existentes y su evolución a medio plazo. 1. Introducción: Introducción a los sistemas de comunicaciones móviles. Movilidad de usuarios, de terminales, de servicios, y de redes. Movilidad en redes de telecomunicación (sistemas celulares). Movilidad en redes IP (IPv4 e IPv6). Evolución y perspectivas. 2. Sistemas de comunicaciones celulares: Historia de las redes celulares. Sistema GSM. Sistema GPRS. Sistemas celulares 3G: UMTS. Provisión de servicios en redes 3G: OSA. Evolución de los sistemas celulares 3G. 3. Movilidad en redes IP: Soporte de movilidad en redes IPv4. Soporte de movilidad en redes IPv6. Soluciones de micro-movilidad. Movilidad de redes (NEMO). 4. Acceso y redes inalámbricas: Tecnologías inalámbricas: WLL, HomeRF, Bluetooth, estándares 802.11, WCDMA. Acceso a redes IP a través de tecnologías inalámbricas. Redes de acceso multi-salto. Redes ad-hoc móviles. 5. Redes 4G: Evolución y convergencia de redes 3G y redes IP. Problemática y soluciones en las redes 4G.

Berkeley:

The University of Berkeley (US) has a Special Course on Wireless Communications and Mobile Computing, in some aspects similar to our proposal, but too much oriented to Electrical Engineering students.

Wireless Communications and Mobile Computing - Ubiquitous access to information, anywhere, anyplace, and anytime, will characterize whole new kinds of information systems in the 21st Century. These are being enabled by rapidly emerging wireless communications systems, based on radio and infrared transmission mechanisms, and utilizing such technologies as cellular telephony, personal communications systems, wireless PBXs, and wireless local area networks. These systems have the potential to dramatically change society as workers become "untethered" from their information sources and communications mechanisms. While there is a rich body of knowledge associated with radio system engineering, the needed expertise must build upon this to encompass network management, integration of wireless and wireline networks, system support for mobility, computing system architectures for wireless nodes/base stations/servers, user interfaces appropriate for small handheld portable devices, and new applications that can exploit mobility and location information. Today, there exists no well-defined body of knowledge a student must learn to become proficient in wireless communications and mobile information systems. This is an emerging field, and builds on radio engineering, data communications, computer networks, distributed systems, information management, and applications. This course will follow an interdisciplinary "tall thin" approach, making the physical limitations of communications technologies understandable to the computer scientist, while making the system architecture and applications accessible to the electrical engineer. In the long tradition of advanced graduate courses at Berkeley, this one will combine extensive reading and in-class discussion of the research literature with in-depth independent research projects of the students' own choosing. Content: Overview of the emerging field of mobile computing; Historical perspectives (mainly from the perspective of radio); Land mobile vs. Satellite vs. In-building communications systems; RF vs. IR; Cellular telephony; Mobility support in cellular telephone networks; Personal Communications Systems/Personal Communications Networks; Wireless local area networks; Direct Broadcast Satellite; Low Earth Orbiting Satellites;

Greenwich:

The University of Greenwich, UK, has a degree on Mobile Computing and Communications. Several subjects there touch the objectives of our proposal, but the nearest subject is the course on Mobile Technologies.

Mobile Technologies - Mobile technologies are becoming an integral part of building and deploying modern distributed computing systems. In the last few years, there has been a proliferation of architectures, protocols and standards for wireless and mobile communications. In this context, computer professionals need to be aware of current and emerging technologies in order to design mobile/wireless networks suited to user requirements. This course deals with wireless communication

and the underlying protocols and technologies. The emphasis is on critical evaluation of existing technology options and future developments. The discussion is mainly of layers 1-4 of the OSI model, with some coverage of application level issues. Indicative Content:

Mobile applications - examples, service requirements, technical challenges.
Wireless media (IR, RW, MW): frequencies, range, bandwidth, cellular systems, terrestrial and satellite MW etc. Regulatory and standards bodies - FCC, OfCom, ITU-T etc.
Protocol architectures (OSI layer 2): 2G/3G cellular systems (GSM, GPRS, UMTS), LANs and Piconets (Bluetooth, 802.11); brief mention of DECT, TETRA and other systems.
Network layer issues and protocols - Mobile IP, addressing & routing for mobile systems.
Transport and application layer protocols: WAP and beyond.
Security in wireless systems.

