COURSE DESCRIPTION CARD - SYLLABUS

Course name
Time and frequency in ICT [S1MiKC1>CiCwICT]

Course

Field of study
Microelectronics and Digital Communication

Year/Semester
2/4

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
elective

Number of hours

Lecture
15

Laboratory classes
15

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

2,00

Coordinators

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Lecturers

Prerequisites

A student starting the course should have basic knowledge of data transmission, telecommunications, computer and radio networks. They should know the basic concepts related to signals and systems, including the analysis of signals in the time and frequency domain, and be aware of the importance of synchronization in telecommunications systems. The ability to obtain technical information from documentation and industry standards and basic knowledge of statistical analysis methods are recommended.

Course objective

The course aims to provide students with knowledge about the basic sources of time and frequency signals (quartz oscillators, atomic clocks) and methods of their distribution in teleinformatic networks (NTP, PTP, SyncE, GNSS, radio systems). Students will learn to evaluate time parameters, including time error, time interval error, and time deviation. The subject develops the ability to analyze the quality of synchronization and understand the standards and technologies used in modern telecommunication systems.

Course-related learning outcomes

Knowledge:
The student uses advanced mathematical knowledge to analyze time parameters, such as time error, time interval error, and time deviation, which allows for the evaluation of synchronization quality. (K1_W01)
The student knows the theory of signals and methods of analyzing linear systems, which is necessary to understand the principles of operation of time and frequency signal sources and their propagation in ICT networks. (K1_W02)
The student has knowledge of the structure and standards of telecommunications networks used in the distribution of synchronization signals using protocols such as NTP, PTP, and SyncE. (K1_W13)

Skills:
The student is able to obtain and analyze information from literature and other sources in Polish and English, integrating the obtained information in order to develop issues related to network synchronization and synchronization quality assessment. (K1_U01)
The student is able to analyze the parameters and properties of time and frequency signals, including their propagation and impact on synchronization quality in various transmission conditions. (K1_U08)
The student is able to configure and supervise synchronization networks, selecting appropriate technologies and transmission methods for ICT systems in the context of user mobility and propagation conditions. (K1_U09)

Social competences:
The student notices the changes resulting from technological progress in the field of synchronization of teleinformatic networks and understands the need to learn new standards in order to adapt to the latest achievements in this field. (K1_K01)
The student is aware of the need for a professional approach to the design and implementation of time synchronization systems in ICT networks. He knows the risks resulting from improper design of these systems and is aware of the potential threats to the stability and security of the network. (K1_K02)

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Lecture:
The verification of learning outcomes is conducted through a multiple-choice test. The assessment topics, on which the questions are based, will be made available to students via the university's online learning platform. To obtain a grade of 3.0, it is necessary to earn more than half of the possible points, while the remaining grades are awarded according to the standard grading thresholds, increasing by 10% intervals.
Laboratory:
The learning outcomes are assessed through:
1. Continuous assessment - each verification of knowledge through oral answers to questions asked during laboratory exercises - weight in the final grade: 20%.
2. Reports on the exercises performed, including an analysis of the results' correctness and identification of potential problems - weight in the final grade: 30%.
3. The grade obtained from the test summarizing the exercises, checking both theoretical knowledge and practical skills - weight in the final grade: 50%.
4. Additional points for activity during laboratory classes, e.g., for initiative in solving problems related to the laboratory exercises performed.
To obtain a grade of 3.0, it is necessary to earn more than half of the possible points, while the remaining grades are awarded according to the standard grading thresholds, increasing by 10% intervals.

Programme content

The lecture and laboratory program provides knowledge and skills related to time and frequency synchronization in ICT systems, focusing on modern technologies used in the synchronization of Ethernet networks and 5G/6G industrial networks and includes global time distribution systems via GNSS. The laboratories provide practical experience in the measurement and implementation of synchronization, enabling students to fully understand the challenges related to these issues.

