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INFORMATION SYSTEMS EDUCATION JOURNAL

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Preparing for a Career as a Network Engineer

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Abstract

A network engineer is an Information Technology (IT) professional who designs, implements, maintains, and troubleshoots computer networks. While the United States is still experiencing relatively high unemployment, demand for network engineers remains strong. To determine what skills employers are looking for, data was collected and analyzed from 1,199 nationwide job advertisements listed on Dice.com. Requested skills were then grouped into related categories and summarized. The most frequently requested skills were identified and discussed. The authors also collected data regarding the education level and certifications requested. The results can be used to modify networking courses/curriculum to better prepare students to obtain positions and be successful as network engineers.

Keywords: education, network engineer, job, skills, requirements

1. NETWORKING FIELD

Role of Networks

Networking has become a highly technical, widespread, and necessary technology. It is a part of everyday life: we are using it at workplaces, as well as for education, recreation, and entertainment. The basic understanding is that the network and access to it is there, and the default expectation is that "it just works".
National and local governments worldwide – even countries with huge economic problems – realize the necessity and value of connections and invest in local-, metropolitan-, and wide-area networks.

Networks enable the creation of online learning communities, digital cities, e-government support, virtual organizations, and telecommuting (Tapia et. al., 2011).

The Role of a Network Engineer

A network engineer is an IT professional that manages, and services the network infrastructure of an organization. The duties and responsibilities include a wide range of different technologies that are integrated into local-, wide-area network, and Internet access solutions. The engineers deal with the setup and configuration of devices and equipment that make up the functional parts of the network, such as servers, switches, routers, firewalls,

user computers, and several other devices. The network engineers work with hardware, user and network operating systems, security software, configuration, filtering and monitoring tools, and have to master different networking protocols and standards. They do not get recognition for the network being up and operational, but they always get the grief when it goes down (Norton, 2011). Further, the role of the network engineer is changing rapidly. Besides delivering availability and connections they also have to be adaptable to new technologies and provide a mandated level of reliable networking services. They have to manage costs, and ensure security and application delivery (Metzler, 2011). Based on a survey conducted by Cisco among Cisco Certified Internetwork Expert (CCIE) certificate holders in 2010 the most important skills are related to virtualization and green IT, support of increased collaboration in the workforce through unified communications (UC), and (probably the most in-demand networking skills) security and risk management (Pickett, 2011).

Job Demand

The U.S. Department of Labor in the Occupational Outlook Handbook, 2010-11 Edition predicts that employment of network engineers and computer systems administrators will increase by 23 percent from 2008 to 2018, much faster than the average for all occupations. Computer networks are an integral part of business, and demand for these workers will increase as firms continue to invest in new technologies. Even more, the increasing adoption of mobile technologies means that more establishments will use the Internet to conduct business online. This growth translates into a need for professionals who can help organizations use technology to communicate with employees, clients, and consumers. Growth will also be driven by the increasing need for information security. As cyber attacks become more frequent and increasingly sophisticated, demand will mount for workers with security skills. The predicted skill set includes critical thinking, reading comprehension, systems analysis, active listening, complex problem solving, judgment and decision-making, monitoring, systems evaluation, operation monitoring, and programming (US DoL, 2009).

2. EDUCATION

Education for Network Engineers

Most college or university programs don't offer a degree specifically in Computer Networking. Four-year academic programs that might be suitable for the computer or IT networking field include: Computer Information Systems, Computer Science, Electrical and/or Computer Engineering, Information Technology, Communications Science, Telecommunications, and/or Telecommunications Management.

Different professional organizations have published recommendations regarding how much coverage of networking related issues should be in the body of knowledge in model curricula. The "*Information Technology 2008 Curriculum Guidelines for Undergraduate Degree Programs in Information Technology*" which is the joint work of Association for Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE) Computer Society suggests that the following topics should be covered: networking (22 core hours – including foundations of networking, routing and switching, network management etc.), platform technologies (14 core hours – including computing infrastructures, enterprise deployment software, firmware etc.), information assurance and security (23 core hours – including forensics, information states, security services etc.), and web systems and technologies (22 core hours - including web technologies, information architecture, vulnerabilities etc.). All together they represent 81 hours out of the recommended 314 hours (ACM, 2008).

