Network Engineering for Undergraduates

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***Abstract**: Network engineering is an important emerging engineering discipline that encompasses specific aspects of the digital network and services. The growth of the worldwide digital network and services has increased demand for engineering graduates with core digital networking skills. Undergraduate education in this new engineering discipline requires a strong focus on carrier and service provider technologies. This paper presents network engineering as accredited by Engineers Australia and highlights the degree program focus areas. A network engineering degree program should balance theory with laboratory exercises utilising equipment and systems corresponding to current industry facilities. The digital network is evolving quickly and laboratory facilities need to be updated regularly to ensure currency is maintained. However, replacing expensive laboratory equipment regularly and possibly before the equipment and systems have reached end of life can be difficult to justify and will often require a supporting relationship from a suitable industry partner.*

Introduction

Network engineering has evolved from the communication engineering discipline, which incorporates three technology clusters: (1) devices, (2) systems and (3) networks. Network engineering focuses on the third technology cluster of the communication engineering discipline: networks. Over the past twenty years digital networks have grown in size and complexity and the communication engineering network technology cluster has evolved to match this growth.

Network engineers are finding opportunities in carriers, service providers, support organisations and large businesses. The principal role of a network engineer is to design, implement and support core network functionality. This is principally a behind-the-scenes role and not generally customer-facing, except during the network design phase where customer input is sought.

RMIT University has been at the forefront of communication engineering delivery and development in Australia and has now offered communication engineering training programs for more than 60 years. In 1994, RMIT University offered a Master of Engineering (Telecommunication Engineering) (RMIT 1994) degree to provide a postgraduate degree outcome that complimented the existing Bachelor of Engineering (Communication Engineering) degree program. The term telecommunication engineering was utilised rather than communication engineering simply because, at the time, telecommunication engineering was identified as a more marketable title than communication engineering.

In 2006, a Bachelor of Engineering degree in Network Engineering (RMIT 2007) was offered for the first time. Subsequently, in following years an Associate Degree (Network Engineering) and Master of Engineering (Network Engineering) were offered. The network engineering degree programs were developed over five years and grew from the previous offering within the communication engineering degree program. The network engineering programs were fully accredited by Engineers Australia in 2009.

Network Engineering

Definition

A definition of network engineer was presented by Gregory (2007) as ‘the discipline concerned with developing, implementing and supporting digital networks’. This proposed definition has since been refined by Gregory (2010) to be:

> "The discipline concerned with designing, developing, implementing and supporting digital networks and services".

This current definition provides a more broad understanding of what a network engineer will do today and into the future and is not bound to a particular area within Industry as was the case with previous definitions that tried to build upon the telecommunication heritage of network engineering. One such example of a definition for network engineer that is divided into broad functional areas is provided by the Alliance for Telecommunications Industry Solutions (ATIS 2000) as:

> "**1.** In telephony, the discipline concerned with (a) determining internetworking service requirements for switched networks, and (b) developing and implementing hardware and software to meet them. **2.** In computer science, the discipline of hardware and software engineering to accomplish the design goals of a computer network. **3.** In radio communications, the discipline concerned with developing network topologies."

Switched and packet networks have now merged and there has been considerable blurring of how networks operate with the best features of switched and packet networks being utilised in the high speed networks in use today. It is therefore more appropriate to utilise a single definition for network engineering that does not delineate the role of a network engineer into supporting packet or switched network variants or telephony.

Demand

Demand for network engineering graduates has grown over the past 10 years. A survey of online job advertisements for related engineering disciplines carried out over the last five years is shown in Table 1. The survey results highlight the number of positions identified in each discipline area but does not identify positions that require a graduate engineering degree as a pre-requisite.

Table 1: Engineering Positions (Seek 2010)

Date		**23/8/2006**	**17/10/2006**	**22/3/2007**	**9/4/2007**	**20/7/2010**
Search Type	Last 30 Days					
Classification	Engineering + IT&T + Science & Technology					
Program	**Search Term**	**Total**	**Total**	**Total**	**Total**	**Total**
Network Engineering	Network Engineering	**71**	**62**	**64**	**94**	**37**
	Network Engineer	**446**	**335**	**391**	**497**	**279**
Computer Engineering	Computer Engineering	21	44	49	164	33
	Computer Engineer	6	0	3	4	2
Electronics Engineering	Electronic Engineering	69	62	89	83	57
	Electronic Engineer	14	18	6	8	12
Communication Engineering	Communication Engineering	9	5	6	3	5
	Communication Engineer	3	4	0	1	3
	Telecommunication+Engineer	90	337	474	468	265
	Telecommunication+Engineering			464	452	267
	Telecommunication Engineer					0
	Telecommunication Engineering					6
Electrical Engineering	Electrical Engineering	602	604	726	941	659
	Electrical Engineer	586	587	584	754	460
Biomedical Engineering	Biomedical Engineering	5	8	16	15	4
	Biomedical Engineer	4	1	4	4	0

