Course Title	**Computer Networks**				
Course Code	**DLWSS501**				
Course Type	**Compulsory**				
Level	MSc (Level 2) – Distance Learning				
Year / Semester	1 /1				
Teacher's Name	**Chrysostomos Chrysostomou, PhD**				
ECTS	10	Lectures / week	3	Laboratories / week	0
Course Purpose	The aim of the course is to bring in students to the deep concepts and principles underlying the field of modern networking, and to enable students develop the skills required for the design, application, and evaluation of advanced computer networks. Particular emphasis is given to provide students with deep knowledge of the recent revolutions relating special issues like SDN (software-defined networks), NFV (network functions virtualization), QoE (quality of experience), QoS (quality of service), next-generation Internet systems, and new architectures.				
Learning Outcomes	By the end of the course, the students are expected to: 1. develop in-depth knowledge of the main principles underlying the field of modern networking; 2. justify the position that traditional network architectures are inadequate for modern networking needs; 3. list and explain the key requirements for an SDN architecture, and outline SDN architecture; 4. assess the concept of virtual machine, list and explain the key benefits and requirements of NFV, and outline NFV architecture; 5. analyse the QoS architectural framework, define and evaluate IP performance metrics; 6. describe and assess the motivations for QoE; 7. define QoE, explain and evaluate the factors that could influence QoE; 8. outline how QoE can be measured, and distinguish between subjective and objective assessment; 9. describe and evaluate QoE application areas; 10. translate metrics from QoS to QoE domain; 11. generate the appropriate QoE/QoS mapping model for a given operational situation; 12. define and examine QoE-centric monitoring solutions over a given infrastructure; 13. describe and evaluate QoE-aware applications over QoE-centric infrastructure; 14. define and examine the key security requirements and main threats;				

	15. perform research literature review and apply appropriate methods to pursue research or other detailed investigation of technical issues, and present, explain and report recent advances and open research issues and challenges in advanced computer networks.		
Prerequisites	None	Required	None
Course Content	This course consists of seven (7) units that will be taught within twelve (12) weeks, covering the following topics: • **Weeks 1 & 2 – Modern Networking: *Elements of Modern Networking***: The Networking Ecosystem. Example Network Architectures. Ethernet. Wi-Fi. 4G/5G Cellular. Internet of Things. Network Convergence. Unified Communications. ***Requirements and Technology***: Types of Network and Internet Traffic. Demand: Big Data, Cloud Computing, and Mobile Traffic. Requirements: QoS and QoE. Routing. Congestion Control. SDN and NFV. Modern Networking Elements. • **Weeks 3 & 4 – So*ftware-defined Networks (SDNs):*** Evolving Network Requirements. The SDN Approach. SDN Data Plane: OpenFlow Protocol. SDN Control Plane: Cooperation and Coordination Among Controllers. SDN Application Plane. • **Weeks 5 & 6 – *Virtualization:*** Network Functions Virtualization (NFV): Concepts and Architecture. NFV Functionality. Network Virtualization: Architecture and Benefits. • **Weeks 7 & 8 – *Quality of Service (QoS):*** QoS Architectural Framework. Integrated Services Architecture. Differentiated Services. Service Level Agreements. IP Performance Metrics. OpenFlow QoS Support. • **Weeks 9 & 10 – *QoE: User Quality of Experience:*** The need for QoE. Definition of Quality of Experience. QoE Strategies in Practice. Factors Influencing QoE. Measurements of QoE. Applications of QoE. • **Week 11 – *Network Design Implications of QoS and QoE:*** Classification of QoE/QoS Mapping Models. IP-Oriented Parameter-Based QoS/QoE Mapping Models. Actionable QoE over IP-Based Networks. QoE Versus QoS Service Monitoring. QoE-Based Network and Service Management. • **Week 12 – Security:** Security Requirements. Security Threats.		
Teaching Methodology	The course consists of units that are conducted through the online material, available through the web (e-learning platform), provided to students for studying (directed learning online). These include electronic information (notes, presentations, research articles), but also include rich media content such as narrated presentations. Students are also advised to use the course's textbooks and additional online / print sources for further reading. Furthermore, dynamic online interaction with the students is offered, including tutoring and guidance. To achieve this, asynchronous communication (forum discussions and one-to-one communication such as emails), as well as synchronous (teleconferencing and chat sessions) are provided. Moreover, guided individual and/or group project is given to enable students		

