SYLLABUS

1. Data about the program of study

1.1 Institution	Technical University of Cluj-Napoca
1.2 Faculty	Faculty of Electronics, Telecommunications, and Information Technology
1.3 Department	Communications
1.4 Field of study	Electronic Engineering, Telecommunications, and Information Technologies
1.5 Cycle of study	Master of Science
1.6 Program of study / Qualification	Telecommunications / Master
1.7 Form of education	Full time
1.8 Subject code	TC-E16.30

2. Data about the subject

2.1 Subject name	Traffic Prediction in Telecommunications using Artificial Intelligence						
2.2 Subject area	Theoretical area Methodological area Analytic area						
2.3 Course responsible	Professor Virgil DOBROTA, Ph.D. Virgil.Dobrota@com.utcluj.ro						
2.4 Teacher in charge with seminar / laboratory / project	Professor Virgil DOBROTA, Ph.D. Virgil.Dobrota@com.utcluj.ro Assoc. Prof. Daniel ZINCA, Ph.D. Daniel.Zinca@com.utcluj.ro						
2.5 Year of study	2	2.6 Semester	3	2.7 Assessment	E	2.8 Subject category	DS/DO

3. Estimated total time

3.1 Number of hours per week	4	of which: 3.2 course	2	3.3 laboratory	1
3.4 To Total hours in the curriculum	42	of which: 3.5 course	28	3.6 laboratory	14

Distribution of time	hours
Manual, lecture material and notes, bibliography	20
Supplementary study in the library, online specialized platforms and in the field	12
Preparation for seminars / laboratories, homework, reports, portfolios and essays	20
Tutoring	3
Exams and tests	3
Other activities:	

3.7 Total hours of individual study	58
3.8 Total hours per semester	100
3.9 Number of credit points	4

4. Pre-requisites (where appropriate)

4.1 curriculum	Introduction to artificial intelligence, Traffic theory, Modeling with queuing systems
4.2 competence	N. A.

5. Requirements (where appropriate)

5.1. for the course	Amphitheatre, Cluj-Napoca
5.2. for the seminars / laboratories / projects	Laboratory, Cluj-Napoca

6. Specific competences

Professional competences	C4. Design, implementation and operation of data, voice, video, and multimedia services. This is based on the understanding and the application of fundamental concepts in telecommunications and transmission of information. C5. Selecting, installing, configuring, and operating fixed or mobile telecommunications equipment. Equipping a site with usual telecommunications networks C7. Design, implementation and testing of systems and of various types of applications (signal processing, classification, regression, detection, natural language processing, shape recognition) based on machine learning or deep learning techniques
Cross competences	N.A.

7. Discipline objectives (as results from the key competences gained)

7.1 General objective	Development of professional skills regarding the traffic prediction in telecommunications networks using artificial intelligence.
7.2 Specific objectives	1. Understanding the basic concepts of modeling, classification, and prediction of data traffic. 2. Development of skills and abilities necessary to use algorithms for automatic learning and deep learning in traffic prediction in general, with particularization for telecommunications traffic. 3. Development of skills and abilities necessary to implement software applications related to traffic prediction using software-defined networks, cloud computing, IoT and artificial intelligence.

8. Contents

8.1 Lecture (syllabus)	Teaching methods	Notes
1. Traffic data in telecommunications networks. The role of traffic classification and traffic prediction in network operation and management.	The discipline content and the acquired skills agree with the expectations of the professional	The discipline content and the acquired skills agree with the expectations of the professional
2. Real datasets commonly and widely used in traffic classification and prediction.		
3. Traffic classification methods and models.		
4. Methods and models of data flow prediction		
5. Machine learning algorithms for traffic classification: Support Vector Machine (SVM), Decision Tree (DT), Random Forests (RFs).		
6. Deep learning algorithms for traffic classification.		

7. Statistical models for network data flow prediction (I): AutoRegressive Moving Average (ARMA), AutoRegressive Integrated Moving Average (ARIMA).		
8. Statistical models for network data flow prediction (II): Seasonal AutoRegressive Integrated Moving Average (SARIMA). Time-Series Decomposition, Time-Series Clustering.		
9. Machine learning algorithms for the prediction of data flow in the network: Linear Regression (LR), Support Vector Machine (SVM), Random Forests (RFs).		
10. Deep learning algorithms for the prediction of data flow in the network: Long Short Term Memory (LSTM), Gater Recurrent Unit (GRU), Convolution Neural Network (CNN), Recurrent Neural Network (RNN).		
11. Applications of traffic prediction using artificial intelligence in the Software-Defined Networks (SDN), Cloud Computing and in the Internet of Things (IOT).		
12. Applications of traffic prediction using artificial intelligence for the Quality of Service (QoS) in local networks.		
13. Open research issues and future research trends.		
14. Recap. Examples of subjects from the previous year's exam.		

Bibliography

1. M. Shaygan, C. Meese, W. Li, X. Zhao, M. Nejad, „Traffic Prediction using Artificial Intelligence: Review of Recent Advances and Emerging Opportunities”, Transportation Research Part C: Emerging Technologies, Vol. 145, December 2022, 1039212023, Elsevier.
2. A. Volkov, et. al., “IoT Traffic Prediction with Neural Networks Learning Based on SDN Infrastructure”, In: V.M. Vishnevskiy, K.E. Samouylov, D.V. Kozyrev (editors), “Distributed Computer and Communication Networks”, DCCN 2020. Lecture Notes in Computer Science, vol 12563. Springer, Cham, https://doi.org/10.1007/978-3-030-66471-8_6.
3. A. Chen, J. Law, and M. Aibin, "A Survey on Traffic Prediction Techniques using Artificial Intelligence for Communication Networks", Telecom, MDPI, 2021, Vol. 2, No. 4, pp. 518-535.
4. F. Rau et. al., “A Novel Traffic Prediction Method Using Machine Learning for Energy Efficiency in Service Provider Networks”, Sensors, MDPI, 2023, Vol. 23, Issue 11. https://doi.org/10.3390/s23114997.