The "*IS 2010 Curriculum Guidelines for Undergraduate Degree Programs in Information Systems"* is the joint work of the Association for Computing Machinery (ACM) and the Association for Information Systems (AIS). The curriculum guidelines include topics from IS 2010.3 Enterprise Architecture (including audit and compliance, system administration, IT control and management frameworks, emerging technologies etc.), and IS 2010.4 IT Infrastructure (including core computing system architecture concepts, virtualization of computing services, networking, network security and security devices, etc.). The document does not specify the number of credits, contact hours, or even courses, but the two references are part of seven recommended areas (ACM, 2010).

Accreditation organizations such as the *Accreditation Board for Engineering and Technology* (ABET), do not define specific hours or curriculum guidelines for accredited programs but they require that students be exposed to networking as part of their required studies (ABET, 2010).

Different programs focus on different technologies including Microsoft, UNIX, Cisco, and Novell. Post-secondary education offers certifications at different levels related to all of these systems. But researchers mostly agree that it probably matters little which networking technology one learns. More importantly, students should recognize that technology changes rapidly, and it is highly unusual that studying just one field would be sufficient for a lifetime career (Yuan & Zhong, 2010; Uzunboylu, Bicen, & Cavus, 2011).

Computer networking involves a number of fundamental technologies including switching, Transmission Control Protocol/ Internet Protocol (TCP/IP), the Open Systems Interconnection (OSI) model, Ethernet, internetworking, and others. Their combinations in real-life cases and business situations assume complexity and involve a wide range of different solutions coming from various vendors.

On the job market many companies view college degrees as a sign of commitment to the professional field. Network technology changes very quickly, so in addition to proof of a person's current knowledge, they also look for employees with the ability to learn new technologies in the future. Up-to-date certifications can effectively demonstrate contemporary knowledge, but college degrees best demonstrate one's general learning ability.

Salaries

Salary.com reports the national salary average of 80 IT networking-related positions, which can then be fine-tuned based on education, years of experience, position in the organization (direct reports versus reports to), job performance, location, company size, and industry. For example, with 5-10 years experience security experts can expect a salary of around $102,000, client technology managers - $98,000, Local Area Networks (LAN)/Wide Area Networks (WAN) administrators - $70,000, and network technology technicians around $54,000. With the importance of these IT jobs and increased demand in the field, salaries are increasing by 2-5% on an annual basis and are further supported by additional benefits. This trend has been reported not only in the United States but also worldwide (Culpepper, 2011). The numbers correspond with the statistical data provided by Bureau of Labor Statistics (BLS, 2010). Unemployment rates remain at half of the national average.

What Employers Want

Forester conducted a survey of 1,500 individuals responsible for managing, evaluating, or hiring network professionals. The survey was conducted in 10 countries to gather data about the various job roles within the network and to understand how skills requirements would change over a five-year time horizon. The results clearly showed that "… managing talent in the network environment is becoming increasingly challenging for CIOs, IT managers, and HR decision-makers." Some of the major findings of the study indicate that organizations seek more network certifications; skills like security, risk, and performance management are emerging as important, regardless of the role of the individual in the IT organization; IT (including networking) is an increasingly global industry, requirements are consistent across geographies (Forester, 2008).

Dice.com, the highly rated technology job board, published a special report on May 1, 2011 with the title "*America's tech talent crunch*." The job market numbers and the number of academic degrees conferred in related subject areas describe well the challenge facing American businesses in need of tech-skilled new hires in 2011 and beyond (Dice, 2011). They also report that there is an increasing number of states where organizations have a difficult time filling positions, and/or that the pace of education and training cannot keep up with the creation of new positions.

3. RESEARCH RESULTS

Methodology

A national search for jobs with "Network Engineer" in the title was performed at Dice.com. Dice.com is one of the major job boards for technical positions. A total of 1,199 sequential job positions were downloaded from April through May 2011. Obvious duplicate jobs were eliminated. Only positions where it was

clear that Network Engineer was the primary job assignment were used. For example, Network Security Engineer and Network Sales Engineer were not included. Both entry/junior level and senior network engineer positions were included.

Job requirements for the 1,199 jobs were examined. The tables below categorize the requested skills by types of protocols, standards, operating systems, etc.

