



Title:	Embedded Systems Networking APPROVED
Long Title:	Embedded Systems Networking
Module Code:	COMP8044
Duration:	1 Semester
Credits:	5
NFQ Level:	Advanced
Field of Study:	Computer Science
Valid From:	Semester 1 - 2017/18 (September 2017)
Module Delivered in	1 programme(s)
Module Coordinator:	Sean McSweeney
Module Author:	Donna OShea
Module Description:	The IoT is a rapidly emerging new paradigm that has the capacity in changing the way we live in the world forever. IoT refers to the ability to connect any thing to the Internet, such as a watch, house, dog, car etc. Using the Internet and wireless communications infrastructure these things will be capable of communicating with each other and their users. However connecting objects that we use in our everyday lives to the Internet is a non-trivial task and requires specialist skills and knowledge. This module aims to equip students with this knowledge so that they understand the landscape of communication protocols, standards, reference architectures required to connect devices to the Internet and the Cloud.
Learning Outcomes	
<i>On successful completion of this module the learner will be able to:</i>	
LO1	Describe the main application areas, IoT devices and reference architectures for the Internet of Things (IoT).
LO2	Discuss the main challenges and opportunities in realizing the IoT and the Future Internet vision.
LO3	Evaluate how protocols handle data communications in a network consisting of IoT devices.
LO4	Create and configure a network of IoT devices facilitating end to end communication.
LO5	Design and develop a IoT application that leverages the use of an IoT platform and connects the IoT application to the Cloud.
Pre-requisite learning	
Module Recommendations <i>This is prior learning (or a practical skill) that is strongly recommended before enrolment in this module. You may enrol in this module if you have not acquired the recommended learning but you will have considerable difficulty in passing (i.e. achieving the learning outcomes of) the module. While the prior learning is expressed as named CIT module(s) it also allows for learning (in another module or modules) which is equivalent to the learning specified in the named module(s).</i>	
Incompatible Modules <i>These are modules which have learning outcomes that are too similar to the learning outcomes of this module. You may not earn additional credit for the same learning and therefore you may not enrol in this module if you have successfully completed any modules in the incompatible list.</i>	
No incompatible modules listed	
Co-requisite Modules	
No Co-requisite modules listed	
Requirements <i>This is prior learning (or a practical skill) that is mandatory before enrolment in this module is allowed. You may not enrol on this module if you have not acquired the learning specified in this section.</i>	
No requirements listed	

Module Content & Assessment

Indicative Content

The Internet of Things

Introduction to IoT. Application areas of IoT. Devices associated with IoT i.e. RFID, WSN, sensors, watches etc. IoT reference architectures. The Future Internet and The Web of Things.

Opportunities & Challenges in IoT

Security - basic network security, key management in networks of thousands of devices, attacks. Data privacy. Difficulties and challenges in developing IoT applications. Energy and power - Energy awareness and energy harvesting. Network functions, (re)programming abstractions, network synchronization.

Protocols for IoT devices

OSI Network model and layers - Data Link, MAC and PHY. MAC Protocols - IEEE802.15.4, Zigbee etc. MAC - contention free, fixed assignment and dynamic assignment; and contention based - synchronous and asynchronous. MAC protocol examples. MAC design drivers. PHY Specification - frequency range, communication techniques, modulation and channels. Impact of wireless medium and environment on communication.

Networking for IoT

Network Topologies – basic network topologies. Modes of operation. Wireless implementations. Routing approaches – hierarchical, location based, proactive, on-demand, distance vector, WRP, etc. IPv6 - energy and bandwidth modifications; 6LoWPAN. Middleware – interaction models; publish-subscribe; implementation i.e. MQTT etc. Labs creating a WSN network.

Developing applications for the IoT

Hands-on work using the Contiki operating system. Exploring sensing, communication and gaining an understanding of the Contiki OS and the challenges of IoT development.

Assessment Breakdown	%
Course Work	50.00%
End of Module Formal Examination	50.00%

Course Work				
Assessment Type	Assessment Description	Outcome addressed	% of total	Assessment Date
Practical/Skills Evaluation	Leveraging the development of the simple WSN and IoT application the student is expected to use an IoT platform and connect the application to the cloud.	4,5	50.0	Every Second Week

End of Module Formal Examination				
Assessment Type	Assessment Description	Outcome addressed	% of total	Assessment Date
Formal Exam	End of semester formal examination.	1,2,3,4,5	50.0	End-of-Semester

Reassessment Requirement
<p>Repeat examination Reassessment of this module will consist of a repeat examination. It is possible that there will also be a requirement to be reassessed in a coursework element.</p>

The institute reserves the right to alter the nature and timings of assessment

Module Workload

Workload: Full Time				
<i>Workload Type</i>	<i>Workload Description</i>	<i>Hours</i>	<i>Frequency</i>	<i>Average Weekly Learner Workload</i>
Lecture	Lecture underpinning learning outcomes.	2.0	Every Week	2.00
Lab	Lab supporting content delivered in class.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Independent Study.	3.0	Every Week	3.00
Total Hours				7.00
Total Weekly Learner Workload				7.00
Total Weekly Contact Hours				4.00