8.2 Laboratory	Teaching methods	Notes
1. Capture and analysis of data traffic in local networks using Wireshark	Practical experiments on physical, virtual, cloud and emulator equipment.	N/A
2. Capture and analysis of data traffic in local networks using NetFlow.		
3. Extracting relevant traffic features from large datasets using CICFlowMeter-V3 application.		
4. Software application of network data traffic classification: TCP protocol fingerprinting to detect implementation version.		

5. Software application of network data traffic classification: automatic detection of common Application Layer protocols (HTTPS, DNS, DHCP, SNMP, etc.)		
6. Software application of network traffic prediction using the ARMA, ARIMA and SARIMA statistical methods.		
7. Software application of network traffic prediction using the Reservoir Computing		
8. Software application of network traffic prediction using the LSTM algorithm on a provided dataset.		
9. Software application of network traffic prediction using the GRU algorithm on a provided dataset.		
10. ONOS, RYU, and ODL Software-Defined Network controllers with traffic prediction.		
11. Software application of IOT traffic prediction in wireless sensor networks.		
12. Software application for integrating traffic prediction into the Quality of Service QoS.		
13. Software application for integrating traffic prediction into management and orchestration of public/ private/ hybrid cloud.		
14. Recovery laboratory.		

Bibliography

1. T. Erl, E. Monroy, “Cloud Computing: Concepts, Technology, Security, and Architecture”, Second Edition, Pearson Education, 2023.
2. C. Jackson, J. Gooley, A. Iliesiu and A. Malegaonkar, “Cisco Certified DevNet Associate DEVASC 200-901 Official Cert Guide”, Cisco Press, 2020.
3. D.A. Margin and V. Dobrota, "Overview of Echo State Networks using Different Reservoirs and Activation Functions," 2021 20th RoEduNet Conference: Networking in Education and Research (RoEduNet), Iasi, Romania, 2021, pp. 1-6, doi: 10.1109/RoEduNet54112.2021.9637715.
4. D.A. Margin, I.A. Ivanciu and V. Dobrota, "Deep Reservoir Computing using Echo State Networks and Liquid State Machine," 2022 IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom), Sofia, Bulgaria, 2022, pp. 208-213, doi: 10.1109/BlackSeaCom54372.2022.9858322.

Online references

1. “Ryu Documentation”, Ryu, 2024, [Online], Available: https://ryu.readthedocs.io/en/latest/.
2. “Open Network Operating System (ONOS)”, Open Network Foundation, 2024, [Online], Available: https://opennetworking.org/onos/.
3. “OpenDaylight”, OpenDaylight Project the Linux Foundation, 2024, [Online], Available: https://www.opendaylight.org/

9. Bridging course contents with the expectations of the representatives of the community, professional associations and employers in the field

The discipline content and the acquired skills are in agreement with the expectations of the professional Competences acquired will be used in the following COR occupations (Electronics Engineer; Telecommunications Engineer; Electronics Design Engineer; System and Computer Design Engineer; Communications Design Engineer) or in the new occupations proposed to be included in COR (Sale Support Engineer; Multimedia Applications Developer; Network Engineer; Communications Systems Test Engineer; Project Manager; Traffic Engineer; Communications Systems Consultant).

10. Evaluation

Activity type	10.1 Assessment criteria	10.2 Assessment methods	10.3 Weight in the final grade
10.4 Course	The level of acquired theoretical knowledge and practical skills	Theoretical Test (mark T) : 10 questions with multiple choice answers + 4 problems	T, max 10 pct. 50%
10.5 Seminar/ Laboratory	The level of acquired knowledge and abilities	Project (P): oral and practical exam based on laboratory and project (usually 2p is granted for work during the semester).	P, max. 10 pct. 50%

10.6 Minimum standard of performance

Qualitative point of view

Minimal theoretical and practical knowledge:

- ✓ Understanding the basic concepts regarding modeling, classification, and prediction of data traffic.
- ✓ Understanding the algorithms for automatic learning and deep learning in traffic prediction.

Minimal acquired competences:

- ✓ Ability to realize a software application related to traffic prediction using artificial intelligence.
- ✓ Ability to provide and to implement traffic data collection solutions to create training and testing databases.

Quantitative point of view

- ✓ N=(T+P)/2, N ≥ 5, T ≥ 5, P ≥ 5

Date of filling in:	**Responsible**	**Title First name SURNAME**	**Signature**
20.06.2024	Course	Professor Virgil DOBROTA, Ph.D.	
	Applications	Professor Virgil DOBROTA, Ph.D.	
		Assoc. Prof. Daniel ZINCA, Ph.D.	

Date of approval in the Council of the Communications Department 10.07.2024	Head of Communications Department Prof. Virgil DOBROTA, Ph.D.
Date of approval in the Council of the Faculty of Electronics, Telecommunications and Information Technology 11.07.2024	Dean Prof. Ovidiu POP, Ph.D.