Course guide
270127 - SDX - Distributed Network Systems

Last modified: 30/01/2024

Unit in charge: Barcelona School of Informatics
Teaching unit: 701 - DAC - Department of Computer Architecture.

Degree: BACHELOR'S DEGREE IN INFORMATICS ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: JORDI GUITART FERNANDEZ

Others:

PRIOR SKILLS

Students require knowledge of operating systems (OS) and computer networks (XC)

REQUIREMENTS

- Pre-Corequisite SO
- Pre-Corequisite XC

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CT5.6. To demonstrate knowledge and capacity to apply the fundamental principles and basic techniques of parallel, concurrent, distributed and real-time programming.
CT6.4. To demonstrate knowledge and capacity to apply the characteristics, functionalities and structure of the Distributed Systems and Computer and Internet Networks guaranteeing its use and management, as well as the design and implementation of application based on them.
CTI1.3. To select, deploy, integrate and manage information system which satisfy the organization needs with the identified cost and quality criteria.
CTI3.1. To conceive systems, applications and services based on network technologies, taking into account Internet, web, electronic commerce, multimedia, interactive services and ubiquitous computation.
CTI3.2. To implement and manage ubiquitous systems (mobile computing systems).
CTI3.4. To design communications software.

Generical:
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

TEACHING METHODOLOGY

During the course there will be two types of activities:

a) Activities focused on the acquisition of theoretical knowledge.
b) Activities focused on the acquisition of knowledge through experimentation by implementing and evaluating empirically in the laboratory the mechanisms explained at a theoretical level.

The theoretical activities include participatory lecture classes, which explain the basic contents of the course, besides the reading of articles/reports, either as preparation for lectures or as to facilitate the subsequent development of important concepts. In order to work the transversal competence the articles will be written in English.

The practical activities include seminar laboratories where students implement (in groups of 2) the mechanisms described in the lectures. The seminars require a preparation by reading the statement and supporting documentation, and a further elaboration of the conclusions in a report. In order to work the transversal competence the seminar documentation will be written in English.

LEARNING OBJECTIVES OF THE SUBJECT

1.Understand the definition of distributed system and its possible applications, as well as challenges to be faced to design and implement it.
2.Understand the basic system architectures in distributed systems.
3.Understand the basic mechanisms of communication in a distributed system: invocation of remote operations, message-based communication, event-based communication and channel-based communication (streams), and write distributed applications that communicate by sending messages.
4.Understand the problem of time and events ordering in a distributed system and explain and implement the mechanisms of logic clocks to attack this problem and algorithms to synchronize physical clocks in a distributed system.
5.Describe, compare and implement algorithms for the coordination of processes in a distributed system, including the coordination necessary to ensure mutual exclusion, leader election, multicast group communication and consensus.
6.Understand the application of replication in a distributed system, as well as the consistency problems introduced, and describe the corresponding consistency models and their implementation.
7.Understand and compare basic features of name resolution services for flat, structured and attribute-based names, and implement and evaluate one of these systems.
8.Understand and compare the basic characteristics of distributed filesystems (e.g. NFS).
9.Understand and compare the basic characteristics of Web-based distributed systems: web servers, application servers, Web Services, Content Distribution Networks (CDN), and implement and evaluate one of these systems.
10.Understand the Peer-to-Peer (P2P) computing model, compare the characteristics of non-structured P2P systems and structured systems based on DHTs, and implement and evaluate one of these systems.
11.Know the most important distributed computing paradigms (volunteer computing, Grid and Cloud) and their characteristics.
12.Know the paradigms of Mobile and Ubiquitous Computing and their problems.
13.Understand articles, assignments, and any source of technical information written in English

STUDY LOAD

Type	Hours	Percentage
Hours small group	30,0	20.00
Guided activities	6,0	4.00
Self study	84,0	56.00
Hours large group	30,0	20.00