The terminology "network engineer" and "network engineering" are now well known and accepted within industry. Companies have identified with the terminology by categorising staff positions in this discipline area and advertising jobs using the terms "network engineer" and "network engineering".

Courses

Network engineering encompasses the transmission of information over a digital network. The engineering concepts and technologies that network engineering includes are multiplexing, routing, switching, management, design, capacity planning, performance, services and security.

Prior to the introduction of the Bachelor of Engineering (Network Engineering) industry was consulted about the contents of a specialised undergraduate network engineering degree program. The consultation process with about ten organisations that encompassed equipment suppliers, integrators, operators and regulators led to the development of four core and six elective courses.

A typical engineering degree may include 32 courses spread equally across the four year degree duration. The list below provides specialist network engineering courses identified as introductory, intermediate or advanced. Introductory courses are suitable for year two or year three, intermediate courses are suitable for year three or four and advanced courses are suitable for year four of an undergraduate degree program. Knowledge areas have been logically separated between the courses so that there is very minor overlap in material being taught in each of the courses. Where course material overlap does occur it is often because there is a need to refresh students on the material or to introduce the topic for a subsequent course.

The network engineering stream courses are:

- Network Engineering. The course provides students with an introduction network engineering including TCP/IP, the digital network and the Internet, setting up small networks, routers and firewalls. (introductory course)
- Network Infrastructure. The course provides students with a detailed understanding of the types of equipment and systems that form a digital network and their operation. The course includes details about types of networks and the equipment that is used on each network type. The course focuses on the design and operation of customer premise networks and data centres. Customer premise networks are wire-line and wireless networks designed to be private single or multi-layered networks that facilitate the operation of internal and external services and applications. Students complete study towards optional industry qualifications. (introductory course)
- Network Software Engineering. The course provides students with an introduction to the functionality embedded into network devices to provide connectivity and services. Network convergence is a feature of current telecommunication systems. Students are introduced to formal description techniques, state-machines, conformance testing and validation. A real-time connection oriented service is used in the course to provide students with an understanding of the engineering implementation of embedded software, protocols, system components and message passing. (introductory course)
- Advanced Network Engineering. The course provides students with advanced digital network concepts and principles. The course introduces students to internetworking. The course content covers theory, standards and protocols. Students are provided with an opportunity to analyse network operation mechanisms, design and implement a network and conduct network management. (intermediate course)
- Network Management and Security. The course provides students with an introduction to methods used to manage digital networks including management systems and how security is employed within the digital network. Students are shown how management and security functions are employed within networks and devices and the protocols that are used to facilitate implementation of management and security. (intermediate course)
- Network Design and Switching. The course provides students with an understanding of digital network design and switching. The course focuses on network design and switching systems used in packet switching networks. The learning activities include gaining an understanding of backbone network connection, core routers and interconnection between carrier and service provider networks. (advanced course)
- Network Planning and Performance. The course provides students with an introduction to the concept of network planning and performance. Digital networks provide a limited resource: information carrying capacity. Students are shown how network planning and performance are

important to the successful operation of all digital networks. Students should gain an understanding of the principles and concepts that are applied to network planning and how network performance may be optimised and how network design is affected by capacity planning. Students are introduced to techniques that are used to provide information streams with different characteristics including priority and routing. (advanced course)