Workload: Part Time				
<i>Workload Type</i>	<i>Workload Description</i>	<i>Hours</i>	<i>Frequency</i>	<i>Average Weekly Learner Workload</i>
Lab	Lab supporting content delivered in class.	2.0	Every Week	2.00
Lecture	Lecture underpinning learning outcomes.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Independent Study.	3.0	Every Week	3.00
Total Hours				7.00
Total Weekly Learner Workload				7.00
Total Weekly Contact Hours				4.00

Module Resources

Recommended Book Resources

- Zach Shelby, Carsten Bormann 2009, *6LoWPAN: The Wireless Embedded Internet*, Wiley [ISBN: 9780470747995]
- Ian F. Akyildiz, Mehmet Can Vuran 2010, *Wireless Sensor Networks*, John Wiley & Sons Ltd. [ISBN: 9780470036013]

Supplementary Book Resources

- Bassi, A., Bauer, M., Fiedler, M., Kramp, T., Kranenburg, R., Lange, S., Meissner, S. (Eds.) 2013, *The IoT-A Book "Enabling Things to Talk"*, Springer Open [ISBN: 9783642404030]

Recommended Article/Paper Resources

- Perera, C., Liu, C.H., Jayawardena, S. and Chen, M. *A Survey on Internet of Things From Industrial Market Perspective*, IEEE Access, vol. 2, 1660
- Zanella, A., Bui, N., Castellani, A., Vangelista, L. and Zorzi, M. *Internet of Things for Smart Cities*, IEEE Internet of Things Journal, vol. 1, 22
- Botta, A., De Donato, W., Persico, V. and Pescapé, A. *On the Integration of Cloud Computing and Internet of Things*, 2014 International Conference on Future Internet of Things and Cloud (FiCloud), Aug 2014
- Chien, T.V., Chan, H.N. and Huu, T.N. *A comparative study on operating system for Wireless Sensor Networks*, 2011 International Conference on Advanced Computer Science and Information System (ICACISIS), Dec 2011, 73
- Villaverde, B.C., Pesch, D., Alberola, R.D.P., Fedor, S. and Boubekeur, M. 2012, *Constrained Application Protocol for Low Power Embedded Networks: A Survey*, 2012 Sixth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 4-6 July 2012
- Langendoen, K. and Meier, A. 2010, *Analyzing MAC protocols for low data-rate applications*, ACM Transactions on Sensor Networks (TOSN), Volume 7 Issue 2, August 2010
<http://dl.acm.org/citation.cfm?id=1824775>
- Baccour, N., Koubâa, A., Mottola, L., Zúñiga, M.A., Youssef, H., Boano, C.A. and Alves, M. 2012, *Radio link quality estimation in wireless sensor networks: A survey*, ACM Transactions on Sensor Networks (TOSN), Volume 8 Issue 4, September 2012
<http://dl.acm.org/citation.cfm?id=2240123>
- Gnawali, O., Fonseca, R., Jamieson, K., Kazandjieva, M., Moss, D. and Levis, P. 2013, *CTP: An efficient, robust, and reliable collection tree protocol for wireless sensor networks*, ACM Transactions on Sensor Networks (TOSN), Volume 10 Issue 1, November 2013
<http://dl.acm.org/citation.cfm?id=2529988>
- Winter, T. et al 2012, *RPL: IPv6 routing protocol for low-power and lossy networks*, Internet Engineering Task Force (IETF), Request for Comments: 6550 [ISSN: 2070-1721]
<https://tools.ietf.org/html/rfc6550>
- Dunkels, A., Gronvall, B. and Voigt, T. 2004, *Contiki - A Lightweight and Flexible Operating System for Tiny Networked Sensors*, Proceedings of the 29th Annual IEEE International Conference on Local Computer Networks [ISSN: 0-7695-22]
<http://dx.doi.org/10.1109/LCN.2004.38>
- Dunkels, A., Schmidt, O., Voigt, T. and Ali, M. 2006, *Protothreads: Simplifying Event-driven Programming of Memory-constrained Embedded Systems*, Proceedings of the 4th International Conference on Embedded Networked Sensor Systems [ISSN: 1-59593-3]
<http://doi.acm.org/10.1145/1182807.1182811>
- Ghadimi, E., Landsiedel, O., Soldati, P., Duquennoy, S. and Johansson, M. 2014, *Opportunistic Routing in Low Duty-Cycle Wireless Sensor Networks*, ACM Transactions on Sensor Networks (TOSN), Volume 10, Numer 4 [ISSN: 1550-4859]
<http://doi.acm.org/10.1145/2533686>

Other Resources

- website: *Contiki OS*
<http://www.contiki-os.org/>
- Website: *MQTT resource page*
<http://mqtt.org/>
- Website: *OpenIoT Resource page*
<http://open-platforms.eu/library/openiot-the-open-source-internet-of-things/>
- Website: *Xively by LogMein*
<https://xively.com/>

- Website: *ThingWorx Internet of Things and M2M applications*
<http://www.thingworx.com/>
- Website: *ETSI Machine to Machine Communications*
<http://www.etsi.org/technologies-clusters/technologies/m2m>

Module Delivered in

Programme Code	Programme	Semester	Delivery
CR_KDNET_8	Bachelor of Science (Honours) in Computer Systems	5	Mandatory