Total learning time: 150 h

CONTENTS

Concepts underlying distributed systems

Description:
Definition of a distributed system. Potential applications of a distributed system. Examples of distributed systems. Challenges to design and implement a distributed system: heterogeneity, lack of global view, security, coordination, asynchrony, openness transparency, fault tolerance, scalability. Basic system architectures in distributed systems: centralized (client-server), decentralized (peer-to-peer), hybrid

Interprocess communication

Description:
Types of communication in a distributed system: direct vs. indirect (space and time uncoupling), persistent vs. transient, synchronous vs. asynchronous, discrete vs. continuous. Basic communication paradigms in distributed systems: remote procedure call, message passing, message queuing, group communication, publish/subscribe, shared data spaces, shared-memory, mobile code, stream-oriented. Invocation of remote procedures (RPC): basic operation, parameter passing, extensions of the basic model, failure handling, remote method invocation (RMI). Message-oriented communication based on : transient (Sockets) vs. persistent (MOM). Event-based communication: publish/subscribe systems. Stream-based communication: transmission modes, quality of service

Time and order

Description:
Time and events ordering in a distributed system. Logical clocks: happened-before relation, Lamport logical clocks (scalar, vector). Algorithms to synchronize physical clocks in a distributed system: Cristian (NTP), Berkeley.

Coordination and agreement

Description:
Coordination of processes in a distributed system to ensure mutual exclusion: permission-based algorithms (centralized, Lin's, Maekawa's, Ricart & Agrawala's), token-based algorithms (token ring). Coordination of processes in a distributed system for the election of leader: Bully, Ring. Coordination of processes in a distributed system for multicast group communication: basic reliable multicast, scalable reliable multicast, ordered multicast (FIFO, causal, total), atomic multicast.

Consistency and replication

Description:
Replication and consistency in a distributed system. Data-centered strong consistency models: strict, sequential, causal, FIFO. Data-centric relaxed consistency models: usage of synchronization variables. Client-centric consistency models: eventual, monotonic-read, monotonic-write, read-your-writes, writes follow-reads. Replica placement (permanent, initiated by the server, initiated by the client) and propagation of updates (push-pull protocols). Implementations of consistency models: primary-based protocols (remote-write, local-write) and replicated-write protocols (active replication, quorum-based protocols)

Naming systems

Description:
Name resolution services for flat names: broadcasting, forwarding pointers, home-based solutions, DHTs. Name resolution services for structured names: name spaces, iterative resolution, recursive resolution, DNS. Name resolution services for attribute-based names: directory services (LDAP)

Distributed file systems

Description:
Architectures of distributed file systems: remote access model, upload / download model, the basic idea of □□clustered architectures (stripping + replication). Semantics of file sharing: UNIX semantics, session semantics, immutable files, transactional semantics. Basic features of the NFS distributed file system. Basic features of the Coda distributed file system

Distributed Web-based systems

Description:
Architectures of distributed Web-based systems: client/server, servlets, server clusters, Web Services. Communication protocols in distributed Web-based systems: HTTP, SOAP, WSDL. Name services in distributed Web-based systems: URL, DNS, UDDI. Synchronization mechanisms in distributed Web-based systems. Replication and caching in distributed Web-based systems: Proxies, Content Distribution Networks (CDN): Akamai, redirection schemes (URL Rewriting, DNS redirection)

Peer-to-Peer (P2P) systems

Description:
Peer-to-Peer (P2P) computing model, its advantages, and its applications. Non-structured centralized P2P systems: BitTorrent. Non-structured decentralized P2P systems with flooding-based search: Gnutella. Non-structured hierarchical P2P systems: FastTrack. Structured P2P systems based on DHTs: Chord: organization of the ring, inserting items, searching items with finger tables, inserting nodes; Kademlia: organization of the tree and node state, node lookup and join, finding and storing items.