- Digital Access Systems. The course provides students with an introduction to digital access systems which are a combination of technologies that permits the communication of data, voice, images and music between customers, service providers and carriers. The course covers digital access system network architecture, design, performance analysis and growth areas. The course considers trends in the use optical fibre media and broadband wireless technologies to provide large bandwidth to the desktop, in addition to new advances in digital access technologies. (advanced course)
- Internet Communication Engineering. The course provides students with an introduction to the delivery of services using the digital network by focusing on the fundamentals of these systems and the impact services have on the digital network. The course covers significant services found today, including VoIP, multimedia Digital TV, Digital Radio and Internet based services including ecommerce, games, and virtual worlds. The success of several technologies is discussed and how to apply the technologies to new ventures. (advanced course)
- Network Operations. The course provides students with an introduction to the key concepts of network operations at a strategic level. First a network development life-cycle will be examined to give a big picture of network development from concept to retirement. Next issues to do with network topology and design are examined. Networks must have the ability to multiplex and switch information and so key issues and technologies related to these issues are considered. Finally there is the topic of performance prediction that examines the use of simulation and traffic theory to help predict network performance. Traffic theory has wide application to many areas of technology and planning ranging from telephone system design, to the design of supermarket queues, and aircraft holding patterns. (advanced course)

Discipline

Network engineering is a broad discipline that includes roles for non-graduate engineers, graduate engineers and post-graduate engineers. The purpose of a network engineer is to provide the digital network equipment systems and facilities needed to support the delivery of services to customers.

It is important to differentiate the network engineer roles from that of desktop support or system administration. The desktop support role is customer-facing and involves problem solving on customer premise devices. The system administration role includes the setup and operation of specific applications or services, such as the provision of email, web sites, databases, and other customer applications. The network engineer role includes being the facilitator of the infrastructure that will be used by customers, customer support personnel and system administrators.

Laboratory Resourcing

The network engineering discipline area is rapidly evolving because the digital network is changing daily. This rapid change creates pressure to constantly update laboratory equipment and systems to meet industry expectations of graduate knowledge and attributes. The cost of maintaining suitable laboratory facilities is high, and asking for replacement equipment and systems is difficult especially when end of life has not been reached. The situation is that digital network technologies are rapidly evolving. An example is the recently announced Australian National Broadband Network which includes a move to fibre to the premise (FTTP) and 4G Long Term Evolution (LTE) over the next 10 years and this is to occur at a point in time when many companies have only just finished rolling out digital subscriber line ADSL2+ systems or are still in the process of doing so.

It is important therefore to maintain close and managed relationships with industry. RMIT University has maintained a close relationship with several large multi-national organizations including Cisco Networks, Juniper Networks and more recently Huawei (2010). The relationship with large multi-

national organizations is important when access to specialized hardware and software is required for laboratory exercises.

An example of the access to specialized software was the provision of laboratory licenses by Cisco Networks to the Ciscoworks application that is used in several courses to demonstrate network management and monitoring principles and concepts.

Juniper Networks facilitated a complete set of routers necessary to provide training equivalent to that required for customer networks and carrier or service provider interconnection, including BGP and MPLS capability.

The Huawei (2010) announcement is another exciting step towards attaining the equipment and systems to ensure that the network engineering graduates have the knowledge, capabilities and attributes suitable for new technologies including 4G LTE, fiber Gigabit Passive Optical Networks (for FTTP) and Next-Generation broadband applications. These technologies will be at the core of the National Broadband Network announced last year by the Australian Government.

Reflections

To reflect on the success of the undergraduate network engineering program and course delivery two measures are presented and the results demonstrate that the undergraduate network engineering degree program has been a success.

At RMIT University near the end of all degree program courses students are surveyed to capture student feedback on the course. The surveys consist of numerical and written feedback components. The undergraduate network engineering degree program courses have achieved very positive above average outcomes from the student survey results.

The enrolment growth in the undergraduate network engineering program was about 35 in the first year and this number has grown to more than 60 in 2010. The total number of enrolments in 2010 at RMIT University across the three network engineering programs (associate degree, undergraduate and postgraduate) is now more than 140. The enrolment in the network engineering programs is now comparable with the communication/telecommunication engineering programs and the trends indicate that the network engineering programs will continue to grow. The move towards a National Broadband Network and 4G LTE networks should provide further impetus for growth in the need for network engineering graduates.

Conclusion

The network engineering discipline is now establishing itself as an important engineering discipline that contributes by supporting the world-wide digital network and services. Network engineering has evolved from the existing communication engineering discipline into a discipline in its own right and has grown to meet the technology changes associated with the digital network and services.

This paper has presented a definition for network engineer and specialist courses that may be offered in a network engineering program. The network engineering courses are continually evolving to ensure that graduates have the attributes required by industry and also to ensure that the degree maintains Engineers Australia accreditation.

Resourcing network engineering laboratories is an expensive cost that should be identified early and carefully managed. A close relationship with one or more industry participants is important as this relationship may provide an opportunity to offset the cost of laboratory equipment and system provision.

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