Protocols and services associated with Wide Area Networks (WANs) are presented in the first three tables. Table 1 indicates the number of jobs that listed specific routing protocols. Border Gateway Protocol (BGP) was the most frequently requested protocol. It is an exterior gateway protocol (EGP) that is used to link autonomous systems. This would explain the high demand for this protocol. The other items listed are interior gateway protocols (IGP). The general term "Router" in the job ads just adds emphasis to the importance of this area in general. Cisco's IOS was requested by 13.2% of companies.

Table 1. Routing Protocols

Protocol	*N*	*%*
Border Gateway Protocol (BGP)	409	34.1%
Open Shortest Path First (OSPF)	355	29.6%
Enhanced Interior Gateway Routing Protocol (EIGRP)	234	19.5%
Cisco Internetwork Operating System (IOS)	158	13.2%
Router	144	12.0%
Routing Information Protocol (RIP)	74	6.2%
Intermediate System To Intermediate System (IS-IS)	34	2.9%
Interior Gateway Routing Protocol (IGRP)	22	1.8%
Routing Information Protocol – version 2 (RIP-2)	1	0.1%

Table 2 lists the other protocols requested. One would expect IP to have the largest percentage of requests, due to the vast body of knowledge it covers such as subnetting and understanding addressing in terms of route aggregation. Subnetting itself was specifically mentioned in 1.4% of the positions. When a specific version of IP was mentioned, it is interesting to see the higher percentage for IPv6, indicating the move to IPv6. However, the numbers for IPv4 reflect the current coexistent need for the two protocols. Voice over IP (VoIP) is the third most requested item. TCP is used more than User Datagram Protocol (UDP). Internetwork Control Message Protocol (ICMP) is the protocol in the TCP/IP suite that is used for router-to-router communication of problem conditions in the internetwork.

Table 2. Other Protocols

Other Protocols	*N*	*%*
Internet Protocol (IP)	561	46.8%
Transmission Control Protocol (TCP)	387	32.3%
Voice over Internet Protocol (VoIP)	253	21.1%
User Datagram Protocol (UDP)	42	3.5%
IPv6	26	2.2%
IPv4	19	1.6%
Subnetting	17	1.4%
Internetwork Control Message Protocol (ICMP)	11	0.9%

Table 3. WAN Services

WAN Services	*N*	*%*
WAN	534	44.5%
Integrated Services Digital Network (ISDN)	103	8.6%
Asynchronous Transfer Mode (ATM)	84	7.0%
Frame Relay	77	6.4%
T3/ DS-3	62	5.2%
T1	60	5.0%
SONET	45	3.8%
OC-3	31	2.6%
OC-12	17	1.4%
OC-48/OC-192/OC-768	12	1.0%

Table 3 summarizes WAN Services. General wide area network experience was requested in 44.5% of the positions. Asynchronous Transfer Mode (ATM) and Frame Relay appear to be popular services, as one would expect. The relatively high number for Integrated Services Digital Network (ISDN) is somewhat surprising. ISDN showed up as ISDN in general as well as Basic Rate Interface (BRI) and Primary Rate Interface (PRI) specifically.

Most of the ISDN requested was the PRI variety (66 of the 103 requests). This has the same bandwidth as a T1. Knowledge of T1s was requested almost as much as T3s. This is somewhat of a surprise as the T1 bandwidth is so low given the availability of services such as Synchronous Optical Network (SONET) today. SONET was requested in table 3 and will probably increase in frequency over the years. The very high speeds for SONET, OC-48 (2.488 Gbps), OC-192 (10 Gbps), and OC-768 (40

Gbps) were only requested in one percent of positions but only a few companies would be using these speeds regularly today.

Tables 4 – 8 cover concepts and standards relating to LANs and network components. Switches, LANs, and VLANs were the most requested topics in Table 4.

Table 4. LAN Topics

LAN Topics	*N*	*%*
LAN	490	40.9%
Switch	127	10.6%
Virtual Local Area Network (VLAN)	94	7.8%
Spanning Tree Protocol - 802.1d	58	4.8%
Wireless LAN (WLAN)	44	3.7%
VLAN Tagging - 802.1q	26	2.2%
Storage Area Network (SAN)	15	1.3%
802.11a/b/n	13	1.1%
WiMax - 802.16	13	1.1%
802.3	6	0.5%
Token Ring	6	0.5%
40/100 Gigabit Ethernet	2	0.2%

WLANs were requested in general and as specific 802.11 standards. WiMAX, the fixed broadband wireless access standard, was requested as often as the 802.11 (WiFi) standards. It is very surprising to see Token Ring requested at all as it has not been upgraded since the 16 Mbps version in the 1980s.