Distributed computing systems

Description:
Volunteeer distributed computing paradigm: BOINC. Grid paradigm for distributed computing, its characteristics and its applications: Virtual Organizations (VO), OGSA architecture, difference from the cluster and distributed computing. Cloud paradigm for distributed computing, its characteristics, and its applications: Utility Computing, type of Clouds (public, private, community, hybrid), differences with Grid computing, Cloud Services (IaaS, PAAS, SaaS), base technologies for implementation, Cloud infrastructure (datacenters), obstacles to the consolidation of the Cloud

Mobile and ubiquitous systems

Description:
Mobile and ubiquitous systems: volatility, association, interoperability, sensors and context-awareness, adaptation

ACTIVITIES

Developing the lesson "Concepts underlying distributed systems"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
1, 2

Full-or-part-time: 4h
Theory classes: 2h
Self study: 2h

Seminar assignment #1

Description:
Preparation of the seminar with the help of the support material. Implementation and analysis of the requested mechanism. Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
1, 2, 3, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 4h
Laboratory classes: 4h

Reading assignment #1

Description:
Read of the proposed article. Understanding and assimilation of the contents of the article. Making of a reading report

Specific objectives:
1, 2, 3, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 3h
Self study: 3h

Developing the lesson "Interprocess communication"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
3

Full-or-part-time: 6h
Theory classes: 3h
Self study: 3h

Seminar assignment #2

Description:
Preparation of the seminar with the help of the support material. Implementation and analysis of the requested mechanism. Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
4, 5, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 4h
Laboratory classes: 4h

Report about seminari assignment #1

Description:
Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
1, 2, 3, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 4h
Self study: 4h

Developing the lesson "Time and order"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
4

Full-or-part-time: 3h
Theory classes: 1h 30m
Self study: 1h 30m

Reading assignment #2

Description:
Read of the proposed article. Understanding and assimilation of the contents of the article. Making of a reading report

Specific objectives:
4, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 3h
Self study: 3h

Developing the lesson "Coordination and agreement"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
5

Full-or-part-time: 6h
Theory classes: 3h
Self study: 3h

Seminar assignment #3

Description:
Preparation of the seminar with the help of the support material. Implementation and analysis of the requested mechanism. Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
5, 6, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 6h
Laboratory classes: 6h

Report about seminar assignment #2

Description:
Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
4, 5, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 4h
Self study: 4h

Reading assignment #3

Description:
Read of the proposed article. Understanding and assimilation of the contents of the article. Making of a reading report

Specific objectives:
5, 6, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 3h
Self study: 3h

Developing the lesson "Consistency and replication"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
6

Full-or-part-time: 6h
Theory classes: 3h
Self study: 3h

Seminar assignment #4

Description:
Preparation of the seminar with the help of the support material. Implementation and analysis of the requested mechanism. Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
5, 6, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 6h
Laboratory classes: 6h

Report about seminar assignment #3

Description:
Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
5, 6, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 6h
Self study: 6h

Reading assignment #4

Description:
Read of the proposed article. Understanding and assimilation of the contents of the article. Making of a reading report

Specific objectives:
7, 8, 9, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 3h
Self study: 3h

Developing the lesson "Naming systems"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
7

Full-or-part-time: 4h
Theory classes: 2h
Self study: 2h

Partial exam

Description:
Assimilation of the concepts of the course and conduct of the examination

Specific objectives:
1, 2, 3, 4, 5, 6, 7

Full-or-part-time: 9h
Guided activities: 1h 30m
Self study: 7h 30m

Developing the lesson "Distributed file systems"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
8

Full-or-part-time: 4h
Theory classes: 2h
Self study: 2h

Seminar assignment #5

Description:
Preparation of the seminar with the help of the support material. Implementation and analysis of the requested mechanism. Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
7, 9, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 4h
Laboratory classes: 4h

Report about seminar assignment #4

Description:
Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
5, 6, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 6h
Self study: 6h