Course topics

Lecture Topics:
1. Introduction to Time and Frequency Synchronization (1 hr)
Introduction to the fundamental issues of synchronization in telecommunication systems, emphasizing the role of synchronization in communication networks and its importance in industrial 5.0 and WSN systems. A brief overview of synchronization technology in the context of modern networks.
2. Sources of synchronization signals and time distribution (2 hrs)
A discussion of various sources of synchronization signals: quartz oscillators, atomic clocks, and their role in the distribution of time signals in telecommunication systems. Introduction to time distribution systems such as GNSS (GPS, Galileo, GLONASS).
3. Ethernet-based synchronization: SyncE, PTP, White Rabbit (3 hrs)
A detailed analysis of synchronization protocols such as SyncE and PTP and the White Rabbit technology used in Ethernet networks for high-precision synchronization systems.
4. Synchronization in Radio Networks (3 hrs)
Discussion of the challenges and requirements related to synchronization in 5G/6G networks, with an emphasis on new synchronization mechanisms such as Synchronized Time Division Duplex (TDD) and PTP-based synchronization.
5. Synchronization Signal Model and Synchronization Signal Parameters (3 hrs)
Detailed considerations on synchronization signal parameters such as time error and other synchronization quality indicators in various telecommunications systems.
6. Importance of Synchronization in WSNs, Communication Networks and Industry 5.0 (2 hrs)
Analysis of the role of synchronization in WSNs, in the context of Industrial 5.0 systems and the general challenges related to the implementation of synchronization in these areas.
7. Summary (1 hr)
Summary of lectures, Q&A, assessment of acquired knowledge.
Lab topics:
Lab. 1: Measuring the quality of synchronization of devices (5 hrs)
The aim of the laboratory exercise is to practically check the quality of synchronization in devices using crystal oscillators. Students will evaluate the quality of synchronization using measurement tools and comparing the results with standards.
Lab. 2: Implementation of synchronization based on Ethernet (5 hrs)
Students will work with the synchronization system via NTP and PTP protocols. The aim is to understand the synchronization mechanisms in packet networks and their practical application in the laboratory environment.
Lab. 3: Analysis of synchronization quality in GNSS-based systems (5 hrs)
In this project, students will get acquainted with GNSS-based time distribution by performing a time synchronization simulation and evaluating the quality of synchronization in systems based on GPS, Galileo and GLONASS.

Teaching methods

Lectures:
1. Multimedia presentation: the lecturer presents the material using slides, supplemented with photos, videos, and other visual elements, real devices/measurements of synchronization systems.
2. Interactive lecture: the lecturer engages students in discussion, asks questions, and encourages them to share their thoughts, supporting a better understanding of the material and developing critical thinking skills.
3. Case study: the lecturer discusses a specific example, analyzes the problem, and proposes solutions. This allows for the application of theoretical knowledge in practice.
Laboratory:
1. Simulations: Students work with computer programs that imitate real situations.
2. Practical exercises: Students perform tasks under the lecturer's supervision, learning how to apply their knowledge in practice.
3. Group work: Students cooperate to solve problems, share knowledge, and develop communication and teamwork skills.

Bibliography

Basic:
[1] ETSI, "Synchronization in telecommunication networks," ETSI TS 102 031, 2018.

[2] IEEE, "IEEE Standard for Precision Clock Synchronization Protocol for Networked Measurement and Control Systems," IEEE Std 1588-2008, 2008.
[3] ITU-T, "Timing and synchronization in packet networks," ITU-T Rec. G.8272, 2016.

Additional:
[4] S. Galli and L. Musumeci, "Synchronization of Digital Telecommunication Networks," Academic Press, 2003.
[5] L. Shu and M. Youssef, "Time Synchronization in Wireless Sensor Networks," Springer, 2012.

Breakdown of average student's workload

	Hours	ECTS
Total workload	60	2,00
Classes requiring direct contact with the teacher	30	1,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	30	1,00