Course Title	**Communications for Smart Systems**				
Course Code	**DLWSS530**				
Course Type	**Elective**				
Level	Master (2nd Cycle) – Distance Learning				
Year / Semester	1 / 2				
Teacher's Name	**Chrysostomos Chrysostomou, PhD**				
ECTS	10	Lectures / week	3	Laboratories / week	0
Course Purpose	The purpose of the course is to bring in students to the deep concepts and principles underlying the field of key enabling communication technologies for smart systems, and to enable students develop the skills required for the design, application, and evaluation of modern communication networks. Particular emphasis is given to provide students with deep knowledge of recent revolutions relating to special issues like enabling wireless local area network technologies for smart systems, Bluetooth and IEEE 802.15, LTE and 5G systems, wireless sensor networks (WSNs) applications to smart systems, the Internet of Things (IoT), Machine-to-Machine (M2M) Communications, Device-to-Device (D2D) Communications, Smart Transportation Systems (STSs), and Vehicular Networks (VANETs) in Smart City Systems.				
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 key enabling communication technologies for smart systems; 2. recognize the new trend of connected objects in the context of smart systems and their challenges; 3. outline representative examples of WSNs applications in smart systems; 4. identify, analyse and evaluate access technologies to be used for the WSNs applications; 5. define and examine Bluetooth application areas; 6. analyse the characteristics behind the Bluetooth High Speed and Bluetooth Smart; 7. distinguish between High Data and Low Data Rate WPANs; 8. describe the ZigBee architecture; 9. identify IEEE 802.11 family of standards and outline applications of WLANs to smart systems, and the challenges posed; 10. analyse the key enabling technologies for 4G and 5G systems; 11. define and examine the LTE and the LTE-A features, handover management, and the emerging concept of "smart city" in the context of 5G systems; 12. explain the scope of the Internet of Things;				

	13. list and outline the principal components of IoT-enabled things; 14. compare and contrast the ITU-T and IoT World Forum IoT reference models; 15. describe and evaluate different IoT implementations; 16. identify M2M system key elements and technologies; 17. describe and evaluate dominant M2M application domains; 18. identify and outline major advantages and disadvantages of D2D networks; 19. determine the efficacy of D2D networks for proximity services; 20. investigate emerging technologies such as social D2D networks, and simultaneous wireless information and power transfer (SWIPT) for D2D networks; 21. analyse the emerging technologies in the fields of the Smart Cities, focusing on STSs; 22. describe and evaluate VANET applications in smart cities along with challenges, solutions and existing implementations; 23. 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 key enabling communication technologies for smart systems.		
Prerequisites	WSS501	Required	None
Course Content	This course consists of ten (10) units that will be taught within twelve (12) weeks, covering the following topics: • **Week 1 – Introduction and Overview of Key Enabling Technologies for Smart Systems:** Trends and Challenges. Survey of Major Key Enabling Technologies for Smart Systems. Examples. • **Week 2 – Wireless Sensor Networks (WSN) Applications to Smart Systems:** WSN Applications Examples. Access Technologies. Routing Strategies. Power-saving Methods. Security Concerns. • **Week 3 – Bluetooth and IEEE 802.15:** Wireless Personal Area Networks (WPANs). Bluetooth Motivation. Bluetooth Specifications. Bluetooth High Speed and Bluetooth Smart. IEEE 802.15 - High Data and Low Data Rate WPANs. ZigBee. • **Week 4 – Enabling Wireless Local Area Network (WLAN) Technologies for Smart Systems:** Development of IEEE 802.11. IEEE 802.11 Architecture. Smart Systems Solutions and Requirements. • **Weeks 5 & 6 – LTE and 5G systems:** Cellular network evolution. Handover management. Empirical case: smart cities. • **Weeks 7 & 8 – The Internet of Things:** Overview, Architecture and Implementation. The IoT Era. The Scope of the Internet of Things. Components of IoT-Enabled Things. RFID. ITU-T IoT Reference Model. IoT World Forum Reference Model. IoT Implementation.		