Conspicuously absent are requests for specific Ethernet standards such as 802.3ab (1000Base-T), 802.3z (1000Base-SX and 1000Base-LX). As Ethernet is the predominant wired standard, maybe the companies were thinking of it when they requested LANs in general. Knowledge of the Spanning Tree Protocol, which is used to prevent topological loops in networks, and VLAN Tagging, were also requested quite frequently.

Table 5 shows the operating systems requested. If we combine Active Directory with the various versions of Windows Server (17.5%), one can see that both Linux and Unix almost match this number. Of the Microsoft client operating systems Windows XP was the most requested. A surprising entry is Novell NetWare, a skill one would have expected to be no longer needed.

Table 5. Operating Systems

Operating Systems	*N*	*%*
Linux	203	16.9%
Unix	180	15.0%
Active Directory	158	13.2%
Windows XP	57	4.8%
Windows Server NT/2000/2003/2008/2008R2	51	4.3%
Solaris	41	3.4%
Novell NetWare	34	2.8%
Vista	20	1.7%
Windows 7	19	1.6%
RedHat	14	1.2%
CentOS	7	0.6%
OpenBSD	1	0.1%

Requests for knowledge of Database Management Systems (DBMS) are shown in Table 6. Microsoft SQL Server and Oracle are the two main DBMSs as would be expected.

Table 6. Database Servers

Database Servers	*N*	*%*
Microsoft SQL Server	54	4.5%
Oracle	29	2.4%
MySQL	10	0.8%
PostgreSQL	5	0.4%
IBM DB2	3	0.3%

Table 7. Web Servers

Web Servers	*N*	*%*
Microsoft IIS Server	54	4.5%
Apache	23	1.9%
IBM Http Server	7	0.6%
Apache Tomcat	4	0.3%

Table 7 shows the requested web servers. In this sample of companies, the most requested is Microsoft's IIS Server. There were far fewer requests for DBMSs and Web Servers compared to requests for network/server operating systems, which makes sense given the job title searched was "Network Engineer".

Of the other servers requested in the ads, Microsoft Exchange was the clear leader – see Table 8.

Table 8. Other Servers

Other Servers	*N*	*%*
Microsoft Exchange	140	11.7%
Sharepoint	29	2.4%
Citrix Server	4	0.3%
Lotus Domino	1	0.1%

Table 9 shows that a reasonable percentage of companies requested knowledge of virtualization technologies with VMware being by far the most common solution. Blade technology was also requested.

Table 9. Server Technology and Virtualization

Server Technologies	*N*	*%*
VMware	146	12.2%
ESX	45	3.8%
Blade/Blade Servers	27	2.3%
Hyper-V	33	2.8%
Zen	2	0.2%

While some positions requested specific monitoring software (see Table 10), the most requested item was SNMP itself. Most monitoring tools support SNMP.

Table 10. Monitoring Tools

Monitoring Tools	*N*	*%*
Simple Network Management Protocol (SNMP)	115	9.6%
Nagios	17	1.4%
Orion	13	1.1%
Zenoss	2	0.2%
Freenats	1	0.1%
Opsview	1	0.1%
Tclmon	1	0.1%
Zabbix	1	0.1%

Table 11. Protocol Analyzers

Protocol Analyzers	*N*	*%*
Wireshark	42	3.5%
Sniffer	32	2.7%
Netflow	25	2.1%
Ethereal	15	1.3%
Omnipeek	7	0.6%

Protocol analyzers were also requested by several companies, with Wireshark being the most requested. – see Table 11.

The next set of tables relates to degrees and certificates requested in the position listings by companies. Table 12 shows the degrees requested. Combining the degree in Computer Science and Computer Information Systems totals, we see that 34.2% of companies requested a degree in one of the two most common computer related degrees.