	to develop the skills required for integrating the course theory. To this end, research literature review is encouraged by assigning students to identify a specific problem related to some possible open research issues, gather relevant scientific information about how others have addressed the problem, investigate/analyze/evaluate and compose this information in written and orally, via a presentation. Other resources include online tutorials in presentation or video format. Students are assessed based on (a) formative assessment (participation and contribution of the students - dynamic online interactive activities), (b) summative assessment (online quiz, marked project/assignment), and (c) final written examination.
Bibliography	The following textbooks are associated with topics considered at various points throughout this course. • W. Stallings, ***Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud***, Pearson Education, 1st Ed., 2016 • James Kurose and Keith Ross, ***Computer Networking: A Top-Down Approach***, Pearson, 8th Edition, 2020 The above textbooks are recommended as sources of additional reading for students to elaborate on the course's material. Furthermore, students are also encouraged to explore other online / print sources that are related to topics covered in this course such as the following: • R.I. Ansari, H. Pervaiz, S.A. Hassan, C. Chrysostomou, M.A. Imran, S. Mumtaz and R. Tafazolli, "A New Dimension to Spectrum Management in IoT Empowered 5G Networks", IEEE Network, DOI: 10.1109/MNET.2019.1800157, Vol. 33, Issue: 4, pp. 186 – 193, 31 July 2019. • R.I. Ansari, H. Pervaiz, C. Chrysostomou, S.A. Hassan, A. Mahmood and M. Gidlund, "Control-Data Separation Architecture for Dual-Band mmWave Networks: A New Dimension to Spectrum Management", IEEE Access, DOI: 10.1109/ACCESS.2019.2903901, Vol. 7, pp. 34925 – 34937, 08 March 2019. • R.I. Ansari, C. Chrysostomou, S.A. Hassan, M. Guizani, S. Mumtaz, J. Rodriguez and J. Rodrigues, "5G D2D Networks: Techniques, Challenges and Future Prospects", IEEE Systems Journal, DOI: 10.1109/JSYST.2017.2773633 (online, since 15 December 2017), Vol. 12, Issue 4, pp. 3970 – 3984, December 2018. • R.I. Ansari, S.A. Hassan, and C. Chrysostomou, "Device to Device Communication for 5G", Book Chapter in Part IV "System Integration and Case Studies" of the book "Access, Fronthaul and Backhaul Networks for 5G & Beyond", IET, ISBN: 978-1-78561-213-8, August 2017. • Network World. Survival Tips for Big Data's Impact on Network Performance. White paper. April 2014. • IBM Study, "Every Day We Create 2.5 Quintillion Bytes of Data." Storage Newsletter, October 21, 2011. http://www.storagenewsletter.com/rubriques/market-reportsresearch/ibm-cmo-study/ • M.N. Shaikh, R.I. Ansari, S. Arain, and C. Chrysostomou, "Performance Analysis of a Hybrid CoMP Scheme for Heterogeneous Networks", Proceedings of the 2nd Global Conference on Wireless and Optical Communications (GC-WOC'17), Malaga, Spain, September 18-20, 2017. • C. Chrysostomou, A. Pitsillides, "Fuzzy Logic Control in Communication Networks", Book Chapter in "Foundation on Computational Intelligence", in Book Series "Studies in Computational Intelligence", Springer Verlag, Germany, Vol. 2, SCI 202, pp. 197-236, ISBN: 978-3-642-01532-8, May 2009. • P. Rahimi, C. Chrysostomou, H. Pervaiz, V. Vassiliou and Q. Ni, "Joint Radio

Resource Allocation and Beamforming Optimization for Industrial IoT in SDN-based Virtual Fog-RAN 5G-and-Beyond Wireless Environments", IEEE Transactions on Industrial Informatics, DOI: 10.1109/TII.2021.3126813, 15 November 2021.
- P. Rahimi, C. Chrysostomou, H. Pervaiz, V. Vassiliou and Q. Ni, "Dynamic Resource Allocation for SDN-based Virtual Fog-RAN 5G-and-Beyond Networks", Proceedings of the 2021 IEEE Global Communications Conference (GLOBECOM), Madrid, Spain (Hybrid Conference), December 7 -11, 2021.
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- C. Chrysostomou, A. Pitsillides, A. Sekercioglu, "Fuzzy Explicit Marking: A Unified Congestion Controller for Best-effort and Diff-serv Networks", Elsevier Computer Networks Journal (COMNET), Vol. 53, Issue 5, pp.650-667, 9 April 2009.
- C. Chrysostomou, A. Pitsillides, L. Rossides, M. Polycarpou, A. Sekercioglu, "Congestion Control in Differentiated Services Networks using Fuzzy-RED", Special Issue on "Control Methods for Telecommunication Networks" in Elsevier/IFAC Control Engineering Practice (CEP) Journal, Vol. 11, Issue 10, pp. 1153-1170, October 2003.
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- P. Rahimi, N.D. Khan, C. Chrysostomou, V. Vassiliou and B. Nazir, "A Secure

	Communication for Maritime IoT Applications Using Blockchain Technology", Proceedings of the 16th International Conference on Distributed Computing in Sensor Systems (DCOSS 2020), pp. 244–251, technically co-sponsored by IEEE, California, US (Virtual Conference), June 15 – 17, 2020. • M.A. Cheema, H.K. Qureshi, C. Chrysostomou and M. Lestas, "Utilizing Blockchain for Distributed Machine Learning based Intrusion Detection in Internet of Things", Proceedings of the 16th International Conference on Distributed Computing in Sensor Systems (DCOSS 2020), pp. 429–435, technically co-sponsored by IEEE, California, US (Virtual Conference), June 15 – 17, 2020. • I. Andrea, C. Chrysostomou, and G. Hadjichristofi, "Internet of Things: Security Vulnerabilities and Challenges", Proceedings of the 20th IEEE International Symposium on Computers and Communications (IEEE ISCC 2015), Larnaca, Cyprus, July 6, 2015.
Assessment	The students are assessed via continuous assessment throughout the duration of the Semester, which forms the Coursework grade and the final written exam. The coursework and the final exam grades are weighted 50% and 50%, respectively, and compose the final grade of the course. Various approaches are used for the continuous assessment of the students, such as dynamic online activities, online quizzes, project written/oral composition and presentation. The assessment weight, date and time of each type of continuous assessment is being set at the beginning of the semester via the course outline. An indicative weighted continuous assessment of the course is shown below: • Two dynamic interactive / participation activities: 2 * 5% = 10% • One marked assignment/project: 1 * 15% = 15% • Presentation of project: 1 * 10% = 10% • An online quiz: 1 * 15% = 15% • One closed-book, 3-hour exam: 50% The criteria considered for the assessment of each type of the continuous assessment and the final exam of the course are the comprehension of the fundamental concepts and theory of each topic, the application of the theory in solving related problems and the ability to apply the above knowledge in examining recent advances and open research issues and challenges in advanced computer networks. The final assessment of the students is formative and summative and is assured to comply with the subject's expected learning outcomes and the quality of the course.
Language	English