	• **Week 9 – Machine-to-Machine (M2M) Communications:** Concept of M2M Technology. M2M System Key Elements and Technologies. M2M Application Domains. • **Week 10 – Device-to-Device (D2D) Communications:** Concept of D2D Technology. Performance and Different Network Deployment Scenarios. • **Week 11 – Smart Transportation Systems (STSs) in Critical Conditions:** Smart Transportation Systems. Network Design for Smart Transportation Systems in Critical Conditions. QoS Applications for STS. • **Week 12 – Vehicular Networks (VANETs) in Smart City Systems:** VANET Architecture. Vehicular Cloud Infrastructure. VANET Challenges and Solutions in Smart Cities. Vehicular Clouds Challenges and Solutions in Smart Cities. Open Issues and Future Directions in Vehicular Smart City Systems.
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 and assess case studies of evaluating communication technologies and application domains in smart systems, gather relevant scientific information about how others have addressed the identified research topic, 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. • M. S. Obaidat and P. Nicopolitidis, ***Smart Cities and Homes: Key Enabling Technologies***, Morgan Kaufmann, 1st Ed., 2016 • C. Beard and W. Stallings, ***Wireless Communication Networks and Systems***, Pearson Education, 1st Ed., 2016 • W. Stallings, ***Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud***, Pearson Education, 1st Ed., 2016

	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: • 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. • 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. • P. Rahimi, C. Chrysostomou, I. Kyriakides and V. Vassiliou, "An Energy-Efficient Machine-Type Communication for Maritime Internet of Things", Proceedings of the 11th Annual IEEE Information Technology, Electronics and Mobile Communication Conference (IEMCON 2020), pp. 668–676, Vancouver, Canada (Virtual Conference), November 4-7, 2020. • P. Rahimi, C. Chrysostomou and V. Vassiliou, "Social-Aware Clustering for D2D Multicast Content Sharing in 5G Networks", Proceedings of the 2020 IEEE Global Information Infrastructure and Networking Symposium (GIIS 2020), Tunis, Tunisia (Virtual Conference), October 28-30, 2020 [Best paper award]. • 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. • P. Rahimi and C. Chrysostomou, "Improving the Network Lifetime and Performance of Wireless Sensor Networks for IoT Applications based on Fuzzy Logic", Proceedings of the 15th International Conference on Distributed Computing in Sensor Systems (DCOSS 2019), pp. 667–674, technically co-sponsored by IEEE, Santorini, Greece, May 29-31, 2019. • R.I. Ansari, S.A. Hassan, and C. Chrysostomou, "A SWIPT-based Device-to-Device Cooperative Network", Proceedings of the 24th International Conference on Telecommunications (ICT 2017), technically co-sponsored by IEEE,

Limassol, Cyprus, May 3-5, 2017.
- R.I. Ansari, S.A. Hassan, and C. Chrysostomou, "Energy Efficient Relay Selection in Multi-hop D2D Networks", Proceedings of the 12th International Wireless Communications & Mobile Computing Conference (IWCMC 2016), technically co-sponsored by IEEE, Paphos, Cyprus, September 5-9, 2016.
- Z. Zinonos, C. Chrysostomou, and V. Vassiliou, "Fuzzy Logic Control for Mobility Management in Industrial Wireless Sensor Networks", Book Chapter in "Cooperative Robots and Sensor Networks", 2nd Edition, in Book Series "Studies in Computational Intelligence", Springer Berlin Heidelberg, Vol. 554, pp. 205-230, ISBN: 978-3-642-55029-4, 2014.
- Z. Zinonos, C. Chrysostomou, and V. Vassiliou, "Wireless Sensor Networks Mobility Management using Fuzzy Logic", Elsevier Ad Hoc Networks Journal, DOI: 10.1016/j.adhoc.2013.12.003 (online, since 26 Dec 2013), Vol. 16, pp. 70-87, May 2014.
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- C. Chrysostomou, C. Djouvas and L. Lambrinos, "Fuzzy Logic based Adaptive Decision Support in Autonomous Vehicular Networks", Book Chapter in "Computational Intelligence for Decision Support in Cyber Physical Systems", in Book Series "Studies in Computational Intelligence", Springer, Vol. 540, pp. 215-236, ISBN: 978-981-4585-36-1, 2014.
