Title:	Future Internet APPROVED
Long Title:	Future Internet
Module Code:	COMP9052
Credits:	5
NFQ Level:	Expert
Field of Study:	Computer Science
Valid From:	Semester 1 - 2017/18 (September 2017)
Module Delivered in	2 programme(s)
Module Coordinator:	Donna OShea
Module Author:	Donna OShea
Module Description:	The interconnection of smart objects and "things" is driving the Internet to the edge of its architectural capability and capacity and are creating new engineering requirements for the Internet. However, the ossification of the Internet has to date prevented it from meeting these requirements as stakeholder agreement is required before any change can be applied over the Internet's network of networks. This module will discuss the challenges and driving forces behind the Future Internet (FI) and enabling technologies behind its development.

Learning Outcomes	
On successful completion of this module the learner will be able to:	
LO1	Critically discuss the future research direction of Software Defined Networking (SDN) and Network Function Virtualisation (NFV) networks with particular reference to the Future Internet vision.
LO2	Analyse the network architecture and elements for Software Defined Networks (SDN) and Network Function Virtualisation (NFV) networks.
LO3	Design and implement an SDN network using multiple controllers and virtual switches demonstrating the protocol operation between the architectural components in the network.
LO4	Analyse the performance of the SDN network by using verification and troubleshooting techniques.
LO5	Examine the main security threats and challenges that exist in SDN Networks.

Pre-requisite learning
Module Recommendations *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).*
No recommendations listed
Incompatible Modules *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.*
No incompatible modules listed
Co-requisite Modules
No Co-requisite modules listed
Requirements *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.*

No requirements listed
Co-requisites
No Co Requisites listed

Module Content & Assessment

Indicative Content
The Future Internet The Future Internet and its main driving forces. Service Aware Networks and Network Aware Services. Network Virtualisation approaches and history - VLANs, Overlay networking, active network, SDN, FlowVisor, RouteFlow, SDN. Network virtualisation projects and testbeds.
Data Centre Network Virtualisation Data Centre components and topology. Data Centre virtualisation architecture - virtual data centre, virtual network. Data Centre virtualisation projects and classifcation. Requirements of data centre network virtualisation. Virtualised edge data centres.
Network Function Virtualisation (NFV) NFV overview and history. Challenges and Opportunities. NFV Architecture - infrastructure, virtual network function and services, management and orchestration. Business models and design consideration. Standardisation, projects and implementations. Research challenges. Service chaining. OPNFV Platform Architecture. The OPNFV Community labs and IOVisor.
Software Defined Networking (SDN) SDN overview and history. SDN Architecture - Planes - data, management and control. Interfaces - northbound and southbound. Eastbound and Westbound. Network Operating System (NOS). Network abstraction.SDN Protocol specifications: Border Gateway Protocol (BGP); Cisco Application Centric Infrastructure (ACI); OpenFlow. OpenFlow versions. Virtual Network Embedding Problem. SDN Controllers - Floodlight, POX, NOX, Beacon. Open source distributed controllers - ONOS, ONIX. Eventually consistently problem. Brewer's CAP Theorem. SDN vSwitches - Open vSwitch, Pica8, OpenFlowJ. Alternatives to OpenFlow i.e. P4 etc.
SDN Implementation SDN Protocol specifications: Border Gateway Protocol (BGP); Cisco Application Centric Infrastructure (ACI); OpenFlow. OpenFlow versions. Components of an OpenFlow Switch. Flow and group tables. Rule matching. Action handling. Table misses. Counters, metering and metadata.
SDN Security Issues Security challenges at Northbound, southbound, eastbound and westbound interfaces. Data plane layer security issues. Controller layer - single point of failure, Denial of Service (DoS) attacks. Firewall and placement. Threats and vulnerabilities.
Future Research Directions SDN in wireless networks and Wireless Sensor Networks (WSNs). Named Data Networking (NDN). Information Centric Networking (ICN).