Reading assignment #5

Description:
Read of the proposed article. Understanding and assimilation of the contents of the article. Making of a reading report

Specific objectives:
10, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 3h
Self study: 3h

Developing the lesson "Distributed Web-based systems"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
9

Full-or-part-time: 4h
Theory classes: 2h
Self study: 2h

Developing the lesson "Peer-to-Peer (P2P) systems"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
10

Full-or-part-time: 6h
Theory classes: 3h
Self study: 3h

Seminar assignment #6

Description:
Preparation of the seminar with the help of the support material. Implementation and analysis of the requested mechanism. Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
10, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 6h
Laboratory classes: 6h

Report about seminar assignment #5

Description:
Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
7, 9, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 4h
Self study: 4h

Developing the lesson "Distributed computing systems"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
11

Full-or-part-time: 4h
Theory classes: 2h
Self study: 2h

Reading assignment #6

Description:
Read of the proposed article. Understanding and assimilation of the contents of the article. Making of a reading report

Specific objectives:
11, 12, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 3h
Self study: 3h

Developing the lesson "Mobile and ubiquitous systems"

Description:
Class preparation with the help of the support material. Understanding and assimilation of the lesson contents and their subsequent application

Specific objectives:
12

Full-or-part-time: 4h
Theory classes: 2h
Self study: 2h

Report about seminar assignment #6

Description:
Preparation of the seminar with the help of the support material. Implementation and analysis of the requested mechanism. Making of a report of the seminar explaining the work done and the conclusions drawn

Specific objectives:
10, 13

Related competencies :
G3. THIRD LANGUAGE: to know the English language in a correct oral and written level, and accordingly to the needs of the graduates in Informatics Engineering. Capacity to work in a multidisciplinary group and in a multi-language environment and to communicate, orally and in a written way, knowledge, procedures, results and ideas related to the technical informatics engineer profession.

Full-or-part-time: 6h
Self study: 6h

Final Exam

Description:
Assimilation of the concepts of the course and conduct of the examination

Specific objectives:
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

Full-or-part-time: 12h
Guided activities: 3h
Self study: 9h

GRADING SYSTEM

A) Individual written mid-term exam.
B) Individual written final exam.
-- B1) Evaluation of contents included in the mid-term exam, for the students that failed.
-- B2) Evaluation of contents not included in the mid-term exam, for all the students.
C) Assessment of reading reports and article discussion.
D) Evaluation of the laboratory seminars.

For the students that have passed the mid-term exam (A>=5) and do not perform the B1 part of the final exam, the final grade will be calculated in the following way:

Final Grade = 0.25 x A + 0.25 x B2 + 0.2 x C + 0.3 x D

Otherwise, the final grade will be calculated as follows:

Final Grade = 0.25 x B1 + 0.25 x B2 + 0.2 x C + 0.3 x D

The grading of the transversal competence will be done through the evaluation of the activities C and D, which provide the supporting documentation in English.

BIBLIOGRAPHY

Basic:
- Steen, M. van ; Tanenbaum, A.S. Distributed systems. 3rd ed. Pearson Educación, 2017. ISBN 9781543057386.
- Coulouris, G.; [et al.]. Distributed systems: concepts and design. 5th ed., int. ed. Addison-Wesley/Pearson Education, 2012. ISBN 9780273760597.
- Ghosh, S. Distributed systems: an algorithmic approach. 2nd ed. Chapman and Hall/CRC, 2014. ISBN 9781466552982.

Complementary:
- Armstrong, J. Programming Erlang: software for a concurrent world. 2nd ed. Raleigh, N.C: Pragmatic Bookshelf, 2013. ISBN 9781937785536.
- Cesarini, F.; Thompson, S. Erlang programming. O'Reilly, 2009. ISBN 9780596518189.
- Guitart, J.. Slides for SDX Lectures.
- Guitart, J.. Seminar Assignments for SDX.