From the widespread offer of these courses it becomes clear that the relevance of our proposal is felt world-wide. As detailed in section A4, the proposal addresses multiple aspects of the courses presented above, exploiting well-known teaching practices. The course is particularly targeted for the engineering students aimed at building global distributed communications and computation environments.

A2 – Objectives

The objectives of this course are threefold:

1. To provide the students with the knowledge required to understand (a) emerging communications networks, (b) their computational demands, (c) the classes of distributed applications and services enabled by these networks, and (d) the computational resources required to create the new networks and the new applications;
2. To provide the students with the practical skills required to develop services and applications for new integrated networks;
3. To enable the students to identify the relationships between the global, pervasive, computation environment and the communications infrastructure which supports it.

A3 –Learning outcomes

At the end of this course, students should be able to:

1. Describe integrated communications networks.
2. Enumerate and compare major communications technologies, and describe their architectures and capabilities.
3. Describe the emerging paradigms in communications networks integration.
4. Identify the computational demands of the emerging integrated networks, both from the functional and performance points of view.
5. Explain why integrated networks demand new computational approaches and the use of new information technologies.
6. Describe the concept of service oriented architectures and provide detailed examples of existing solutions.
7. Be able to evaluate available technologies for the design and implementation of wireless networks according to user requirements
8. Develop services to support the concept of service oriented architecture for specific technological environments (e.g. for mobile networks), specially focusing on current commercial trends.
9. Develop user services and applications over integrated networks.
10. Create innovative applications that exploit the emerging capabilities of integrated networks.

A4 – Program

The course consists of 6 parts. Part 1 and 2 address the concepts and trends of the new global wireless environments; first from the traditional telecom operator perspective, and then from the perspective of new communications paradigms. Parts 3 and 4 survey and compare the communications technologies, and the protocols and the functions required to build a seamless and transparent service environment .In Part 5, the Service Oriented Architectures are addressed and one of them is studied in detail. Part 6 addresses the technologies and the concepts required to develop services and applications, which enable the realization of the global communications paradigm, both from the users and the telecom operator perspectives.

1. New generation networks overview
    a. Integration of services and technologies
    b. Networks evolution
    c. Standards and market issues
2. Trends for the emerging communications networks
    a. Self-organized networks
    b. Opportunistic networking
    c. Peer-to-peer networks
3. Communications networks technologies
    a. Fundamentals of communications
    b. Wired technologies (LAN, cable, xDSL)
    c. Wireless technologies (WLAN, WMAN, UMTS)
    d. Broadcast and satellite technologies (DVB, DMB)
4. Protocols and functions for integrated networks
    a. Mobility management
    b. Authentication and access control
    c. Quality of service
    d. Billing
    e. Service discovery
5. Service oriented architectures
    a. Architecture, service logic, and components
    b. Mobile example: 3G - Integrated Multimedia Subsystem.
6. Services and applications in novel generation networks
    a. Web services
        i. XML and SOAP
        ii. UDDI and WSDL
    b. Services and applications platforms
        i. Intelligent networks
        ii. Mobile execution evironment
        iii. CAMEL
        iv. Parlay/OSA
    c. Positioning and location
    d. Messaging services
    e. Broadcasting services

A5 – Learning methods

Students will be provided with lecture notes and reading material, ranging from lecture books to research papers. Furthermore, the course will be supplemented by working exercises. On a bi-weekly basis,

students will be required to realize exercises and class work, which will reinforce the lecture contents. By the end of the course, students will have to prepare a short presentation on a research item associated with the course.

A6 – Assessment

Students will be evaluated by:

- Final written examination – evaluating the overall comprehension of the subject
- Class work – evaluating different detailed aspects of the taught subjects
- Final Presentation – evaluating the ability of the student to understand research questions on the area.