Assessment Breakdown	%
Course Work	100.00%

Course Work

Assessment Type	*Assessment Description*	*Outcome addressed*	*% of total*	*Assessment Date*
Project	In this project the student will be given a topic relevant to the vision of future internet and they will be expected to critically analyse and discuss future research directions based on the existing state of the art in the area.	1,2,5	50.0	Week 9
Project	The student will be expected to design a SDN/NFV network examining the main architectural components and implement the network as designed. The students may also be required to critically assess the performance and security challenges that exist in the designed network and opportunities of enhanced network security by design.	2,3,4,5	50.0	Sem End

No End of Module Formal Examination

Reassessment Requirement

Coursework Only
This module is reassessed solely on the basis of re-submitted coursework. There is no repeat written examination.

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

Module Workload

Workload: Full Time				
Workload Type	*Workload Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Theoretical treatment of relevant topics.	2.0	Every Week	2.00
Lab	Lab-based practical work.	2.0	Every Week	2.00
Independent & Directed Learning (Non-contact)	Study, project work, extra reading.	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				
Workload Type	*Workload Description*	*Hours*	*Frequency*	*Average Weekly Learner Workload*
Lecture	Theoretical treatment of relevant topics.	2.0	Every Week	2.00
Lab	Lab-based practical work.	2.0	Every Week	2.00
Lab	Study, project work, extra reading.	2.0	Every Week	2.00
			Total Hours	6.00
			Total Weekly Learner Workload	6.00
			Total Weekly Contact Hours	6.00

Module Resources

Recommended Book Resources

- **Paul Goransson Chuck Black 2014, *Software Defined Networks: A Comprehensive Approach*, 1st Ed., Morgan Kaufmann [ISBN: 9780124166752]**
- **William Stallings 2015, *Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud, Addison-Wesley Professional*, Addison-Wesley Professional [ISBN: 9780134175393]**

Supplementary Book Resources

- **Thomas D. Nadeau, Ken Gray 2013, *SDN: Software Defined Networks: An Authoritative Review of Network Programmability Technologies*, 1st Ed., O'Reilly Media [ISBN: 9781449342302]**

Recommended Article/Paper Resources

- **N. McKeown, T. Anderson, H. Balakrishnan et al. *OpenFlow: enabling innovation in campus networks*, ACM SIGCOMM Computer Communication Review, Vol. 38, Issue 2**
- **Open Networking Foundation 2015, *TR-518 Relationship of SDN and NFV***
- **Sherwood, R., Gibb, G., Yap, K. K., Appenzeller, G., Casado, M., McKeown, N., & Parulkar, G 2009 *Flowvisor: A network virtualization layer*, OpenFlow Switch Consortium, Tech Report, 1**
- **Feamster, N., Rexford, J., & Zegura, E 2013, *The road to SDN*, Queue, 11(12)**
- **Stallings, W. 2013, *Software-defined networks and openflow*, The Internet Protocol Journal, 16(1), 2**
- **Chowdhury, N. M., Boutaba, R 2009, *Network virtualization: state of the art and research challenges*, IEEE Communications Magazine, 47(7)**

Other Resources

- **Website: *Open Networking Foundation***
  http://opennetworking.org
- **Website: *Project Floodlight***
  http://www.projectfloodlight.org/floodli ght/
- **Website: *OpenDaylight***
  https://www.opendaylight.org/
- **Website: *Mininet - An Instant Virtual Network on your laptop***
  http://mininet.org/
- **Website: *IO Visor Project***
  https://www.iovisor.org/
- **Website: *P4 Programming Language***
  http://p4.org/
- **Website: *Mini-NDN***
  https://github.com/named-data/mini-ndn
- **Website: *Named Data Networking***
  https://named-data.net/
- **Website: *Information Centric Networking***
  https://datatracker.ietf.org/rg/icnrg/ch arter/

Module Delivered in

Programme Code	Programme	Semester	Delivery
CR_KCLDC_9	Master of Science in Cloud Computing	2	Elective
CR_KCLDC_9	Master of Science in Cloud Computing	1	Elective