Table 12. Degree Requirements

Degree Requirements	*N*	*%*
Degree In Computer Science	313	26.1%
Bachelors Degree	123	10.3%
Degree In Information Systems	97	8.1%
Masters Degree	13	1.1%

Table 13. Certificate Requirements

Certificate Requirements	*N*	*%*
Cisco		
Cisco Certified Network Professional (CCNP)	371	30.9%
Cisco Certified Network Associate (CCNA)	283	23.6%
Cisco Certified Internetwork Expert (CCIE)	226	18.8%
Cisco Certified Design Professional (CCDP)	50	4.2%
Cisco Certified Network Professional CCNP Voice CCNP Voice (Previously CCVP)	41	3.4%
Microsoft		
Microsoft Certified Systems Engineer (MCSE)	84	7.0%
Microsoft Certified Systems Administrator (MCSA)	21	1.8%
Microsoft Certified IT Professional (MCITP)	19	1.6%
CompTIA		
A+	8	0.7%
Network +	1	0.1%
Security		
CISSP	43	3.6%
TS/SCI	33	2.8%
DoDD 8570 Compliant	9	0.8%
GIAC	4	0.3%
CISM	3	0.3%

Different types of certificates were also listed as requirements in many positions – see Table 13. As expected, Cisco and Microsoft certificates were the most requested. The fact that 23.6% of companies requested the entry-level Cisco certificate (CCNA) shows how high the bar is for our students. Security certificates were also requested as shown in Table 13, demonstrating the importance for network engineers to have proven knowledge in this ever more important area of networking.

Ta**ble 14. Vendors**

Vendors	*N*	*%*
Cisco	870	72.6%
Juniper	199	16.6%
HP	102	8.5%
Dell	28	2.3%
Ericsson	4	0.3%
Siemens	2	0.2%
Alcatel-Lucent	1	0.1%
Netgear	1	0.1%

Table 14 lists vendors in the networking field that were requested in the positions. Care needs to be taken with the interpretation of this data as, in the case of Cisco for example, a company could be listed for a variety of reasons (for a certificate, a specific router/switch, etc.).

Nevertheless, it points to the practical nature of the requirements of these employers.

The final table provides a general summary of the relative importance employers appear to place on the different areas. As shown in Table 15, various routing protocols were the most requested skill with a total of 1,431 in the job listings. This represented 22.6% of the 6,339 total tabulated skill requests in tables 1-11. This was followed by items from the Other Protocols category 1,316 (22.6%) and by WAN services 1,025 (16.2%).

Table 15. Summary

Skill area	*N*	*%*
Routing Protocols	1431	22.6%
Other Protocols	1316	20.8%
WAN Services	1025	16.2%
LAN Topics	894	14.1%
Operating Systems	785	12.4%
Server Tech & Virtualization	252	4%
Other Servers	174	2.7%
Monitoring Tools	151	2.4%
Protocol Analyzers	121	1.9%
Database Servers	101	1.6%
Web Servers	88	1.4%

4. CONCLUSIONS

The tables above contain a wealth of information for faculty teaching in the networking area. One example is the significance of coverage of certain networking topics. In the internetworking area, we can see the importance of covering TCP/IP, BGP, OSPF, and EIGRP. In the LAN area the coverage of the Spanning Tree Protocol is not the most requested, yet it was requested much more than e.g. the 802.11 protocols. Sometimes students do not see the value of what may appear to them as just a theoretical topic, yet it clearly has practical applications.

In the operating systems area, Linux and Unix show up very strong, a message to faculty that this material should be offered in the curriculum. Virtualization is another area that needs to be in a curriculum, albeit in a more minor role.

In positions seeking network engineers, it is interesting to note that database and web server technologies were also requested. The requests for these other servers demonstrate that one of our students, a future employee of one of these companies, will typically have to have multiple areas of expertise. Another interesting point is that employer expectations can be quite high in terms of practical skills. For example, Cisco's IOS was requested by 13.2% of the companies.

Information systems students can take heart from the data in Table 12, which shows that a degree is important to employers. They may not be as happy to see the number of companies requesting certificates and many of these are requests for the higher-level certificates!

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Editor's Note:

This paper was selected for inclusion in the journal as a ISECON 2012 Meritorious Paper. The acceptance rate is typically 15% for this category of paper based on blind reviews from six or more peers including three or more former best papers authors who did not submit a paper in 2012.