- C. Chrysostomou, C. Djouvas and L. Lambrinos, "Contention Window Adaptation for Broadcast Beaconing in Vehicular Ad Hoc Networks", Proceedings of the 10th International Wireless Communications & Mobile Computing Conference (IWCMC 2014), technically co-sponsored by IEEE, Nicosia, Cyprus, August 4-8, 2014.
- C. Chrysostomou, C. Djouvas and L. Lambrinos, "Dynamically Adjusting the Min-Max Contention Window for Providing Quality of Service in Vehicular Networks", Proceedings of the 11th Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net'12), technically co-sponsored by IEEE, Ayia Napa, Cyprus, June 19 - 22, 2012.
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	December 2013. • Iwaoka M. IEEE 802.11ah use case – industrial process automation, http://mentor.ieee.org/802.11/dcn/11/11-11-0260-01-00ah-tgah-use-caseindustrial-process-automation.ppt, 2011. • British city promotes high-tech healthcare as a smart city service, http://smartcitiescouncil.com/article/british-city-promotes-high-tech-healthcare-smart-city-service, 2013. • Love clean streets, http://www.lovecleanstreets.com/, 2015. • Cisco: the Internet of everything for cities, http://www.cisco.com/web/about/ac79/docs/ps/motm/IoE-Smart-City_PoV.pdf, 2013. • Cimmino A, Pecorella T, Fantacci R, Granelli F, Rahman TF, Sacchi C, Carlini C, Harsh P. The role of small cell technology in future smart city applications. Trans Emerg Telecommun Technol. 2014, 25(1):11–20. • Bjerke BA. LTE-Advanced and the evolution of LTE deployments. IEEE Wireless Commun. 2011, 18(5):4–5. • Machine-to-machine (M2M), IoT Agenda, TechTarget, https://internetofthingsagenda.techtarget.com/definition/machine-to-machine-M2M, August 2019. • International Telecommunication Union, "Focus Group on M2M Service Layer - ITU", http://www.itu.int/en/ITU-T/focusgroups/m2m/Pages/default.aspx, 2013 [online]. • Machine to machine. In: Wikipedia, The Free Encyclopedia. Wikimedia Foundation, Inc, https://en.wikipedia.org/wiki/Machine_to_machine, January 2022 [online]. • Smart Mobility 2030—Singapore ITS Strategic Plan. http://www.lta.gov.sg/content/ltaweb/en/roads-and-motoring/managing-traffic-and-congestion/intelligent-transport-systems/SmartMobility2030.html, [Online]. • Kitchin K. “The real-time city? Big data and smart urbanism”. Springer GeoJ. 2014;79(1):1–14. • IBM. Cisco and the business of smart cities—how two of the IT industry’s largest companies plan to rewire urban living. http://www.information-age.com/industry/hardware/2087993/ibm-cisco-and-the-business-of-smart-cities, [Online]. • European Smart Cities. http://www.smart-cities.eu/index.php?cid=7&ver=4, [Online]. • Amsterdam smart city – Smart Parking. http://amsterdamsmartcity.com/projects/detail/id/64/slug/smart-parking, [Online]. • The Digital Road Authority–Incident Management. http://amsterdamsmartcity.com/projects/detail/id/76/slug/the-digital-road-authority-incident-management, [Online]. • Gerla M, Lee E-K, Pau G, Lee U. Internet of vehicles: from intelligent grid to autonomous cars and vehicular clouds,” in Internet of Things (WF-IoT), 2014 IEEE World Forum on, March 2014. p. 241–46. • Kantarci B. Cyber-physical alternate route recommendation system for paramedics in an urban area. In: IEEE wireless communications and networking conference (WCNC), March 2015. p. 2276–81. • Hartenstein H, Laberteaux KP. VANET: vehicular applications and inter-networking technologies. United Kingdom: John Wiley & Sons Ltd; 2010.
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