A7 – Literature References

Students will be provided with several papers on the issues taught. Nevertheless, several books exist that can/will be used as supporting material for the course:

- Wireless and Mobile Network Architectures, Yi-Bing Lin, Imrich Chlamtac Wiley, 2001
- Wireless IP and Building the Mobile Internet, Sudhir Dixit, Ramjee Prasad, Artech House, 2002.
- The 3G IP Multimedia Subsystem, Merging the Internet and the Cellular Worlds, Gonzalo Camarillo and Miguel a. Garcia-Martin,Wiley, Second Edition, 2005
- Network Convergence - Services, Applications, Transport, and Operations Support, Hu Hanrahan, Wiley 2007
- Advanced Wireless Networks - 4G Technologies, S. Glisic, Wiley, 2006.
- Mobile Communications, Jochen Schiller, Second Edition, Addison-Wesley, 2003
- Wireless Communications - Principles and Practice, Theodore S. Rappaport, Second Edition, Prentice Hall, 2002
- Mobile IP Technology and Applications, Stefan Raab and Madhavi W. Chandra, Cisco Press, 2005

A8 – Other points

The team is willing to consider this subject for the CMU doctoral programme, although this will depend on the requirements. Note that one of the elements of the team is coordinating the implementation of the MSIN, a joint Masters at UA with CMU.

B. Team

B.1 Brief Description

The team proposing this programme is ideally suited to its presentation, under the overall objective of a computer communications subject essential for a proper understanding of the area of universal distributed communications.
The team has a remarkable record of past scientific experience in these areas: Prof Moreira has been involved in the last years on the problematic of smart places, an area central to the concepts of pervasive communications; Prof. Ricardo is leading the Network and Service area inside INESC, and addressing communication technologies for ambient networks; and Prof. Aguiar has been developing a group on heterogeneous networking, where application-level issues (such as pervasive environments) play a strong part. Overall, the three teams have in the last three years published in this thematic more than 25 papers/chapters in journals/books, more than 100 papers in international conferences, and have more than a dozen of PhD students on the area. Again in the last three years, the team was involved in 10 european-funded projects surrounding the central areas of this course.
Besides the academic excellence, it should be noticed that the teaching experience of these three professors in the area is also very large. All of them have been lecturing to graduate and under-graduate degrees subjects similar to those described in section A.4, to the different degrees proposed in their respective university, to a compounded total of more than 35 years of teaching.
Finally, and an issue not to neglect: the relationships between the members of the team have been established for long, and previous shared worked already exists (such as previous work on optical wireless, or current work in European projects), or is planned (in pending submissions for FCT funding). Currently this team is working together in a subject lectured to the MAP-Tele, “Wireless Networks and Protocols”, having thus already demonstrated their ability in working together in the context of collaborative teaching for post-graduate studies.

B.2 CVs resumed

(note: for brevity sake, only recent publications are presented in these CVs)

Adriano Moreira is an Associate Professor in the Department of Information Systems, University of Minho, since 1996. He received the "Licenciatura" degree in Electronics and Telecommunications Engineering and the Ph.D. degree in Electrical Engineering, respectively in 1989 and 1997, from the University of Aveiro - Portugal. He has been a voting member of the IEEE 802.11 working group where he participated in the specification of the infrared physical layer. His research interests are in indoor optical wireless transmission systems, wireless local area networks, and mobile and context-aware computing. His research activities have been developed within the ubicom@uminho research group at the University of Minho, which has been focusing its research in the creation of technologies for smart places. In the past few year he participated in many research projects funded by national and European programs, such as Supporting Location Based Internet Services (AROUND, FCT), Easy and friendly access to geographic information for mobile users (HYPERGEO, IST), Value Added Environments for Dynamic Support to Location-Based Services in UMTS Networks (VADE, FCT), Environmental Policy via Sustainability Indicators On a European-wide NUTS-III Level (EPSILON, IST), Location contexts for location-aware applications (LOCAL, FCT), and USability-drivEn open platform for MobilE GOVernment (USE-ME.GOV, IST). He is a member of the IEEE and the Communications Society.

Publications (last five years)